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Influence of Water and Nitrogen on Soil Physical Properties in Puddled Rice

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ABSTRACT

A study was carried out on a silty clay loam soil (Typic Haplustept) at Indian Agricultural Research Institute, New Delhi to study the impact of water regimes, nitrogen level, FYM and their interaction on soil physical properties in rice during 1999 and 2000. Treatments included three water regimes, namely, I_c (continuous submergence); I_1 (irrigation one day after disappearance of water) and I_3 (irrigation 3 days after disappearance of water) and six N levels *viz.*, N_0 (Control i.e no nitrogen); N_{60} (60 kg N ha^{-1}); N_{120} (120 kg N ha^{-1}); N_{150} (150 kg N ha^{-1}); N_{120F} (120 kg N ha^{-1} of which 50% was applied through urea and 50% through FYM) and N_{150F} (150 kg N ha^{-1} of which 50% was applied through urea and 50% through FYM). Results indicated that application of FYM and increase in N level reduced bulk density (ρ_b), but increased saturated hydraulic conductivity (*Ks*) and the mean weight diameter (MWD). Irrigating one or three days after disappearance of ponded water resulted in increase in *Ks* and MWD of soil aggregates as compared to continuous submergence With the same level of *N*, the treatments involving application of FYM reduced ρ_b, but increased *Ks*, MWD and water retention at 0.01 MPa.

Key words: Water, Nitrogen, N, FYM, Physical properties, Puddled rice

Introduction

Water and nutrient management in rice are the two vital issues as they play an important role in modifying the soil physical properties, which in turn regulate the long-term productivity and sustainability of crop yields. These factors act either singly or interactively to change soil physical health. Rice is a major consumer of water and fertilizer nitrogen. It has been reported that under continuous submerged conditions, the amount of water required to produce one kg of rice is about 4000 litres (Tuong, 1999). However, there is a wide gap between water actually used for evapotranspiration and water requirement due to heavy percolation and bypass losses. Abedin *et al.* (1991) reported percolation losses as high as 1850 mm during the whole rice season. According to Tuong *et al.* (1996), 41-57 % of applied water was lost as bypass flow. In addition to high N demands by the rice crop, low *NUE* in submerged conditions increases the cost of fertilizer input.

Studies have been carried out by various workers to economize the scarce natural resource (water), and reduce the amount of nitrogenous fertilizer as well as to improve the soil physical conditions. Randhawa and Rajput (1985) indicated that saving irrigation water up to 35% in rice is possible by scheduling the irrigation one day after the disappearance of water instead of continuous submergence with out significantly affecting the yield. Increasing the gap between two irrigations from one to four days after disappearance of ponding water was observed to improve the soil physical condition (Mishra *et al.*, 1991). Water use efficiency also increased with increase in the gap between two irrigations (Singh *et al.*, 2001). Apparent N recovery is reported to be lower under continuous submergence as compared to irrigating one day after disappearance of water (Kumar and Singh, 1984). Use of organic manure to substitute a part of nitrogenous fertilizer helps not only in reducing the cost of input but also in improving the soil physical health (Karim *et al.*, 1989). It increases N uptake and water retention (Yaduvansi 2001).

Individual effects of water, nitrogen and FYM on soil physical properties in rice have been studied by various workers but research findings on their interaction effects are not available. The present study was undertaken to study the influence of water regimes, N levels, FYM application and their interactions on soil physical properties with a view to derive an optimum irrigation schedule and N dose and explore the possibility of substitution of fertilizer N by FYM to reduce the soil physical deterioration as a consequence of puddled rice cultivation.

Materials and methods

Site and climate

The field experiments were conducted on the research farm of Indian Agricultural Research Institute (IARI), New Delhi, during 1999 and 2000.

The field is situated at 28° 38" N latitude and 77° 10" E longitudes at an elevation of 228 m above MSL. Climate is semi arid type with a mean annual temperature of 25°C and average rainfall of 650 mm during the monsoon. The soil is classified as Typic Haplustept and is silty clay loam in texture. The physical and chemical characteristics of the soil are given in Table 1.

Experimental design and treatment details

The experimental design followed was split plot with water regimes as main plot treatments and fertilizer nitrogen treatments as sub plots. The three water regimes were: I_C (continuous submergence), I_1 (irrigation one day after disappearance of water) and I_3 (irrigation 3 days after disappearance of water). Six N treatments were taken as sub plot treatments *viz.*, N_0 (Control i.e. no nitrogen); N_{60} (60 kg N ha^{-1}); N_{120} (120 kg N ha^{-1}); N_{150} (150 kg N ha^{-1}); N_{120F} (120 kg N ha^{-1} of which 50% was applied through urea and 50% through FYM) and N_{150F} (150 kg N ha^{-1} of which 50% was applied through urea and 50% through FYM). All the treatments were replicated thrice.

