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Soil properties in rice-based cropping systems as influenced by fertigation levels in the eastern plains of Bihar

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Abstract
An experiment at Bihar agricultural college, Sabour Bhagalpur was carried out in split plot design with three fertigation levels of nitrogen in main plots (nitrogen @ 20, 40 and 60 kg ha^{-1} in rice with irrigation @ 200, 300 and 400 mm in post rice crops) and six rice-based cropping systems as subplot treatments (rice followed by either durum wheat, barley, linseed, chickpea, lentil, lathyrus) on the on-going experiment initiated from 2014. The findings of the research after four years of continuous fertigation and cropping systems practice was that they had no significant change in the soil properties such as pH, EC and bulk density at all the different soil depths considered (0-15 cm, 15-30 cm and 30-45 cm). Soil carbon content was increased with increasing nitrogen levels. The concentrations of available nitrogen, phosphorus and potassium were found to be vary among all the levels of fertigation as well as cropping systems and there was reduction in content with move to the lower soil depths. The higher values for all soil parameters were observed under nitrogen level of @ 60 kg ha^{-1} in rice through fertigation followed by 400 mm irrigation in post-rice crop compared to other levels of fertigation and cropping systems. Finally, it can be concluded that fertigation and cropping systems had non-significant on soil properties even after four cropping cycles; however, there was slight increment in organic carbon status of soil.

Keywords: Drip fertigation, cropping system, physico-chemical properties

Introduction
Most of the world observed land degradation due to intensive agriculture for maximum yield. Intensive agriculture has accelerated worsening soil factor such as soil erosion, depletion of nutrient, prompting soil structure deterioration and reduction of organic carbon. Rice (*Oryza Sativa*) is the major stable food grain crop of India. Rice - wheat cropping system is widely practice in this country. This cropping system is predominant of North and Central India which is mainly concentrated in Indo- Gangetic plains. In some regions of eastern India, farmers grow lentil as second crop by broadcasting the seeds within the standing rice crop in well-moistened soils without any tillage 15-20 days prior to the harvest of rice (relay cropping) and obtain much less yield from lentil (Bandyopadhyay *et al.* 2016) [1]. In the soil ammonia binding can be enhance by application of light irrigation water (Li *et al.* 2008) [11]. To take care of land fertility and land health for ampule of production and productivity, soil management is prime agenda in today's scenario. In this regards sufficient practices for irrigation and fertilizer will be one of the suitable practices to maintain soil fertility by maintaining productivity and soil health. In this perspective fertigation (Irrigation and fertilizer application) is one tool. Application of fertilizer with irrigation system, lower the volatilization loss of ammonia. (Li *et al.* 2008) [11] applications of fertilizer by medium of irrigation is term Fertigation enhance efficiency (Biswas, 2010) [3]. It allow release of fertilizer in slow and limited amount to the soil rhizosphere, which influence plants for higher uptake as well as increasing the fertilizer use efficiency. Traditional system of fertilizer application is not enough for intensive cropping in present scenario. Hence, in rice based cropping system fertigation not merely requirement for production of crops with quality rather also for maintaining physicochemical of soil and sustainability for environment.

Materials and Methods
The present investigation was conducted during the fourth rice crop in the system (Kharif, 2017). The experimental farm of Bihar Agricultural College, Sabour, Bhagalpur comes under

the Middle Gangetic plain region of Agro-climatic Zone IIIA at the geographical coordinates of 24º 13´ 45´´ N latitude, 87º 02´ 48´´ E longitude and located in sub-tropical climate with hot desiccating summer, cold winter and moderate rainfall. The average annual rainfall is 1231.4 mm, precipitating mostly between mid-June to mid-October (during south west monsoon). sub-humid zone of Bihar.

