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Interactive effect of Nanoclay polymer composites and fertility levels on dry matter accumulation of linseed (*Linum usitatissimum* L.) under different irrigation frequency

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Abstract
A field experiment was conducted during 2014 and 2015 to evaluate the effect of the nanoclay polymer composites and fertility levels on dry matter accumulation of the linseed (*Linum usitatissimum* L.) under different irrigation frequency. The treatments consisted three irrigation levels (no irrigation, one irrigation and two irrigations) and six fertility levels with NCPC (Control, 50% RDF, 100% RDF, NCPC 100 kg ha^{-1}, NCPC 100 kg ha^{-1} loaded with 50% RDF and NCPC 100 kg ha^{-1} loaded with 25% RDF). However, the interaction effect of irrigation levels and fertility levels with NCPC was observed significant on the dry matter accumulation of linseed crop at all the growth stages. The highest dry matter were recorded at 30 DAS (0.227, 0.207 and 0.217 g plant^{-1}), 60 DAS (5.04, 5.00 and 5.02 g plant^{-1}), 90 DAS (10.72, 9.59 and 10.15 g plant^{-1}), and at harvest (10.91, 9.76 and 10.33 g plant^{-1}) with the application of two irrigations + 100% RDF during both the years and in pooled analysis, respectively. Likewise, higher dry matter accumulation was found at the time of harvesting (80.02, 72.04, 60.62 and 78.48, 69.57, 55.94 per cent) with the application of two irrigations + 100% RDF over control during both the years, respectively. The present study highlighted the practical importance of the nanoclay polymer composites and fertility level on dry matter accumulation of the linseed under different irrigation frequency.

Keywords: Linseed, dry matter accumulation, irrigation, fertility levels, NCPC

Introduction
In Indian agriculture, oilseeds have a prestigious place next to cereals. India has world's third largest edible oil economy after the U.S. and China, and is the second largest importer after China. Linseed is cultivating worldwide over 2.62 million ha and production is 2.65 mt. India ranks first in the world in respect of acreage accounting for 23.8 per cent and sixth in production contributing 10.2 per cent (FAO, 2014). In India, cultivating ~ 2.7 lakh ha with the production of 1.3 lakh tonnes and productivity is 477 kg ha^{-1}. Its cultivation is mostly confined to Madhya Pradesh, Chhattisgarh, Jharkhand, Bihar, Uttar Pradesh and Maharashtra. The highest growing area (1.16 lakh ha) and production (55 lakh tonnes) of linseed is in Madhya Pradesh while the highest productivity in Rajasthan (1013 kg ha^{-1}) (DES, 2018; Ashoka *et al*., 2017) [1].

Among the oilseed crops grown during Rabi, linseed (*Linum usitatissimum* L.) is next in importance to rapeseed (*Brassica campestris* L.) and mustard *(Brassica juncea*L.) in the area as well as production. Linseed is an important and well-known oilseed as well as a fiber crop. It is popular due to its higher industrial importance (Meena *et al.*, 2017a, b) [13]. Its fiber is using in cloth, canvas, water-resistant pipes, packaging material, reinforcement of plastic and alternative for fiberglass. However, its oil is used as a good dying agent in varnish, paints, printing press, ink, high-quality soap, oil color, wood treatment, building, and construction industry, *etc.* (Ahlawat, 2014) [2]. Linseed seeds contain 30-40 per cent olive (Hayat and Ali 2004) [8]. Among the agronomic practices known to augment the crop yield, moisture supply is of vital importance (Meena *et al*., 2018a, b).

In view of the above, Nanotechnology has many applications in the field of agriculture to manage in water stress condition; yield level may be sustained or enhanced by using new advanced initiatives like superabsorbent polymer (SAP). The differences in yield levels with the use of SAP and farmers practices showed greater potentialities of achieving higher

Productivity in agricultural as well as horticultural crops (Sharma *et al.,* 2012) [19]. The adequate and balanced supply of plant nutrients is of critical importance in improving the productivity of oilseeds (Varma *et al*., 2017 b) [21]. Linseed crop responds to S application remarkably depending on soil type and source of its use. The functions of S within the plant are closely related to those of N, and both nutrients have synergistic response (Dutta *et al.,* 2017). P and S are generally deficient in the majority of our Indian soils and needs to the much attention on maintenance of P and S in soils (Bharose *et al.,* 2011) [4]. Hence, the objective of the present study was to elucidate the physiological basis of dry matter accumulation variations in linseed through accommodate on irrigation levels and balanced nutrition through inclusion of chemical fertilizers with nanoclay polymer composite.