Crop management

Transplanting was done on 22nd July, 1999 at a spacing of 20 x 15 cm. Well decomposed FYM with 0.57 % N was applied 10 days before transplanting as per the treatments. Half of the N dose of each treatment was applied as basal dose and rest half was applied in 2 equal splits at tillering and panicle initiation stage. Irrigation water was managed as per the treatments. Crop was harvested on 15th November 1999. During 2000, seedlings were transplanted on 26th July and the crop harvested on 3rd November of the same year.

Soil sampling and analysis

Soil samples were taken from four points in each plot with the help of hammer auger from six different depths and mixed thoroughly to prepare a composite sample. Sampling was done in each of the three replications. All samples were air dried and a portion was passed through 2 mm sieve and the rest of the clods were broken by hand in such a manner that the size of the clods remained between 5-8 mm. Less than 2 mm size fraction of the auger samples were used for determining texture, field capacity and permanent wilting point and the other fraction (5-8 mm) was used for aggregate size distribution and mean weight diameter estimation. Core sampler was used for collecting undisturbed soil samples for estimation of bulk density and saturated hydraulic conductivity. Soil physical properties were studied at harvest of both the crops.

Table 1. Physical and chemical characteristics of the soil

Soil parameters	Soil depth (cm)			
	0-15	15-30	30-60	60-90
Texture	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay loam
Sand (%)	45.90	52.50	58.20	64.40
Silt (%)	32.80	29.20	28.70	18.40
Clay (%)	21.30	18.30	17.90	13.10
pH (1:2, soil : water)	7.86	7.98	7.89	7.83
E.C. (dS m^{-1})	0.38	0.25	0.16	0.17
Bulk Density (Mg m^{-3})	1.45	1.54	1.65	1.68
Hyd. Cond. (cm hr^{-1})	0.28	0.39	0.93	0.95
Field Capacity (at 0.01 MPa, %)	20.39	19.63	16.94	16.25
PWP (at 1.5 MPa, %)	12.04	11.71	10.11	10.26
Organic C (%)	0.64	0.58	0.37	0.31
Available K (kg ha^{-1})	338.32	221.65	186.56	170.32
Available P (kg ha^{-1})	28.50	19.15	16.51	7.98
Available N (kg ha^{-1})	148.20	146.10	117.40	91.85

Results and discussion

The effects of water, nitrogen, FYM and their interaction on soil physical properties are presented and discussed thus :

Soil bulk density (ρ_b)

Bulk density increased with depth in all treatments and reduced with increase in nitrogen levels (Fig 1) This effect was significant up to 30 cm depth in all the water regimes during 1999. In the 1st layer, it decreased from 1.57 Mg m^{-3} in N_0 to 1.50 Mg m^{-3} in N_{150} During 2000, N effects were significant only within 15 cm. Water regimes had no significant effect on soil bulk density, but a decreasing trend was observed with reduction in amount of irrigation water. Substitution of 50 % of N through FYM significantly reduced the bulk density. The percentage reduction was highest under N_{150} level and under I_C water regime (Fig 1).

Reduction in bulk density by application of N may be attributed to production of higher root biomass with increasing N dose which resulted in increase in organic carbon content, better aggregation and more pore space (Pablico *et al.*, 2000, Singh *et al.*, 2000; Mishra and Sharma, 1997). Decrease in bulk density with the application of N in form of urea has also been reported by Chaudhry *et al.* (1999). Application of FYM increased the organic matter content and hence, resulted in reduced bulk density. Singh *et al.* (2000) reported similar results.

Saturated Hydraulic Conductivity (Ks)

Generally, the hydraulic conductivity was lower in 15-30 cm soil depth as compared to the surface layer but beyond 30 cm depth, the hydraulic conductivity increased significantly in all treatments. *Ks* increased with N levels in all water regimes (Fig 2). Average data of both the years show that, within 0-15 cm depth under I_C water regime, it increased from 0.32 cm hr^{-1} in N_0 to 0.51 cm hr^{-1} in N_{150}. Application of FYM further increased *Ks*. During 1999, under I_C water regime with 120 kg N (N_{120} treatment), *Ks* was 0.45 cm hr^{-1} in non-FYM treated soil which was significantly lower than that in FYM treated soils that is, in N_{120F} treatment (0.63 cm hr^{-1}). The same trend was observed in the second year also. This increase was more with increase in FYM levels. Under I_3 and 150 kg N ha^{-1} with the application of FYM to substitute 50% N, *Ks* was 0.54 cm hr^{-1}, which is significantly higher than that in only urea treated soils (0.51 cm hr^{-1}) (Fig 2). Significant difference in *Ks* was observed under different water regimes. Among the various water regimes, the magnitude of *Ks* was $I_3 > I_1 > I_C$.