Methodologies

The experiment was conducted in kharif season after the harvesting of rabi crop fallow field treated with glyphosate@ 1 kg a.i. ha^{-1} with 2,4-D @ 1 kg a.i. ha^{-1}. Recommended dose of fertilizer (N- 60, 40 and 20 kg ha^{-1} N in three split dose, SSP and MOP 40 kg P_2O_5 ha^{-1} and 20 kg ha^{-1} for rainfed rice) was applied through zero tillage. Out of different doses of N level, two remaining dose was applied by means of fertigation at different interval such as panicle initiation and at time of tillering stage. Sahbhagi Dhan variety of rice was taken for experiment. The main plot consists of 6 sub plot (4.0 m x 4.2 m). Crop spacing maintain by 30 cm apart for the convenient of laterals of drip irrigation. Soil samples collected at three depths at 0-15 cm, 13-30 cm and 3045 cm after harvesting of rice crop. Measurement of physiochemical parameter pH (Jackson, 1973) [9], EC (Jackson, 1973) [9], available N (Subbiah and Asija, 1956) [17], available P Olsen *et al*. (1954) [12], available K (Hanway and Heidel, 1952) [8]. Bulk density (Blake and Hartge, 1986) [4]. In split plot 3 fertigation(W_1= N @ 20kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops, W_2= N @ 40kg/ha in rice through fertigation followed by 300 mm irrigation in post-rice crops, W_3= N @ 60kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops) and sub plot consider rice based cropping system (C_1=Rice-Durum Wheat,C_2=Rice-Barley,C_3=Rice- Linseed C_4=Rice-Chickpea C_5=Rice-Lentil C_6=Rice-Lathyrus.)

The data for various parameters was analyzed for variance as for a split plot design considering the three fertigation regimes as the main plot treatments and six of the rice based cropping systems as sub plot treatments (Gomez and Gomez, 1984) [6].

Results and Discussions

Soil pH

Table 1 displays no significant relationship that the fertigation with 40 kg N ha^{-1} in rice followed by 300 mm irrigation in post rice crops recorded highest pH (7.29) and lowest in fertigation with 20 kg N ha^{-1} in rice followed by 200 mm irrigation in post rice crops (7.22) at 0-15 cm soil depth. No significant variation in pH was found at subsurface soil *i.e.* 15-30 cm and 30-45 cm. although higher magnitude of pH (mean of three depths) was found in the rice-lentil cropping system. Highest value of soil pH was found in 30-45 cm soil depth irrespective of treatment. It was observed that leaching losses of bases and hydrogen ion from surface soil raises the pH of soil, Schwab, Owensby, Kulyingyong (1990) [13].

Table 1: Efficacy of cropping systems and Fertigation on soil pH after 4th Rice crop

Treatment	Depth (cm)		
	0-15	**15-30**	**30-45**
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	7.22	7.23	7.36
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	7.29	7.41	7.48
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	7.24	7.28	7.39
SEm (±)	0.20	0.25	0.34
LSD (p≤0.05)	NS	NS	NS
C_1=Rice-Durum Wheat	7.22	7.22	7.41
C_2=Rice-Barley	7.34	7.20	7.34
C_3=Rice- Linseed	7.18	7.14	7.38
C_4=Rice-Chickpea	7.34	7.35	7.40
C_5=Rice- Lentil	7.39	7.28	7.47
C_6=Rice-Lathyrus	7.33	7.33	7.47
SEm (±)	0.33	0.28	0.19
LSD (p≤0.05)	NS	NS	NS
Interaction			
SEm (±)	0.21	0.23	0.27
LSD (p≤0.05)	NS	NS	NS

Electrical Conductivity (EC)

In Table 2, result showed there was non-significant effect on soil EC (Electrical conductivity). Application of nitrogen @ 60 kg ha^{-1} in rice through fertigation followed by 400 mm irrigation in post-rice crops (0.23 dSm^{-1}) recorded highest EC among the all fertigation management system whereas rice-chickpea cropping system recorded highest EC (0.25 dSm^{-1}) among the six cropping system practices. The fluctuation in values of EC was observed in between the treatments it might be due to the contribution of dissolved ions and salt from soil as well as irrigation and rain water which release of ionic species due to prevalent reduction and oxidation processes as also reported by Sur *et al.* 2010.

