International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 1879-1883

Received: 17-07-2017
Accepted: 18-08-2017

Kashinath Dandoti
Department of Seed Science and Technology, University of Agricultural Sciences, Raichur, Karnataka, India

NM Shakuntala
Department of Seed Science and Technology, University of Agricultural Sciences, Raichur, Karnataka, India

Sangeetha Macha
Department of Seed Science and Technology, University of Agricultural Sciences, Raichur, Karnataka, India

SN Vasudevan
Department of Seed Science and Technology, University of Agricultural Sciences, Raichur, Karnataka, India

Correspondence
Kashinath Dandoti
Department of Seed Science and Technology, University of Agricultural Sciences, Raichur, Karnataka, India

Effect of seed polymer coating with micronutrients on growth, seed yield and quality of linseed (*Linum usitatissimum* L.)

Kashinath Dandoti, NM Shakuntala, Sangeetha Macha and SN Vasudevan

Abstract
A field experiment was conducted at the Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Raichur to study the influence of seed polymer coating with micronutrients on growth, seed yield of linseed. The experiment consisted of twenty three different seed polymer coating treatments with various combinations of $ZnSO_4$, boron, ammonium molybdate, $FeSO_4$, $CaSO_4$ including control. Among the different treatments imposed, seed polymer coating (@ 2 ml/kg) of linseed seeds with the combination of ZnSO4 + Boron + Ammonium molybdate + FeSO4 + $CaSO_4$ (each @ 1 g/kg) of seed recorded significantly higher plant height, leaf area index, chlorophyll content, days to 50% flowering, number of capsules per plant, number of seeds per capsule, seed yield, 1000 seed weight compared to all other treatments and control.

Keywords: Polymer, Micronutrients, Linseed, Seed treatment, Yield

Introduction
Linseed or flax (*Linum usitatissimum* L.) is an important crop of tropical as well as temperate zone of the world and grown as winter crop of Asia and summer crop of Europe. Based on diversity of plant type, linseed has two centres of origin *i.e.,* South West Asia and the Mediterranean region of Europe. It is an annual plant belongs to the genus *Linum* and the family linaceae. In fact, the name *Linum* is originated from the Celtic word *lin* or "thread," and the name *usitatissimum* is Latin for "most useful" (Kolodziejczyk and Fedec, 1995) [8]. Linseed is grown both for oil and fibre purpose. If it is grown only for seed, it is called as oil flax, seed flax or linseed and when cultivated for fibre purpose, it is called fibre flax. Long stemmed linseed produces a high quality fibre and short stemmed linseed bears larger seeds of high oil content. In India, primary oil bearing types are grown, while fibre bearing types are grown mainly in European countries.

The major linseed growing countries are India, Russia, Argentina, Canada, United States America, China, Egypt and Brazil *etc.* The total world linseed production is of 2.05 mt with a productivity of 82.6 Kg ha^{-1} in an area of 24.85 m ha. While in India an area of 292.1 thousand ha with a production of 141.7 thousand tonnes and a productivity of 484 kg ha^{-1} (Anon., 2014) [3]. Rajasthan is the highest producer of linseed in India. In Karnataka, linseed is grown over an area of 0.06 lakh ha with a production of 0.02 lakh tonnes and productivity of 329 kg ha^{-1} (Anon., 2014) [3]. Karnataka is ninth largest grower of linseed after Rajasthan, Madhya Pradesh, Chhattisgarh, Maharashtra, Uttar Pradesh, Jharkhand, Bihar and Orissa. The area under flax is decreasing year after year due to great competition of other economic winter crops resulting a gap between production and consumption. Therefore, it is necessary to increase flax productivity per unit area which could be achieved by using high yielding cultivars and improving the fertilization and other agricultural practices.

Seed polymer coating is the sophisticated process of applying precise amount of active ingredients along with a liquid polymer directly on to the seed surface without obscuring its shape, seed size and weight. Thus polymer forms a flexible film that adheres and protects the active ingredients, preventing the dusting off and loss of active ingredients during handling. This technology helps in precise and uniform application of fungicides, insecticides, bio agents, micronutrients, colours and other additives (Bharthi and Srinivasan, 2010) [10].