The increase in *Ks* observed by increasing N rate and FYM application may be due to decrease in bulk density as reported in the earlier section. Increase in *Ks* with N and FYM application was also observed by Mishra and Sharma (1997). Decrease in *Ks* in I_C water regime as compared to I_1 and I_3 may be due to reduction in macro pores as a result of dispersion of soil particles under continuous submergence (Sharma and De Datta, 1986).

Water retention at 0.01 MPa (Field Capacity) and at 1.5 MPa (Permanent Wilting Point)

Water retained by the soil at field capacity (FC) and at Permanent Wilting Point (PWP) generally reduced with depth. Significant increase in FC with increasing N levels was observed in both the years, e.g. during 1999, it increased from 20.77 % in N_0 to 24 55 % in N_{150} in the 0-15 cm layer and I_C water regime. Similar result was also observed for other water regimes and 15-30 cm layer. During 2000 it increased from 19.46 % in N_0 to 20.12 % in N_{150} in the 0-15 cm layer and I_C water regime. With the application of FYM, the water retention at FC increased significantly up to 30 cm depth. Water regimes had no significant effect on FC during 1999, but during 2000 it was significantly higher in I_3 treatment (20.38 % in 0-5 cm layer and N_0 treatment) than I_C (19.46 % in the same treatment and layer). FC in I_C and I_1 were statistically at par. Effect of water regimes and N levels on PWP was not significant statistically and hence data are not presented.

Increase in water retention 0.01 MPa potential with the application of FYM is due to increase in total and macro porosity as reflected by increase in *Ks* and decrease in bulk density. Similar increase FC by organic waste was observed by Mbagwu (1988). Increase in FC and PWP by combined use of FYM and N fertilizer was also reported by Singh *et al.* (2000).

Mean Weight Diameter (MWD)

There was a significant increase in MWD with increasing N rates (Fig 3). On an average it increased from 0.38 in N_0 to 0.64 in N_{150} in I_C water regime of the 1st layer (0-5 cm). Similar results were obtained for other water regimes in the 2nd layer (5-10 cm) also. In the 1st layer MWD was highest under I_3 water regimes (0.5 mm), which was significantly higher compared to I_C (0.38 mm). MWD under I_1 was statistically at par with I_3.