Table 2: Efficacy of cropping systems and Fertigation on electrical conductivity (dSm^{-1}) after 4th Rice crop

Treatment	Depth (cm)		
	0-15	**15-30**	**30-45**
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	0.20	0.22	0.24
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	0.21	0.24	0.25
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	0.23	0.23	0.25
SEm (±)	0.05	0.11	0.09
LSD (p≤0.05)	NS	NS	NS
C_1=Rice-Durum Wheat	0.23	0.25	0.25

C_2=Rice-Barley	0.21	0.22	0.24
C_3=Rice- Linseed	0.19	0.22	0.24
C_4=Rice-Chickpea	0.25	0.25	0.26
C_5=Rice- Lentil	0.22	0.21	0.22
C_6=Rice-Lathyrus	0.19	0.22	0.26
SEm (±)	0.20	0.30	0.28
LSD (p≤0.05)	0.02	0.03	0.02
Interaction			
SEm (±)	2.11	1.04	1.15
LSD (p≤0.05)	0.04	NS	NS

Available Nitrogen

Fertigation and cropping system non-significantly affect available N (Nitrogen). Table 3 shows that at the depth of 0-15 cm, fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available N (193.74 kg ha^{-1}). Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available N (158.88 kg ha^{-1}) in 15-30 cm soil depth. At the depth of 30-45 cm, fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available N (151.91 kg ha^{-1}). Cropping systems did not have any significant influence in available N irrespective of soil depth, although higher magnitude of Available N (mean of three depth) was found in the rice-lathyrus cropping system. This could be because of greater uptake of nitrogen from deeper soil layers in treatments receiving larger inputs of water through fertigation. The data shows that after the harvest of the rice crop, the available nitrogen content in the soil surface was minimum in rice-chickpea cropping system followed by that in the rice-durum wheat cropping system and maximum in rice-barley and rice-lentil cropping system, both of which were statistically similar. For instance the mineral fertilizer addition in durum wheat, barley, lentil and chickpea amounted to 120, 80, 18 and 18 kg ha^{-1}, respectively. The variability of Av. N content in soil it might be due to variable doses of application of fertilizer which may be hampered the biological nitrogen fixation. The available nitrogen content in the 15-30 cm and 30-45 cm soil layers was also significantly lower in rice-chickpea cropping system in comparison to other cropping systems. The same factor might be responsible for lower depth as 0-15 cm depth as well as cropping pattern system. The decline of available N content in soil it might be due to lowered down of organic carbon content with depth as well the root density of lower plant which ultimately lowering the microorganism population leads to minimal biological proliferation (Benbi and Senapati, 2010) [2]. N uptake was minimal as observed in Barley from the surface layer in comparison to Wheat. The response of N at field level was observed for annual cropping systems, in that it was fallowed a cereal crop than a legume crop or a a system where cereal is sown after the harvesting of legume (Shah *et al.* 2003) [15]. The part of nodulated roots system and aboveground crop residues, left over after the harvesting and other different components of the crop which had been harvested; provide potential sources of valuable N which replenishing the N pools in soil (Giller, 2001) [7].

Table 3: Efficacy of cropping systems and Fertigation on soil available nitrogen (kg ha^{-1}) after 4th Rice crop'

Treatment	Depth (cm)		
	0-15	**15-30**	**30-45**
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	185.90	152.78	142.32
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	188.51	155.40	144.50
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	193.74	158.88	151.90
SEm (±)	5.37	1.86	1.98
LSD (p≤0.05)	NS	NS	NS
C_1 = Rice-Durum Wheat	196.36	155.40	148.42
C_2 = Rice-Barley	189.38	157.14	144.94
C_3 = Rice- Linseed	178.05	154.53	146.68
C_4 = Rice-Chickpea	185.03	155.40	144.94
C_5 = Rice- Lentil	188.51	151.91	142.32
C_6 = Rice-Lathyrus	198.97	159.75	150.17
SEm (±)	6.64	3.61	4.10
LSD (p≤0.05)	NS	NS	NS
Interaction			
SEm (±)	11.51	6.25	7.10
LSD (p≤0.05)	NS	17.72	NS

