INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

EFFECT OF NANOCLAY POLYMER COMPOSITE ON GROWTH AND YIELD OF LENTIL IN A LONG TERM TRIAL UNDER RAINFED CONDITION

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ABSTRACT
Nanotechnology is now an emerging technology in the field of agriculture. The effect of nanoclay polymer composite (NCPC) is very much promising in soil. The present research was formulated to investigate its effect on lentil growth parameters during 201-2013 and 2013-2014 in a long term trial under rainfed condition. Lentil is one of the major protein supplying pulse crop (28.5%) in India after chickpea. NCPC successfully increased the grain yield of lentil from 833.6 kg/ha to 845.3 kg/ha when NCPC was applied in combination with 100 % N through farm yard manure (FYM). Besides grain yield, stubble yield also varied from 4.3% to 38.5 % over control. Its application also enhanced the other growth parameters like root length, plant dry weight, number of pods, primary branches *etc*. The effect NCPC in combination with FYM gave significantly higher yield than control. Application of either FYM alone or the effect of NCPC combination with NCPC increased the available nutrients and moisture retention capacity in soil and enhanced microbial activity responsible for organic matter decomposition and mineralization. The residual and cumulative effect of FYM and NCPC was also affected in enhanced production of subsequent crop like lentil under rainfed condition. So, its application is very much relevant in agriculture under rainfed condition.

KEY WORDS: nanoclay polymer composite, rainfed, lentil.

INTRODUCTION
Rainfed area assumes special significance in terms of ecology, agricultural productivity and livelihood for millions of rural households in India. Rainfed agriculture is complex, diverse and risk prone. Rainfed rice based cropping system in eastern Uttar Pradesh is characterized by low level of productivity and input usage which coupled with vagaries of monsoon result in wide variation and instability in yields. The *'rice fallow'* in India occupies nearly 12 million hectares (Singh *et al*., 1998) with more than half in the states of eastern India. The rice fallows represent an enormous underutilized resource (Musa *et al*., 2001). An additional pulse crop in rice-fallows will facilitate diversification of cereal-based cropping system, improve soil fertility and consequently enhance the productivity of rice, which is important, especially under the reported prevailing situation of declining partial and total factor productivity of rice-wheat and rice-rice cropping systems in the Indo-Gangetic Plain (IGP) region. Introduction of rabi crop in rice fallows is the key to poverty alleviation in rainfed rice based agro-ecosystems and deserves priority attention. Crop based inventory reveals rainfed farming as major source of livelihood security for the poor and marginal farmers in India. Rice based productions system are common in the watershed and in the eastern Uttar Pradesh even under rainfed situation. The average productivity of most of the crops under rainfed situation is very low compared to district, state and national production level. The continued mono-cropping of rice has resulted in imbalances in soil fertility and productivity due to various degradation processes including declining soil organic matter levels, build-up of pests, diseases and weeds, and so on. After green revolution (1965-66), due to intensive cultivation and imbalanced application of inorganic fertilizer the soil quality has declined. There is a need for a second green revolution to meet the demand of ever growing population with decline in cultivable area and natural resources. Rainfed ecosystem can play a crucial role opined by many eminent personalities. Our research work was confined within the transect-4 section of the IGP region under rainfed ecosystem, where mainly rainfed rice is grown during *kharif as a sole crop* and in certain case chickpea/ or lentil is grown as a 2nd crop during *rabi* season. This warrants integrated approach for improving as well as maintaining the sustainability in soil health and input management under rainfed system. The main problem in rainfed system is water, as we have to depend on rainfall and better utilization of rainwater coupled with this inputs like nutrient, crop residue management is another important point under rainfed system. Due to low availability of water, nutrient mobility as well as availability is hampered. The most important property of nanoclay polymer composite is superabsorbent and slow release of water and nutrient. It also reduced the use of fertilizer. Here, it plays the most important role to overcome the above mentioned bottlenecks of growing second crop after rice. The effect of nanoclay polymer composite (NCPC) on the growth and yield parameters of various crops are very little studied. A novel poly (acrylic acid-*co*-acrylamide) $AlZnFe_2O_4$/ potassium humate superabsorbent hydro gel nanocomposite (PHNC) was synthesized. The soil amendment with 0.1 to 0.4 w/w% of PHNC remarkably enhanced the moisture retention at field

