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Growth and yield analysis of hydrogel and *Trichoderma* combinations in linseed varieties under rainfed condition

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ABSTRACT
Field experiments were conducted during rabi seasons of 2015 and 2016 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) to find out the growth and yield analysis of super absorbent hydrogel and Trichoderma combinations in linseed varieties. Among the varieties, RLC-92 found significant in producing maximum plant height, no. of branches, leaf area index and dry matter production over Kartika, Deepika and Garima. The maximum number of capsules and seed yield was recorded by RLC-92 and Garima. RLC-92 and Deepika produced highest oil yield during the investigation. The highest B:C ratio was found under RLC-92 followed by Garima. Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of Trichoderma treated seed recorded significantly higher growth and yield attributes but the higher B:C ratio was calculated under Seed treatment with Trichoderma @ 10 g kg^{-1} during both the years the investigation.
Keywords: *Hydrogel, Trichoderma, Growth, linseed, varieties.*

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INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an important oilseed and fiber crop in the world. Linseed has different industrial value and is produced mostly in India, Canada, China, USA, Argentina and Russia. Linseed is one of the most important industrial oilseed crops of India and stands next to rapeseed-mustard in *rabi* oilseeds in area and production. India is the second largest producer of linseed, next to Canada in the world with an area of 5.25 lakh ha, total production of 2.11 lakh tones per annum and productivity of 403 kg ha^{-1}. India has 18.8 per cent of worlds recorded linseed area but produces less than 10% of total world production. In India, Madhya Pradesh leads in yield and acreage, followed by Uttar Pradesh, Maharashtra, Bihar, Rajasthan, Karnataka and West Bengal also grow linseed in large areas. In Uttar Pradesh linseed is grown on 78 thousand hectare area producing 27 thousand tones with an average yield of 410 kg ha^{-1} [10]. In general, linseed oil has a high level of linolenic acid (35-66%), which imparts it the property of drying oil, suitable for manufacturing paints, stains, inks, varnishes and linoleum etc. Linseed is generally grown in rainfed or dry land areas where the residual moisture of previous crop is only source of water, thereby crop many time suffers from the water stress conditions results in drastic decrease in productivity of crop.The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability. Hydrogel are super absorbents that absorb and store water hundreds of times their own weight,*i.e.* 400-1500 g water per dry gram of hydrogel [1, 5]. Their performance is determined by the chemical properties of the hydrogel, such as molecular weight, formation conditions of the hydrogel, as well as the chemical composition of the soil solution or irrigation water. Water held in the expanded hydrogel is intended as a soil reservoir for maximizing the efficiency of plant water uptake. Commonly used hydrogel can be generally divided into three classes: natural polymers, synthetic hydrogels usually consist of polyacrylamides (PAM) and polyvinyl alcohols. Fully synthetic polymers are chemically cross-linked to prevent them from dissolving in solution [8].In recent years, low-input agricultural systems have gained increasing importance in many industrialized countries, for reduction of environmental degradation. Cropping system component of integrated farming systems with reduced inputs have been developed. It is under these conditions that plants are expected to be particularly dependent on beneficial rhizosphere microorganisms. Key

components of soil micro biota form symbiotic relationships with the roots of most terrestrial plants, improving the nutritional status of their host and protecting it against several soil-borne plant pathogens. The incidence and the effect of root colonization vary depending on the plant species.As the many bio-inoculants are used as plant growth promoting and bio-control agent but *Trichoderma* is used less as growth promoter [6].The *Trichoderma* is able to enhance the yields of many crops may be due to microbes which reduced disease infestation, secretes organic acid which converted insoluble form of nutrient to soluble form and also provided some additional micro nutrient, vitamins, auxin etc. [7] reported that, IAA levels were shown to be increased by the *Trichoderma* isolates that also promoted plant growth which led to give higher yield.The objective of the study was to determine the effect of hydrogel based *Trichoderma* combinations on growth and yields in linseed varieties.