Micronutrients play an important role in increasing the yield levels in pulses, oilseed and legumes through their direct effects on the plant and through symbiotic nitrogen fixation process. The deficiency of these nutrients has been very pronounced under multiple cropping systems due to excess removal of the nutrients by high yielding varieties and hence their exogenous application is urgently required. The micronutrients are required in relatively smaller quantities for plant growth and they are as important as macronutrients and often they act as co-factors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants (Marschner, 1995; Mengel *et al.*, 2001 and Alloway, 2008). It is estimated that, the extent of micronutrient deficiency in the Indian soils are 47, 35, 15, 13, 4 and 2 per cent for Zinc, Boron, Molybdenum, Iron, Manganese and Copper respectively. While, in Karnataka it is 78, 39, 32 and 5 per cent for Zinc, Iron, Boron and Copper respectively (Anon., 2013) [2].

Micronutrient application through seed treatment improves the stand establishment, advances phenological events, increases yield and micronutrient contents in grain in most of the crops. In many cases, micronutrient application through seed treatment performed better or similar to other application methods (Singh *et al.*, 2003) [14]. Being an easy and cost effective method of micronutrient application, seed treatment with polymer offer an attractive option for resource-poor farmers (Johnson *et al.*, 2005) [7].

Material and Methods

This experiment was carried out in order to investigate effect polymer coating with micronutrients on growth, seed yield of linseed. The experimental design was randomized block design (RBD) in three replications was conducted during rabi season of 2015-16 at Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Raichur.

Each replication of this design consisted of 23 treatments and a total of 69 plots were analyzed. The treatments involving T_1: Absolute control, T_2: Polymer @ 2 ml per kg, T_3: T_2 + $ZnSO_4$ @ 1 g per kg of seed, T_4: T_2 + $ZnSO_4$ @ 2 g per kg of seed, T_5: T_2 + Boron @ 1g per kg of seed T_6: T_2 + Boron @ 2 g per kg of seed, T_7: T_2 + Ammonium molybdate @ 1 g per kg of seed, T_8: T_2 + Ammonium molybdate @ 2 g per kg of seed, T_9: T_2 + $FeSO_4$ @ 1 g per kg of seed, T_{10}: T_2 + $FeSO_4$ @ 2 g per kg of seed, T_{11}: T_2 + $CaSO_4$ @ 1 g per kg of seed, T_{12}: T_2 + $CaSO_4$ @ 2 g per kg of seed, T_{13}: (T_3 + T_5), T_{14}: (T_3 + T_7), T_{15}: (T_3 + T_9), T_{16}: (T_3 + T_{11}), T_{17}: (T_5 + T_9), T_{18}: (T_5 + T_9), T_{19}: (T_5 + T_{11}), T_{20}: (T_7 + T_9), T_{21}: (T_7 + T_{11}), T_{22}: (T_9 + T_{11}), T_{23}: (T_3 + T_5 + T_7 + T_9+ T_{11}) were studied in a Randomized Block Design (RBD), with three replications, using linseed variety NL-115.

The plant height, leaf area index, chlorophyll content, days to 50 per cent flowering, number of capsules per plant, number of seeds per capsule, seed yield, 1000 seed weight were recorded in all the treatments.

Results and Discussion

The yield determining components (number of capsules per plant, number of seeds per capsule, 1000 seed weight and seed yield) were significantly influenced by seed polymer coating (@ 2 ml/kg) of linseed seeds with the combination of $ZnSO_4$ + Boron + Ammonium molybdate + $FeSO_4$ + $CaSO_4$ (each @ 1 g/kg) of seed respectively.

Table 1: Influence of seed polymerization with micronutrients on plant height, leaf area index, chlorophyll content at different growth stages in linseed