capacity as compared to the un-amended soils. Seed germination and seedling growth of wheat (*Triticum aestivum* L.) was considerably increased and a delay by 6–9 days in wilting of seedlings was observed in the soil amended with PHNC, resulting in improved wheat plant establishment and growth. The germination percentage of the wheat varied from 80 to 98 per cent shoot length increased from 15 cm to 30 cm, and shoot fresh weight varied from 85 top 162 mg whereas dry weight varied from 16 to 35 mg respectively from increase in nanocomposite from o.1 to 0.4 % (Shahid *et al.,* 2012). Nanoclay polymer loaded with plant growth promoting organisms or biofertilizaer showed significant growth of maize under stress and normal conditions (Molesmi *et al.,* 2011). At the level of 225 kg/ha of Superabsorbent polymer applied to soybean, yield increased up to 6147 kg/ha than the control (Yazdani *et al.,* 2007). Mahdi *et al*., 2010 investigated the effects of different levels of water deficiency stress and super absorbent on yield, antioxidant enzymes activity and cell membrane stability in mustard. plant growth-promoting rhizobacterium (*Azospirillum brasilense* strain Az) and a biocontrol fungus (*Trichoderma harzianum* strain T24) have been evaluated for their individual and combined production of hydrolytic enzymes, nitrogen fixation and their possible role in growth promotion of tomato seedlings in ca-alginate matrix (El-Katany, 2009). Moghadam *et al*., 2009 evaluated the role of super absorbent polymer use in oilseed rape (*Brassica napus* L.) genotypes, under drought stress, evaluating some agronomic (total biomass, seed yield, yield components and harvest index) and physiological characters (chlorophyll content), under field conditions, the use of 7% of superabsorbent increased agronomic and physiological characters performance. Field results showed that drought stress and absence of super absorbent lead to a decrease in all agronomic parameters. Bres and Weston, 1993 also evaluated the effect of incorporated hydro gel amendments to a soilless growth medium on ammonium, nitrate, and water retention and tomato *(Lycopersicon esculentum* Mill.) seedling growth. Water retention by the growth medium increased linearly with gel application; Hydro Source generally was more effective than Agri-gel. Keeping the above view in mind, we conducted the research topic on the effect of nanoclay polymer composite (NCPC) on growth and yield of lentil under long term rainfed condition.

MATERIALS & METHODS

The experimental soil sample (0-15) cm depth, was collected from experimental site at research farm of Banaras Hindu University, Varanasi in the year 2012-2013 and 2013- 2014, growing lentil in rice-lentil cropping system under rainfed condition. This experiment has been under the network of the All India Coordinated Research Project on Dryland Agriculture (AICRP-DLA) of the Indian Council of Agricultural Research continuing since 1985. Varanasi falls under the transect 4 of IGP region having semi arid to sub-humid climate with average rainfall of 1081.4 mm and annual potential evapotranspiration of 1525.2 mm. About 87% of the total rainfall is received during monsoon season (June to September). The experimental soil was classified as fine sandy loam mixed hyperthermia *Udic Ustochrept.* The pH and EC (dS/m) of soil was 7.6 and 0.18 respectively. Plant nutrients were supplied only in rainfed rice through organic and inorganic sources of nutrients and second crop lentil cultivated with the residual fertilizer *i.e.* no external application of organic and inorganic fertilizer in lentil, cv. HUL-57 time of sowing is rabi season (last week of October-November 1st week). The six treatments comprising combinations of organic and inorganic sources were tested using NCPC in 5 kg soils arranged in a completely randomized design with three replications under green house condition. The treatments were: control (no nutrient supplemented)-T_1, 100% Recommended Dose of Fertilizer (RDF) i.e. 80-40-30 kg ha^{-1} N: P: K-T_2, 100% N through Farm Yard manure (FYM)-T_3, 50% N through FYM-T_4, 50% RDF + 50% N through FYM-T_5 and Farmer's general practice (20 kg N ha^{-1})-T_6. Nanoclay polymer composite was applied @ 20 kg/ha in each soil of the lentil growing pot which were collected from the field of long term trial.

Preparation of NCPC

Nanoclay polymer composite (NCPC) was prepared from commercially available nano bentonite through the process described by Liang and Liu, 2007.

Growth parameters

The heights of the plants were measured at 30 and 60 DAS after sowing with meter scale. The length of the roots of the uprooted plants was also measured through scale. No of pods per pot was measured at the time of harvesting**.** After harvesting the crop seeds were separated from the plant and were oven dried at 60± 2ºC till a constant weight. After separating seeds from the plant the plant samples were kept in paper bags and oven dried at 60± 2ºC till a constant weight. After harvesting total dry matter of plant samples were recorded.