MATERIAL AND METHODS

A field experiment was conducted to evaluate the effect of hydrogel and *Trichoderma* on crop growth and yields in linseed varieties at Research farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during *rabi*2015 and 2016. The experiment was laid out in Split Plot Design comprises three replications with four linseed varieties *i.e.*Kartika, Deepika, Garima and RLC-92 with six treatment combinations *i.e.* Control, Seed soaking in hydrogel @ 5 kg ha^{-1}, Seed treatment with *Trichoderma* @ 10 g per kg seed , Seed soaking in hydrogel @ 5 kg ha^{-1} followed by seed treatment with *Trichoderma* @ 10 g per kg seed, Furrow application of hydrogel @ 5 kg ha^{-1} and Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed. Soaking with hydrogel was done by mixing of required hydrogel with same amount of water and seed for 12 hrs before sowing. Seed was treated with *Trichoderma* @10 g per kg seed just before sowing of seed. Furrow application of hydrogel was done just before of direct seeding of seeds. Although, hydrogel is not soluble in water but it makes semi-translucent material with seed. A uniform dose of 40 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1}, and 20 kg K_2O ha^{-1} were applied for both years of experiment. The weekly mean minimum and maximum average temperature ranged between 14.8^{0}C to 29.4 ^{0}C and 14.6^{0}C to 28.9 ^{0}C, respectively, during 2015 and 2016. The rainfall received during the period of experiment was 45.5 mm and 1.0 mm during 2015 and 2016, respectively.The overall growth rate of the crop plant is measured at fixed period of time and produced at maximum growth stage (90 DAS). The yield attributes and yield were measured at harvest stage.

RESULTS

Effect on growth attributes

The data on growth attributes at maximum growth stages are presented in Table 1. Data revealed that all growth attributes was significantly varied under different varieties during the investigation. Thesignificantly higher plant height (cm), leaf area index and dry matter production (g $plant^{-1}$) was recorded under RLC-92 over Kartika, Deepika and Garima during both the years of experimentation. The variety RLC-92 on dry matter production was found comparable with Garima during 2016. The significantly highest number of branches $plant^{-1}$ was recorded under Garima (V_3) over Kartika (V_1) and RLC-92 (V_4) and remained comparable with Deepika (V_2) during both the years.The combinations of *Trichoderma* and hydrogel also significantly affected the different growth parameters at maximum growth stage. Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed recorded significantly highest plant height (cm), number of branches ($plant^{-1}$)and dry matter production (g $plant^{-1}$) over the control andremained at par withSeed treatment with *Trichoderma* @ 10 g kg^{-1} and Seed soaking in hydrogel @ 5 kg ha^{-1} followed by seed treatment with *Trichoderma* @ 10 g kg^{-1} during both years of experimentation. The leaf area index was not significantly affected by the different treatments. None of the interaction effect between varieties and hydrogel and *Trichoderma* combination on growth attributeswas found significant during both the years of experimentation.

Effect on yield attributes and yield

The data on yield attributes and yield (Table 2) was significantly influenced by varieties as well different hydrogel and *Trichoderma* combinations. The data reveals thatRLC-92 and Garima recorded significantly higher number of capsule $plant^{-1}$ and seed yield (kg ha^{-1}) over Kartika and Depeeka and remained at par with each other during the experimentation. However, the oil yield (kg ha^{-1}) was significantly higher under variety RLC-92 and Deepika over Kartika and Garima and remained statistically comparable to each other during both the years of experimentation. Among the combinations of hydrogel and *Trichoderma* treatments, Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed recorded significantly maximum capsule $plant^{-1}$ and seed yield (kg ha^{-1}) and oil yield (kg ha^{-1}) and remained comparable with Seed soaking in hydrogel @ 5 kg ha^{-1} followed by seed treatment with *Trichoderma* @ 10 g kg^{-1} during both years of experimentation. However, Seed treatment with

Trichoderma @ 10 g kg^{-1} was also found comparable with highest producing treatment on oil yield (kg ha^{-1}) production during both the years. The interaction between varieties and hydrogel and *Trichoderma* combined treatments failed to reach significance level during both the years.

Table 1: Effect of hydrogel and *Trichoderma* combinations on growth attributes of linseed at maximum growth stage (90 DAS)

Treatments	Plant height (cm)		No. of branches plant^{-1}		Leaf area index		Dry matter production (g plant^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016
Varieties								
V_1: Kartika	57.3	55.4	4.73	4.70	0.765	0.755	7.17	6.73
V_2: Deepika	54.5	50.9	5.15	5.29	0.842	0.834	7.64	7.27
V_3: Garima	62.1	60.1	5.60	5.51	0.561	0.850	8.07	7.51
V_4: RLC-92	73.2	70.5	4.19	4.44	0.887	0.883	8.88	8.13
SEm±	0.88	0.77	0.15	0.14	0.006	0.005	0.22	0.19
CD (0.05)	**3.05**	**2.65**	**0.50**	**0.49**	**0.020**	**0.017**	**0.75**	**0.65**
Hydrogel and *Trichoderma*								
H_1: Control	58.6	56.6	4.41	4.22	0.828	0.821	7.26	6.50
H_2: Seed soaking in hydrogel @ 5 kg ha^{-1}	60.3	57.9	4.75	4.76	0.831	0.826	7.78	7.13
H_3: Seed treatment with *Trichoderma* @ 10 g kg^{-1}	62.9	59.9	4.93	5.22	0.837	0.834	7.92	7.70
H_4: Seed soaking in hydrogel @ 5 kg ha^{-1} followed by seed treatment with *Trichoderma* @ 10 g kg^{-1}	62.8	60.5	5.10	5.29	0.841	0.837	8.39	7.73
H_5: Furrow application of hydrogel @ 5 kg ha^{-1}	61.5	59.0	4.90	4.89	0.837	0.830	7.87	7.47
H_6: Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed.	64.5	61.2	5.41	5.53	0.839	0.835	8.42	8.11
SEm±	0.79	0.75	0.11	0.13	0.006	0.005	0.18	0.14
CD (0.05)	**2.85**	**2.13**	**0.31**	**0.36**	**NS**	**NS**	**0.51**	**0.39**
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