Treatments	Plant height (cm)			Leaf area index (LAI)			Chlorophyll content (SPAD value)		
	Vegetative stage	Flowering stage	Capsule formation stage	Vegetative stage	Flowering stage	Capsule formation stage	Vegetative stage	Flowering stage	Capsule formation stage
T_1: Absolute control	15.0	46.7	49.7	1.36	2.68	0.76	34.1	38.1	30.2
T_2: Polymer @ 2 ml per kg of seed	15.3	47.2	50.2	1.43	2.73	0.79	34.5	38.5	30.5
T_3: T_2 + $ZnSO_4$ @ 1 g per kg of seed	15.4	49.3	52.4	1.49	2.83	0.86	35.1	39.13	31.6
T_4: T_2 + $ZnSO_4$ @ 2 g per kg of seed	16.9	48.7	51.9	1.54	2.92	0.93	35.3	39.30	31.7
T_5: T_2 + Boron @ 1g per kg of seed	17.4	49.6	52.8	1.54	2.94	0.86	36.8	40.80	31.9
T_6: T_2 + Boron @ 2 g per kg of seed	17.2	50.3	53.2	1.55	2.85	0.95	37.4	41.87	32.3
T_7: T_2 + Ammonium molybdate @ 1 g per kg of seed	16.1	47.8	50.6	1.55	2.92	0.90	35.1	39.08	31.5
T_8: T_2 + Ammonium molybdate @ 2 g per kg of seed	18	50.7	53.8	1.56	2.94	1.06	37.7	42.53	32.7
T_9: T_2 + $FeSO_4$ @ 1 g per kg of seed	16.2	48.3	51.1	1.54	2.85	1.05	36.9	40.90	31.9
T_{10}: T_2 + $FeSO_4$ @ 2 g per kg of seed	15.9	47.9	50.8	1.54	3.00	0.95	36.4	40.48	31.8
T_{11}: T_2 + $CaSO_4$ @ 1 g per kg of seed	18	50.5	53.3	1.66	3.09	0.88	37.5	41.93	32.4
T_{12}: T_2 + $CaSO_4$ @ 2 g per kg of seed	16.3	48.5	51.5	1.65	2.94	0.95	36.6	41.10	31.9
T_{13}: (T_3 + T_5)	19.5	52.5	55.3	1.75	3.20	1.14	39.0	43.03	34.2
T_{14}: (T_3 + T_7)	16.9	50.3	53.3	1.57	2.90	0.95	37.2	42.17	32.2
T_{15} : (T_3 + T_9)	17.1	50.5	53.5	1.59	3.04	0.94	37.5	42.50	32.4

T_{16}: ($T_3 + T_{11}$)	17.3	50.7	53.7	1.56	3.08	0.99	37.6	41.90	32.6
T_{17}: ($T_5 + T_7$)	18.6	52.1	54.7	1.64	3.14	1.07	38.3	42.83	33.8
T_{18} : ($T_5 + T_9$)	18.4	51.8	54.2	1.66	3.03	1.09	37.7	42.37	33.4
T_{19}: ($T_5 + T_{11}$)	18.7	52.0	54.5	1.65	2.99	1.01	37.9	42.63	33.5
T_{20}: ($T_7 + T_9$)	18.9	52.2	55.4	1.63	3.09	0.89	37.1	41.23	32.3
T_{21} : ($T_7 + T_{11}$)	18.6	51.5	53.9	1.64	2.96	0.97	37.8	42.15	33.2
T_{22}: ($T_9 + T_{11}$)	18.5	50.6	53.7	1.66	3.05	1.07	37.4	41.96	33.1
T_{23}: ($T_3 + T_5 + T_7 + T_9 + T_{11}$)	20.2	53.7	56.3	1.93	3.44	1.29	40.8	44.38	36.8
Mean	17.34	50.57	53.57	1.61	2.98	0.98	37.31	41.18	33.29
S.Em.±	0.13	0.17	0.12	0.01	0.02	0.01	0.61	0.58	0.58
C.D. at (5%)	0.38	0.48	0.34	0.03	0.05	0.04	1.73	1.64	1.71

Table 2: Influence of seed polymerization with micronutrients on days to 50 per cent flowering, number of capsules per plant and number of seeds per capsule in linseed.

Treatments	**Days to 50% Flowering**	**Number of capsules per plant**	**Number of seeds per Capsule**
T_1: Absolute control	58	53	7
T_2: Polymer @ 2 ml per kg of seed	58	53	7
T_3: T_2 + $ZnSO_4$ @ 1 g per kg of seed	57	54	7
T_4: T_2 + $ZnSO_4$ @ 2 g per kg of seed	56	54	7
T_5: T_2 + Boron @ 1g per kg of seed	56	55	8
T_6: T_2 + Boron @ 2 g per kg of seed	56	54	8
T_7: T_2 + Ammonium molybdate @ 1 g per kg of seed	57	54	7
T_8: T_2 + Ammonium molybdate @ 2 g per kg of seed	56	55	8
T_9: T_2 + $FeSO_4$ @ 1 g per kg of seed	57	54	7
T_{10}: T_2 + $FeSO_4$ @ 2 g per kg of seed	57	54	7
T_{11}: T_2 + $CaSO_4$ @ 1 g per kg of seed	56	55	8
T_{12}: T_2 + $CaSO_4$ @ 2 g per kg of seed	57	54	7
T_{13}: ($T_3 + T_5$)	55	56	8
T_{14}: ($T_3 + T_7$)	57	54	7
T_{15} : ($T_3 + T_9$)	57	54	8
T_{16}: ($T_3 + T_{11}$)	57	54	8
T_{17}: ($T_5 + T_7$)	56	54	8
T_{18} : ($T_5 + T_9$)	56	55	8
T_{19}: ($T_5 + T_{11}$)	56	55	8
T_{20}: ($T_7 + T_9$)	57	54	7
T_{21} : ($T_7 + T_{11}$)	57	54	8
T_{22}: ($T_9 + T_{11}$)	57	55	8
T_{23}: ($T_3 + T_5 + T_7 + T_9 + T_{11}$)	55	56	8
Mean	56	55	8
S.Em.±	0.38	0.72	0.47
C.D. at (5%)	1.08	2.05	1.35