Available Phosphorus

Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available P (24.44 kg ha^{-1}) at 0-15 cm soil depth (Table 4). Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available P (20.11 kg ha^{-1}) at 15-30 cm soil depth. At lower depth, fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops recorded highest P (18.62 kg ha^{-1}). There was no any influence of cropping system in available P irrespective of soil depth, though higher magnitude of Available P (mean of three depths) was found in the rice-lentil cropping system. The crop suffer sufficient dry spell after the harvesting of rice in post-rainy season (November-May) due to lack of amount of enough irrigation water or rainfall (Kar and Kumar, 2009) [10]. The prevalent conditions such as wet as well as dry cycles have major impact on plant available nutrition (Kato *et al.* 2016). The Irrigation by means of Fertigation and soil moisture availability cause ampule amount of P in soil (Bandyopadhyay *et al.* 2016) [1]. The probable clarification for this occurrence is that after the application of substantial amount of P fertilizer in rice field, availability for root rhizosphere leads to more uptake of P from treatments than lower levels of fertigation.

Table 4: Efficacy of cropping systems and Fertigation on soil available Phosphorus (kg ha^{-1}) after 4th Rice crop

Treatment	Depth (cm)		
	0-15	15-30	30-45
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	22.93	18.80	13.70
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	23.39	19.59	15.89
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	24.44	20.11	18.62
SEm (±)	0.83	2.13	2.20
LSD(p≤0.05)	NS	NS	NS
C_1=Rice-Durum Wheat	23.35	19.11	14.83
C_2=Rice-Barley	23.43	20.64	12.98
C_3=Rice- Linseed	23.17	17.52	12.50
C_4=Rice-Chickpea	23.32	21.86	17.54
C_5=Rice- Lentil	25.84	23.05	20.25
C_6=Rice-Lathyrus	22.40	14.83	18.33
SEm (±)	2.26	2.88	2.13
LSD(p≤0.05)	NS	NS	NS
Interaction			
SEm (±)	3.92	4.98	3.69
LSD(p≤0.05)	11.12	14.13	10.45

Available Potassium

In table 5, Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available K (91.47 kg ha^{-1}) at 0-15 cm soil depth. Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available K (108.04 kg ha^{-1}) at 15-30 cm soil depth. At the depth of 30-45 cm fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops having highest available K (124.92 kg ha^{-1}). Highest value of available K was found in 30-45 cm soil depth irrespective of treatments. Non-significant difference was found among the treatments and cropping systems. There was increasing trend of potash availability observed with depth it might be due to leaching of K of the soil that mainly belongs to sandy clay loam textural soil texture. (Table 5). At the depth of 30-45 cm soil before rice establishment, the availability of potash was significantly higher in W_2 and W_1 fertigation regimes and lowest in W_3 fertigation regime. The interaction among Fertigation regimes as well cropping systems ensure significant differences in potash availability across different combinations of treatment at the depth of 30-45 cm before the establishment of rice crop and at the depths of 0-15 cm and 30-45 cm after the harvest of rice crop. In 0-15 cm soil depth K availability was minimal, but K availability increases with increasing depth. As by line drip irrigation method in kharif season when Fertigation with N level there was leaching losses of large amount of soluble K ease K deposition to lower depths (Singh and Singh, 2003) [16]. Obviously, various fertigation regimes were significantly influenced by available K. Higher W_2 and W_1 than W_3 Fertigation regimes due to accumulation of higher amount of available K, same trend was also observed in moderate irrigation. The sub surface layer observed to be higher potassium content (30-45 cm)it might be due to application of large amount of nitrogenous fertilizer in rice-durum wheat cropping system boost crop for uptake of N as well as K from upper surface layer and in turn leads to substantial reduction of soil potassium at upper surface (Singh *et al.* 2003) [16] The uptake of potassium increases up to 145 % after application of nitrogenous and phosphorus in comparison to control (Tandon and Sekhon, 1988) [19].