Effect on Benefit: cost ratio

The data revealed that maximum B:C ratio was calculated with variety RLC-92 followed by variety Garimaduring both the years. Among the hydrogel and *Trichoderma* combined treatments Seed treatment with *Trichoderma* @ 10 g kg^{-1} recorded maximum B:C ratio followed by Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed during both the years.

DISCUSSION

In the present investigation, marked effect of combination of hydrogel and bio-agent (*Trichoderma*) were noticed on growth parameters *viz.* plant height (cm), number of branches (plant^{-1}), dry matter production (g plant^{-1}) and leaf area index (Table). All these data were at their maximum level was associated with treatment having application of hydrogel with seed treatment with *Trichoderma* during both the years of investigation.

Trichoderma increase availability of nutrients like macro (N, P, K) as well as micronutrient (Mo, Zn and Mn) to the roots of crop which helps in turns to increase in photosynthetic activity of plants that later enhances the vegetative growth and ultimately to the yield [3, 11]. Hydrogel improve water holding capacity and nutrient supplying capacity because it retain larger amount of water and increased the size 500-1000 times. Thus reduce the losses of water and provide slowly to plant, this leads to obtain higher growth stature. An increase in yield and yield related attributes could be because of sufficient availability of water and indirectly nutrients supplied by the super absorbent polymer (SAP) to the plants under water stress condition, which in turn lead to better translocation of water, nutrients and photosynthates and finally better plant stand and yield [2, 4].

Table 2: Effect of hydrogel and *Trichoderma* combinations on yield and yield attributes of linseed

Treatments	No. of capsules plant^{-1}		Seed yield (kg ha^{-1})		Oil yield (kg ha^{-1})		B:C ratio	
	2015	2016	2015	2016	2015	2016	2015	2016
Varieties								
V_1: Kartika	44.9	42.7	1329	1295	551.4	531.3	1.52	1.45
V_2: Deepika	47.6	45.9	1376	1333	582.1	561.5	1.48	1.40
V_3: Garima	54.4	52.8	1424	1353	563.2	529.7	1.58	1.45
V_4: RLC-92	55.1	54.3	1484	1434	601.2	584.6	1.66	1.60
SEm±	1.17	1.05	25.3	24.1	9.65	9.24	NA	NA
CD (0.05)	**4.05**	**3.62**	**87.3**	**83.3**	**33.31**	**31.88**	NA	NA
Hydrogel and *Trichoderma*								
H_1: Control	45.8	44.7	1263	1254	512.0	504.9	1.29	1.15
H_2: Seed soaking in hydrogel @ 5 kg ha^{-1}	51.0	48.9	1349	1340	555.3	545.1	1.13	1.11
H_3: Seed treatment with *Trichoderma* @ 10 g kg^{-1}	48.6	48.2	1430	1367	586.7	556.5	1.54	1.43
H_4: Seed soaking in hydrogel @ 5 kg ha^{-1} followed by seed treatment with *Trichoderma* @ 10 g kg^{-1}	53.7	51.1	1456	1405	595.4	565.1	1.29	1.21
H_5: Furrow application of hydrogel @ 5 kg ha^{-1}	47.8	47.1	1412	1357	576.9	549.3	1.22	1.14
H_6: Furrow application of hydrogel @ 5 kg ha^{-1} followed by sowing of *Trichoderma* treated seed.	55.9	53.4	1508	1429	609.5	575.9	1.38	1.32
SEm±	1.13	1.01	23.7	21.5	9.21	9.11	NA	NA
CD (0.05)	**3.22**	**2.88**	**67.5**	**61.5**	**26.29**	**25.96**	NA	NA
Interaction	NS	NS	NS	NS	NS	NS	NA	NA

CONCLUSION

The recent study on linseed has found that the hydrogel and *Trichoderma* both are effective to enhancing the growth as well as the final yield of the crop. *Trichoderma* has proven the symbiotic relationship with enhancing plant height, higher branches and dry matter. The different studies showed that this fungus has bio-fertilizer effect in host crop (9). On the other hand hydrogel was able to provide sufficient water at stress condition leads the higher seed yield as well as higher oil yield.

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