The seed polymer coating with different micronutrients and their combinations *viz*., Zinc sulphate + Borax + Ferrous sulphate + Ammonium molybdate + Calcium sulphate each @ 1 g per kg (T_{23}) recorded significantly highest plant height (Table. 1) at all the three stages *viz.*, vegetative (20.2 cm), flowering (53.7 cm) and capsule formation stage (56.3 cm) compared to control (15 cm, 46.7 cm and 49.7 cm respectively). Further, T_{23} treatment was on par with T_{13} (Zinc sulphate + Boron each @ 1 g per kg of seed) and T_{20} (Ammonium molybdate + Ferrous sulphate each @ 1 g per kg of seed). Increased in plant height due to application of micronutrients might be due to increase in cell division, cell differentiation, meristematic activity, rapid expansion of cell and the formation of cell wall**,** increase in photosynthesis srimathi *et al.* (2014) [15] in sesame.

Leaf area index (LAI) is one of the most important and commonly used indices to analyze the growth of crop plant. In the present investigation, at all stages of growth and among all treatments studied, significantly higher LAI (Table. 1) was recorded with the treatment combination of Zinc sulphate + Borax + Ferrous sulphate + Ammonium molybdate + Calcium sulphate each @ 1 g per kg of seed (T_{23}) (1.93, 3.44 and 1.29) whereas lower LAI (1.36, 2.68 and 0.76) was recorded in control (T_1) during vegetative, flowering and capsule formation stages respectively. The increase in LAI in this treatment might be due to the expansion of crop canopy to utilize the sunlight for photosynthesis. Micronutrient elements play a critical role in plants that lead to increase of leaf area index thereby increased light absorption and increase the amount of dry matter accumulation and economic yield Satyabhama (2015) [12] in groundnut.

Chlorophyll content (SPAD readings) was significantly higher (Table. 1) with the combined application of Zinc sulphate + Borax + Ferrous sulphate + Ammonium molybdate + Calcium sulphate each @ 1 g per kg (T_{23}) (40,8 44.38 and 36.8 SPAD values) during vegetative, flowering and capsule formation stages respectively. However, lower chlorophyll content (34.1, 38.1 and 30.2) were recorded in control. Babaeian (2011) [5] stated that chlorophyll content (SPAD value) was significantly higher when sunflower plants sprayed with Mn alone or in combination with Fe and Zn compared to the control. These results are also in agreement with the findings of Sherin *et al*. (2005) [13] in maize.

In the present investigation significant differences were noticed among the treatments for days to 50 per cent flowering, number of capsules per plant, number of seeds per capsule (Table. 2), seed yield and yield parameters (Table. 3). Significantly higher number of.

Table 3: Influence of seed polymerization with micronutrients on seed yield in linseed.