Statistical Analyses

The significant differences among the treatments were judged by analysis of variance (ANOVA) in completely randomized design (CRD).

RESULTS & DISCUSSION

The average plant height (Table1) was recorded during two critical growth stages (30 DAS and 60 DAS). The maximum height was found in T_3 and minimum height was recorded under control (T_1) at LSD (P=0.05) in both the stage over two years. The mean over two year revealed that 100 % RDF *i.e.* T_2 had 35.2 cm and 36.25 cm at 30 DAS and 60 DAS, respectively whereas in 50 % N through FYM (T_4) it was 33.8 cm and 33.7 cm. 50 % RDF+50% FYM (T_5) recorded 34.2 cm, 32.6 cm after 30 DAS and 60 DAS respectively in 2012-2013, the corresponding value in second year was 33.5 cm and 33.6 cm, respectively. The drastic reduction of average plant height at 60 DAS was due to low nutrient availability in soil and moisture content which was described by Spigel *et al.,* 1984. Due to prevalence of low moisture in soil leading to wilting of plants and subsequently plant height reduced at 60 DAS than at 30 DAS. In 100 % N through FYM (T_3) and 100 % RDF (T_2), at 60 DAS plant height was higher than other treatments due to more residual nutrient level than control. Higher nutrient availability in soil provided low severity of diseases. The maximum average plant dry weight increased under T_3 and T_4, respectively at LSD (P=0.05) level over control. Similar trend was also found under T_2 and T_5. The lowest plant dry weight was found under control may be due to low concentration of available nutrients in soil at later critical growth stages. In 2013-2014, T_3 and T_4 was statistically at par *i.e.* 1.27 gm and 1.28 gm respectively at LSD (p=0.05) = 0.06 over control. In 2012-2013, the average plant root length was maximum in T_3 *i.e.* 12.60 cm and lowest is 3.2 cm under control (T_1). 50% N through FYM (T_4) was 12.3 cm which was statistically at par with T_3. 100 % RDF having average root length of 11.3 cm, T_5 having 10.6 cm followed by Farmer's practice having lowest *i.e.* 8.9 cm over control. In the second year (2013-14) same trend followed in all the treatments. The 100 % N through FYM showed the highest due more water retention capacity and nutrient availability of soil (Bandyopadhyay *et al*., 2011 and Mahdi *et al*., 2010).

TABLE 1: Average Plant height at critical growth stages, plant dry weight and avg. root length in 2012-2013 and 2013-2014

Treatments	Average plant height at 30 DAS (cm)		Avg. Plant height at 60 DAS (cm)		Avg. Plant dry weight (gm)		Avg. root length (cm)	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
T_1	27.3	16.2	19.1	14.0	0.2	0.6	3.2	2.6
T_2	37.2	33.2	38.1	34.4	1.20	1.18	11.3	11.1
T_3	38.5	35.9	39.8	35.1	1.30	1.27	12.6	12.4
T_4	33.3	30.8	36.1	31.3	1.31	1.28	12.3	10.2
T_5	34.2	33.5	32.6	33.6	1.20	1.17	10.6	10.9
T_6	35.0	34.5	33.2	30.5	0.8	0.9	8.9	9.9
SEM±	1.1	0.97	1.18	0.87	0.02	0.02	0.22	0.39
LSD (p=0.05)	3.4	2.98	3.62	2.69	0.07	0.06	0.69	1.21

TABLE 2: Effect of NCPC on Plant height at critical growth stages, plant dry weight and avg. root length in 2012-2013 and 2013-2014

Treatments	Average plant height at 30 DAS (cm)		Avg. Plant height at 60 DAS (cm)		Avg. Plant dry weight (gm)		Avg. root length (cm)	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
T_1	29.0	22.0	20.9	16.6	0.45	0.80	4.5	4.6
T_2	38.0	34.0	38.8	35.2	1.21	1.29	11.8	12.2
T_3	39.8	37.8	40.1	37.4	1.30	1.30	13.0	13.0
T_4	35.0	32.1	37.1	32.7	1.30	1.30	12.6	11.5
T_5	36.0	33.6	33.2	34.3	1.19	1.21	11.5	11.7
T_6	36.0	34.5	34.8	29.9	0.90	0.70	10.3	10.6
SEM±	1.07	1.29	0.91	1.06	0.03	0.02	0.59	0.57
LSD (p=0.05)	3.31	3.96	2.8	3.26	0.08	0.07	1.83	1.77

All the figures in the Table 2 increased the plant height at two critical growth stages after application of NCPC in 2012-2013 and 2013-2014.The average plant height after application of NCPC in both the year was highest in T_3 over control (T_1). The relative enhancement of plant height due to NCPC over the two year of study period varies from 0.5 to 3.75 cm among all the treatments and the maximum enhancement noted in T_1. The Average plant dry weight and the root length after application of NCPC over the two years also increased from untreated NCPC. The average plant dry weight and root length was highest in 100 % N through FYM i.e. T_3 was 1.30 gm and 13.0 cm in both the years over control 0.45 gm and 0.82 gm and 4.5 cm and 4.6 cm. It may be due to the increased availability of nutrients and water in soil through its controlled release property (Guo *et al*., 2005).