Materials and Method

A field experiment was conducted during the winter seasons of 2014 and 2015 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, uttar Pradesh, India. The soil of the experimental field was clay loam having pH 7.83, 7.60, organic carbon 0.41%, 0.43%, available N 219.7, 219.3 kg ha^{-1}, available P_2O_5 23.35, 23.40 kg ha^{-1}, available K_2O 230.20, 226.3 kg ha^{-1} and available sulphur 20.56, 19.80 mg kg^{-1} during both the years, respectively. The experiment consisted of 18 treatments combinations viz., Main plot treatment– three irrigation levels (no irrigation, one irrigation and two irrigation) and Sub-plots treatment–six levels of fertility with NCPC (Control, 50% RDF, 100% RDF, NCPC 100 kg ha^{-1}, NCPC 100 kg ha^{-1} loaded with 50% RDF and NCPC 100 kg ha^{-1} loaded with 25% RDF). The data were analyzed as per the standard procedure for "Analysis of Variance" (ANOVA).

Results and Discussion

Interaction effects of sowing dates and fertility levels

The revealed of the data in table 1, 2, 3 and 4 indicated that the interaction effect of irrigation levels and fertility levels + NCPC were significantly observed on dry matter of linseed during both the years and in pooled analysis. Results indicated that two irrigations were produce maximum dry matter at 30 DAS (0.227, 0.207 and 0.217 g plant^{-1}), 60 DAS (5.04, 5.00 and 5.02 g plant^{-1}), 90 DAS (10.72, 9.59 and 10.15 g plant^{-1}) and at harvest (10.91, 9.76 and 10.33 g plant^{-1}) with the application of 100% RDF that was found at par by two irrigations + NCPC 100 kg ha^{-1} loaded with 50% RDF during both the years and in pooled analysis. While the minimum dry matter accumulation at 30 DAS (0.062, 0.054 and 0.058 g plant^{-1}), 60 DAS (1.16, 1.12 and 1.14 g plant^{-1}), 90 DAS (1.99, 1.93 and 1.96 g plant^{-1}) and at harvest stage (2.18, 2.10 and 2.14 g plant^{-1}) was observed in no irrigation + control plot during both the years and in pooled analysis. Moreover, the application of 100% RDF was increased the dry matter at harvest 79.28, 70.86 and 58.18 per cent over irrigation levels no irrigation, one irrigation and two irrigations with the control plots in pooled analysis, respectively. Further, the application of two irrigation with 50% RDF and NCPC 100 kg ha^{-1} loaded with 25% RDF was observed significantly at par with each other at all stages of the growth in both the years and in pooled analysis.

Besides the soil water plays important role with respect to movement and distribution of nutrients in soil and their uptake by the plants, this in turn determines the osmotic pressure in the plant. These facts clearly suggest the importance of adequate supply of water for optimum metabolic activities in plants resulting into better growth and development that increase the dry matter accumulation of the crop (Chauhan *et al.*, 2008; Datta *et al*., 2017) [5, 6]. The dry matter accumulation plant^{-1} significantly increase with increasing rates of irrigation appears to be on account of greater cellular activities which seem to have increased apical growth and accelerated elongation of internodes (Ahlawat and Gangaiah 2010, Mirshekari *et al.,* 2012) [3, 17]. Application of nitrogen along with phosphorus potassium and sulphur promotes differentiation and expansion of tissues resulting in production of more number of green leaves plant^{-1} thereby increased foliage, in turn might have accelerated the photosynthetic activity in plants producing more plant food material leading thereby to healthy growth (Kalita *et al*., 2005; Kumar *et al*. 2018) [11, 12]. The growth parameters were enhance with application of polymers because this has provided solutions to the problems of the present day agriculture which is to maximize land and water productivity without threatening the environment and the natural resources (Sarkar *et al*. 2014; Yadav *et al.,* 2017) [18, 1].