Table 5: Efficacy of cropping systems and Fertigation on soil available Potassium (kg ha^{-1}) after 4th Rice crop

Treatment	Depth (cm)		
	0-15	15-30	30-45
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	83.85	104.53	122.68
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	83.18	106.47	121.41
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	91.47	108.04	124.92
SEm (±)	2.69	4.13	2.90
LSD (p≤0.05)	NS	NS	NS
C_1 = Rice-Durum Wheat	84.37	106.03	119.02
C_2 = Rice-Barley	90.35	107.22	121.86
C_3 = Rice- Linseed	87.06	97.96	117.82
C_4 = Rice-Chickpea	89.30	110.21	126.19
C_5 = Rice- Lentil	86.17	114.54	124.99
C_6 = Rice-Lathyrus	79.74	102.14	128.13
SEm (±)	3.46	4.32	5.17
LSD (p≤0.05)	NS	NS	14.1
Interaction			
SEm (±)	6.00	7.49	8.96
LSD (p≤0.05)	NS	NS	NS

Bulk density (BD)

In table 6, the BD (Bulk density) was found significant at different depth of the soil. In surface soil (0-15 cm), the highest bulk density was recorded in fertigation with 20 kg N ha^{-1} in rice followed by 200 mm irrigation in post rice crops (1.52 Mg m^{-3}) and the lowest in Fertigation with 60 kg N ha^{-1} in rice followed by 400 mm irrigation in post rice crops and same trend was found in rest two depths. Similar trends were observed in 15-30 and 30-45cm depths. Soil BD was highest (1.52 Mg m^{-3}) in C_1 (rice-durum wheat) and lowest in C_6 (rice- lathyrus) at the depth 0-15 cm. At the depth of 15-30 cm highest BD was found in rice-durum wheat cropping system (1.56 Mg m^{-3}) whereas at 30-45 cm soil depth, maximum BD was in rice- durum wheat. The value of BD was highest in lowest soil depth *i.e.,* 30-45 cm. Bulk density found to be higher where development of abundant plant roots in soils system (Brady and Weil, 2002) [5]. However, in the table the differences in root profuseness expected under various cropping systems was not observed in measurements of the bulk density that taken after the harvest of the rice crop.

Table 6: Efficacy of cropping systems and Fertigation on soil bulk density (Mg m^{-3}) after 4th Rice crop

Treatment	Depth (cm)		
	0-15	15-30	30-45
W_1= N @ 20 kg/ha in rice through fertigation followed by 200 mm irrigation in post-rice crops	1.52	1.55	1.58
W_2= N @ 40 kg/ha in rice through fertigation followed by 300 mm irrigation in post rice crops	1.51	1.54	1.56
W_3= N @ 60 kg/ha in rice through fertigation followed by 400 mm irrigation in post-rice crops	1.48	1.52	1.54
SEm (±)	0.58	1.15	0.98
LSD(p≤0.05)	NS	NS	NS
C_1=Rice-Durum Wheat	1.52	1.56	1.58
C_2=Rice-Barley	1.50	1.52	1.55
C_3=Rice- Linseed	1.50	1.52	1.53
C_4=Rice-Chickpea	1.51	1.52	1.54
C_5=Rice- Lentil	1.50	1.53	1.55
C_6=Rice-Lathyrus	1.49	1.53	1.56
SEm (±)	1.26	1.80	1.30
LSD(p≤0.05)	NS	NS	NS

Conclusion

The fertigation and cropping systems do not have any significant effect on soil EC. The available N content of soil decreased with the increased soil depth. However, the effect of treatments was found to be non-significant. Available P decreased with increase in soil depth with highest being in rice-lentil system at both the lower depths. The effect of different levels of fertigation and cropping systems were found to be non-significant. Among the cropping systems, available K was found to be maximum under Rice- barley cropping system. There was increase in available K content of soil with the increase in soil depth. The effect of different levels of fertigation and cropping system on available K was found to be non-significant but there was a significant effect of interaction between fertigation and cropping system. With the increase in soil depth, increase in bulk density of soil was observed in all the treatments. Although, the effect of fertigation and cropping system on soil properties was found to be non-significant but there was build up in available N, P and K status of soil and favourable effect on soil pH and EC. Slight decrease in soil bulk density too was observed.

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