TABLE 3: Average no of primary branches, no of pods, grain yield and stubble yield in the year 2012-2013 and 2013-2014

Treatments	No. of primary branches	No of pods per plant	Grain Yield (kg/ha)	Stubble Yield (q/ha)
T_1	6.8	51.9	372.3	13.0
T_2	7.8	78.6	745.5	21.6
T_3	8.6	87.0	833.6	24.3
T_4	6.8	74.3	548.0	20.3
T_5	7.7	82.7	787.6	23.2
T_6	7.5	57.6	375.3	17.5
SEM±	0.23	1.34	7.22	0.7
LSD (P=0.05)	0.7	4.12	22.23	2.15

A significantly higher number of pods, primary branches per plant of lentil was recorded in 100% N through FYM (T_3) treated over control (T_1). The statistical analysis revealed that all the treatments produced significantly higher grain yield of lentil over control. Higher grain yield (833 kg/ha) and stubble yield of lentil (24.3 q/ha) was recorded for T_3 (100% N through FYM) which was significantly higher over all the treatments (Table 3). Grain and stubble yield of lentil was influenced more by residual effect of FYM in comparison to inorganic fertilizer. The effect of FYM alone gave significantly higher yield than control. Application of either FYM alone increased the availability of nutrients in soil and enhanced microbial activity responsible for organic matter decomposition and mineralization. The residual effect of FYM was also affected in enhanced production of subsequent crop. The results are in conformity with the works of Mahdi *et al*., 2010. Application of NCPC in each treatment including control significantly increased the number of pods, primary branches per plant of lentil. The maximum number was obtained under 100% N through FYM (T_3) over control (T_1). Higher grain yield (845 kg/ha) and stubble yield of lentil (25.5 q/ha) was recorded for T_3 (100% FYM along with NCPC) which was significantly higher over all the treatments (Table 4). The relative increment of grain yield varies from 1-19 % where as stubble yield varies 4.3% to 38.5% with application of NCPC in different treatment. Grain and stubble yield of lentil was influenced more by residual effect of FYM along with NCPC in comparison to inorganic fertilizer. The effect of FYM alone as well as in combination with NCPC gave significantly higher yield than control. Application of either FYM alone or in combination with NCPC increased the availability of nutrients in soil and enhanced microbial activity responsible for organic matter decomposition and mineralization. The residual and cumulative effect of FYM and NCPC was also affected in enhanced production of subsequent crop. The results are in conformity with the works of Shahid *et al*., 2012, Molesmi, 2011, Yazdani *et al.,* 2007, where polymer increased the yield of crops under rainfed condition.

TABLE 4: Effect of NCPC on average no of primary branches, no of pods, grain yield and stubble yield in the year 2012-2013 and 2013-2014

Treatments	No. of primary branches	No of pods per plant	Grain Yield (kg/ha)	Stubble Yield (q/ha)
T_1	8.5	53.2	399.3	18.0
T_2	10.0	83.0	787.6	23.3
T_3	13.0	92.3	845.3	25.5
T_4	9.3	75.8	563.6	23.0
T_5	9.6	86.3	795.0	24.2
T_6	10.0	60.1	449.3	18.6
SEM±	0.52	2.01	8.71	0.58
LSD (P=0.05)	1.59	6.21	26.85	1.78

CONCLUSIONS

Application of NCPC in combination with FYM is a better option to enhance nutrient availability, moisture retention specially under rainfed conditions because it enhanced the rate of decomposition and microbial activity in soil which increased the grain yield and number of pods, plant height and other growth parameters of lentil. So, instead of only FYM, combination of both NCPC and FYM may produce better crop growth in second crop after rice in a long term trial under rainfed condition.

ACKNOWLEDGEMENT

The senior author is indebted to the University Grant Commission, New Delhi, for granting funds in a major research project on nanotechnology in agriculture (BHU project code-P-01/683).

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