Table 1: Interaction effect of irrigation levels and nutrient management + NCPC on dry matter accumulation (g plant^{-1}) of linseed at 30 DAS

Treatments	2014-15			2015-16			pooled		
	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation
Control	0.062	0.079	0.103	0.054	0.060	0.082	0.058	0.069	0.093
50% RDF	0.089	0.129	0.165	0.077	0.101	0.143	0.083	0.115	0.154
100 %RDF	0.142	0.173	0.227	0.118	0.149	0.207	0.130	0.161	0.217
NCPC 100 kg ha^{-1}	0.088	0.122	0.141	0.066	0.094	0.118	0.077	0.108	0.129
NCPC 100 kg ha^{-1} loaded with 50% RDF	0.137	0.169	0.222	0.117	0.145	0.203	0.127	0.157	0.212
NCPC 100 kg ha^{-1} loaded with 25% RDF	0.093	0.126	0.158	0.075	0.110	0.131	0.084	0.118	0.144
SEm±	0.004			0.003			0.003		
CD (*p*=0.05)	0.011			0.010			0.008		

RDF= Recommended dose of fertilizers; NCPC=Nanoclay polymer composite

Table 2: Interaction effect of irrigation levels and nutrient management + NCPC on dry matter accumulation (g plant^{-1}) of linseed at 60 DAS

Treatments	2014-15			2015-16			pooled		
	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation
Control	1.16	1.54	2.12	1.12	1.26	1.84	1.14	1.40	1.98
50% RDF	1.79	2.72	3.57	1.69	2.31	3.35	1.74	2.51	3.46
100 RDF	3.04	3.76	5.04	2.74	3.52	5.00	2.89	3.64	5.02

NCPC 100 kg ha^{-1}	1.75	2.56	3.00	1.41	2.12	2.73	1.58	2.34	2.86
NCPC 100 kg ha^{-1} loaded with 50% RDF	2.90	3.67	4.90	2.70	3.42	4.87	2.80	3.55	4.88
NCPC 100 kg ha^{-1} loaded with 25% RDF	1.89	2.66	3.41	1.65	2.54	2.85	1.77	2.60	3.13
SEm±	0.09			0.15			0.09		
CD (p=0.05)	0.27			0.44			0.25		

RDF= Recommended dose of fertilizers; NCPC=Nanoclay polymer composite

Table 3: Interaction effect of irrigation levels and nutrient management + NCPC on dry matter accumulation (g plant^{-1}) of linseed at 90 DAS

Treatments	2014-15			2015-16			pooled		
	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation
Control	1.99	2.86	4.15	1.93	2.80	4.13	1.96	2.83	4.14
50% RDF	3.43	5.50	7.41	3.35	4.96	6.77	3.39	5.23	7.09
100 RDF	6.22	7.85	10.72	5.70	7.07	9.59	5.96	7.46	10.15
NCPC 100 kg ha^{-1}	3.33	5.16	6.13	3.25	4.63	5.69	3.29	4.89	5.91
NCPC 100 kg ha^{-1} loaded with 50% RDF	5.92	7.64	10.42	5.63	6.90	9.41	5.78	7.27	9.92
NCPC 100 kg ha^{-1} loaded with 25% RDF	3.63	5.38	7.07	3.42	5.36	6.15	3.52	5.37	6.61
SEm±	0.21			0.22			0.15		
CD (p=0.05)	0.60			0.64			0.43		

RDF= Recommended dose of fertilizers; NCPC=Nanoclay polymer composite

Table 4: Interaction effect of irrigation levels and nutrient management + NCPC on dry matter accumulation (g plant^{-1}) of linseed at harvest

Treatments	2014-15			2015-16			pooled		
	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation	No irrigation	One irrigation	Two irrigation
Control	2.18	3.05	4.34	2.10	2.97	4.30	2.14	3.01	4.32
50% RDF	3.62	5.69	7.60	3.52	5.13	6.94	3.57	5.41	7.27
100 RDF	6.41	8.04	10.91	5.87	7.24	9.76	6.14	7.64	10.33
NCPC 100 kg ha^{-1}	3.52	5.35	6.32	3.42	4.80	5.86	3.47	5.07	6.09
NCPC 100 kg ha^{-1} loaded with 50% RDF	6.11	7.83	10.61	5.80	7.07	9.58	5.96	7.45	10.10
NCPC 100 kg ha^{-1} loaded with 25% RDF	3.82	5.57	7.26	3.59	5.53	6.32	3.70	5.55	6.79
SEm±	0.19			0.21			0.13		
CD (p=0.05)	0.57			0.63			0.39		

RDF= Recommended dose of fertilizers; NCPC=Nanoclay polymer composite

Conclusion

In the rainfed area the water scarcity is the major problem. Superabsorbent polymers hydrogel potentially influence the soil moisture status. The result of the experiment showed that the two irrigations and fertility levels + NCPC (100% RDF and NCPC 100 kg ha^{-1} loaded with 50% RDF) gave higher dry matter accumulation than other combinations. By the application of NCPC farmers can reduce the loss of chemical fertilizers with NCPC application, it have slow releasing capacity of the fertilizers, and increased the water use efficiency.

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