Treatments	Seed yield (g/plant)	Seed yield (q/ha)
T_1: Absolute control	2.76	6.76
T_2: Polymer @ 2 ml per kg of seed	2.81	6.89
T_3: T_2 + $ZnSO_4$ @ 1 g per kg of seed	2.93	7.02
T_4: T_2 + $ZnSO_4$ @ 2 g per kg of seed	2.95	7.04
T_5: T_2 + Boron @ 1g per kg of seed	2.98	7.09
T_6: T_2 + Boron @ 2 g per kg of seed	3.02	7.18
T_7: T_2 + Ammonium molybdate @ 1 g per kg of seed	2.96	7.05
T_8: T_2 + Ammonium molybdate @ 2 g per kg of seed	3.06	7.29
T_9: T_2 + $FeSO_4$ @ 1 g per kg of seed	2.97	7.07
T_{10}: T_2 + $FeSO_4$ @ 2 g per kg of seed	2.95	7.04
T_{11}: T_2 + $CaSO_4$ @ 1 g per kg of seed	3.03	7.26
T_{12}: T_2 + $CaSO_4$ @ 2 g per kg of seed	3.01	7.11
T_{13}: (T_3 + T_5)	3.35	7.83
T_{14}: (T_3 + T_7)	3.14	7.42
T_{15} : (T_3 + T_9)	3.18	7.47
T_{16}: (T_3 + T_{11})	3.21	7.51
T_{17}: (T_5 + T_7)	3.29	7.63
T_{18} : (T_5 + T_9)	3.24	7.58
T_{19}: (T_5 + T_{11})	3.25	7.61
T_{20}: (T_7 + T_9)	3.16	7.43
T_{21} : (T_7 + T_{11})	3.23	7.56
T_{22}: (T_9 + T_{11})	3.21	7.53
T_{23}: (T_3 + T_5 + T_7 + T_9+ T_{11})	3.70	8.14
Mean	3.10	7.32
S.Em.±	0.01	0.04
C.D. at (5%)	0.03	0.11

Table 4: Influence of seed polymerization with micronutrients on test weight and oil content in linseed.

Treatments	Test weight (g)	Oil content (%)
T_1: Absolute control	6.80	37.77
T_2: Polymer @ 2 ml per kg of seed	6.83	37.98
T_3: T_2 + $ZnSO_4$ @ 1 g per kg of seed	6.95	38.30
T_4: T_2 + $ZnSO_4$ @ 2 g per kg of seed	7.00	38.54
T_5: T_2 + Boron @ 1g per kg of seed	7.01	38.58
T_6: T_2 + Boron @ 2 g per kg of seed	7.02	38.64
T_7: T_2 + Ammonium molybdate @ 1 g per kg of seed	7.04	38.31
T_8: T_2 + Ammonium molybdate @ 2 g per kg of seed	7.09	38.77
T_9: T_2 + $FeSO_4$ @ 1 g per kg of seed	6.91	38.36
T_{10}: T_2 + $FeSO_4$ @ 2 g per kg of seed	6.95	38.32
T_{11}: T_2 + $CaSO_4$ @ 1 g per kg of seed	7.06	38.67
T_{12}: T_2 + $CaSO_4$ @ 2 g per kg of seed	7.11	38.54
T_{13}: (T_3 + T_5)	7.10	39.35
T_{14}: (T_3 + T_7)	7.12	38.83
T_{15} : (T_3 + T_9)	7.01	38.85
T_{16}: (T_3 + T_{11})	7.01	38.87
T_{17}: (T_5 + T_7)	7.17	39.34
T_{18} : (T_5 + T_9)	6.91	39.04
T_{19}: (T_5 + T_{11})	7.10	39.07
T_{20}: (T_7 + T_9)	7.07	38.83
T_{21} : (T_7 + T_{11})	7.14	39.03
T_{22}: (T_9 + T_{11})	7.00	38.89
T_{23}: (T_3 + T_5 + T_7 + T_9+ T_{11})	7.30	39.40
Mean	7.03	38.67
S.Em.±	0.01	0.48
C.D. at (5%)	0.03	1.35

capsules per plant (56), number of seeds per capsule (8), seed yield (3.70 g/plant) and seed yield per hectare (8.14 q) was obtained in T_{23} treatment (Zinc sulphate + Borax + Ferrous sulphate + Ammonium molybdate + Calcium sulphate each @

1 g per kg seed). Increase in yield components with this treatment could be due to increased photosynthetic activity and more synthesis, translocation and accumulation of food reserves in seed as evident with higher test weight (7.30 g) and oil content (39.40 %) (Table. 4) compared to control. Similarly combined effect of micronutrients on seed yield and yield attributes were reported by Thakur *et al*. (2009) in groundnut who observed that $ZnSo_4$ application reduce the flower drop, increased number of pods per plant and 100 seed weight. These results are also in accordance with Pawel (2013) [11] in soyabean, Satyabhama (2016) who reported that polymer coating with micronutrients increased the growth components and yield in groundnut and Anup (2016) [4] in cotton.

Conclusion

Seed polymer coating (2 ml kg^{-1} of seed) with combination of micronutrients (Zinc sulphate + Borax + Ferrous sulphate + Ammonium molybdate + calcium sulphate each @ 1 g per kg seed) is beneficial in obtaining higher seed yield and quality attributes in linseed. This will help in improving micronutrient content in seeds.

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