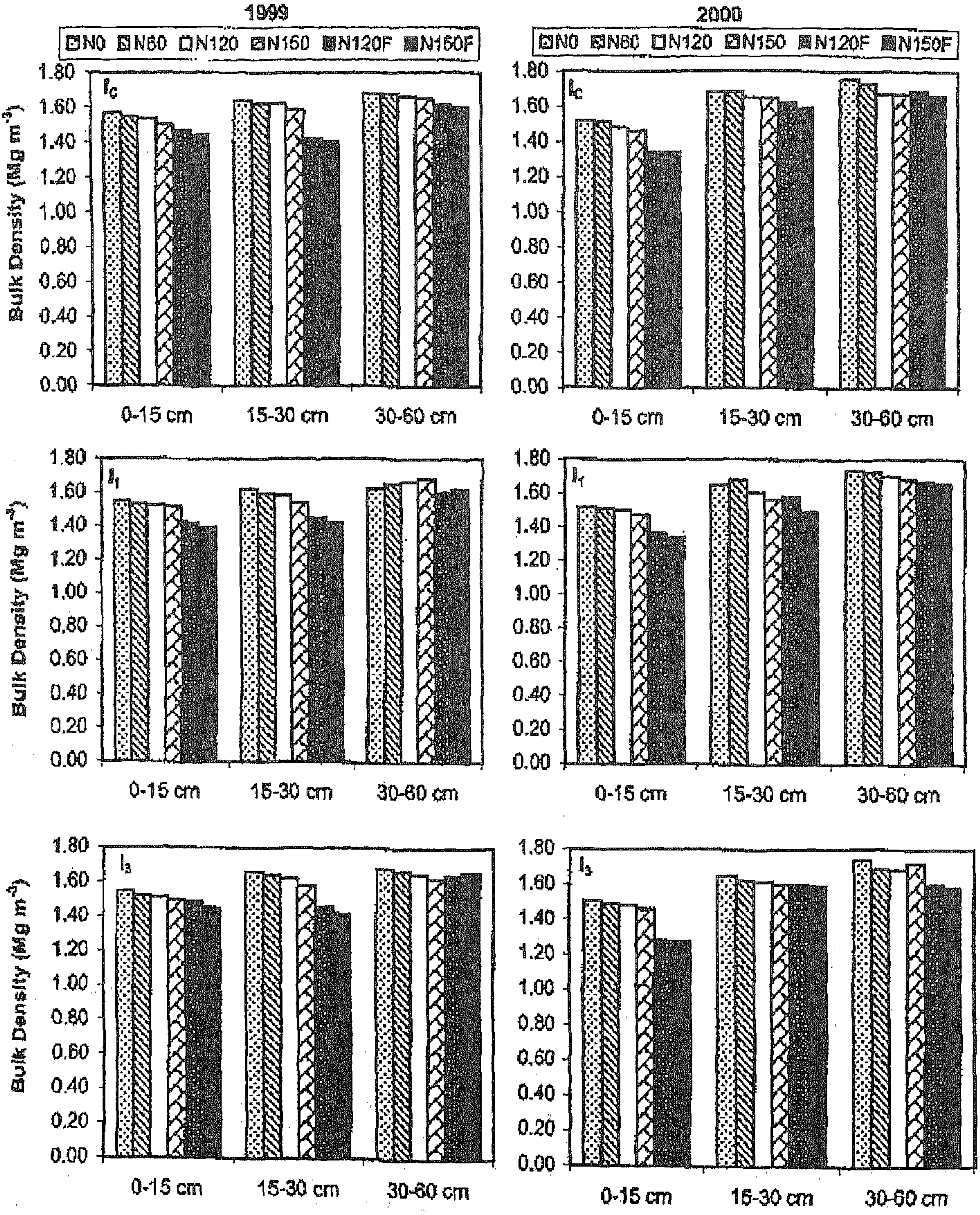

Fig 1. Effect of water, N and FYM on soil bulk density

I_c: continuous submergence, I_1 and I_3: irrigation one day and three days after drainage, respectively; CD (I)=0.0168 in1999 and non significant in 2000; CD (F)=0.0214 in 1999 and 0.0756 in 2000; CD (I): critical difference at 5 % level of significance for water regimes, CD (F): critical difference at 5% level of significance for nitrogen levels

Table 2. Effect of nitrogen levels, water regimes and FYM on Field capacity (water retention at 0.01 MPa) of soil

Treatments	I_C		I_1		I_3		
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	
			1999				
N_0	20.77	18.44	19.44	18.65	17.50	18.51	
N_{60}	21.82	19.28	20.27	19.43	18.10	19.22	
N_{120}	23.54	21.47	21.20	20.34	18.98	20.53	
N_{150}	24.55	22.98	21.98	20.79	19.64	20.99	
N_{120F}	25.06	23.23	23.35	21.53	20.35	21.44	
N_{150F}	25.43	23.98	23.81	23.07	20.68	22.26	
	I	*T*	*D*	*IxT*	*IxD*	*TxD*	*IxTxD*
CD (5%)	NS	0.838	1.592	NS	2.757	NS	NS
			2000				
N_0	19.46	18.92	19.59	19.05	20.38	19.60	
N_{60}	19.52	18.83	20.08	19.12	19.39	18.63	
N_{120}	19.96	19.09	19.84	19.3	19.69	18.94	
N_{150}	20.12	19.24	20.04	19.44	19.84	19.05	
N_{120F}	20.69	19.92	20.45	19.86	20.19	19.32	
N_{150F}	20.66	19.95	20.45	19.93	20.25	19.46	
	I	*T*	*D*	*IxT*	*IxD*	*TxD*	*IxTxD*
CD (5%)	0.1375	0.1671	0.1123	0.2894	NS	NS	NS

I_C = Continuous submergence; I_1 = Irrigation one day after disappearance of ponded water; I_3 = Irrigation three days after disappearance of ponded water. [I: Effect of irrigation; T: Effect of N levels; D: Effect of depth; CD. critical difference at 5% level of significance.

Application of FYM significantly increased the MWD in all the water regimes, e.g. in 0-5 cm layer and I_C water regime it was significantly higher in N_{120F} treatment (0.8 mm) than N_{120} (0.6 mm). Similar increase was observed for N_{150} treatment also (Fig. 3).

Increase in MWD with increased N application and FYM addition may be attributed to increase in the percentage of macro aggregates in the soil, because of production of more organic residues in the fertilized soil. Highest values of MWD in FYM treated plots could be attributed to the beneficial effect of certain polysaccharides formed during decomposition of organic residue by microbial activity (Mishra and Sharma, 1997). Increase in MWD by FYM application was also observed by Kurual and Tripathi (1990).

Reduction in macroaggregates under continuous submergence may be due to breakage of soil aggregates and reduction in their water stability. Higher dispersion rate under I_C water regime is responsible for reduction in macro aggregate percentage (Ray and Gupta, 2001).

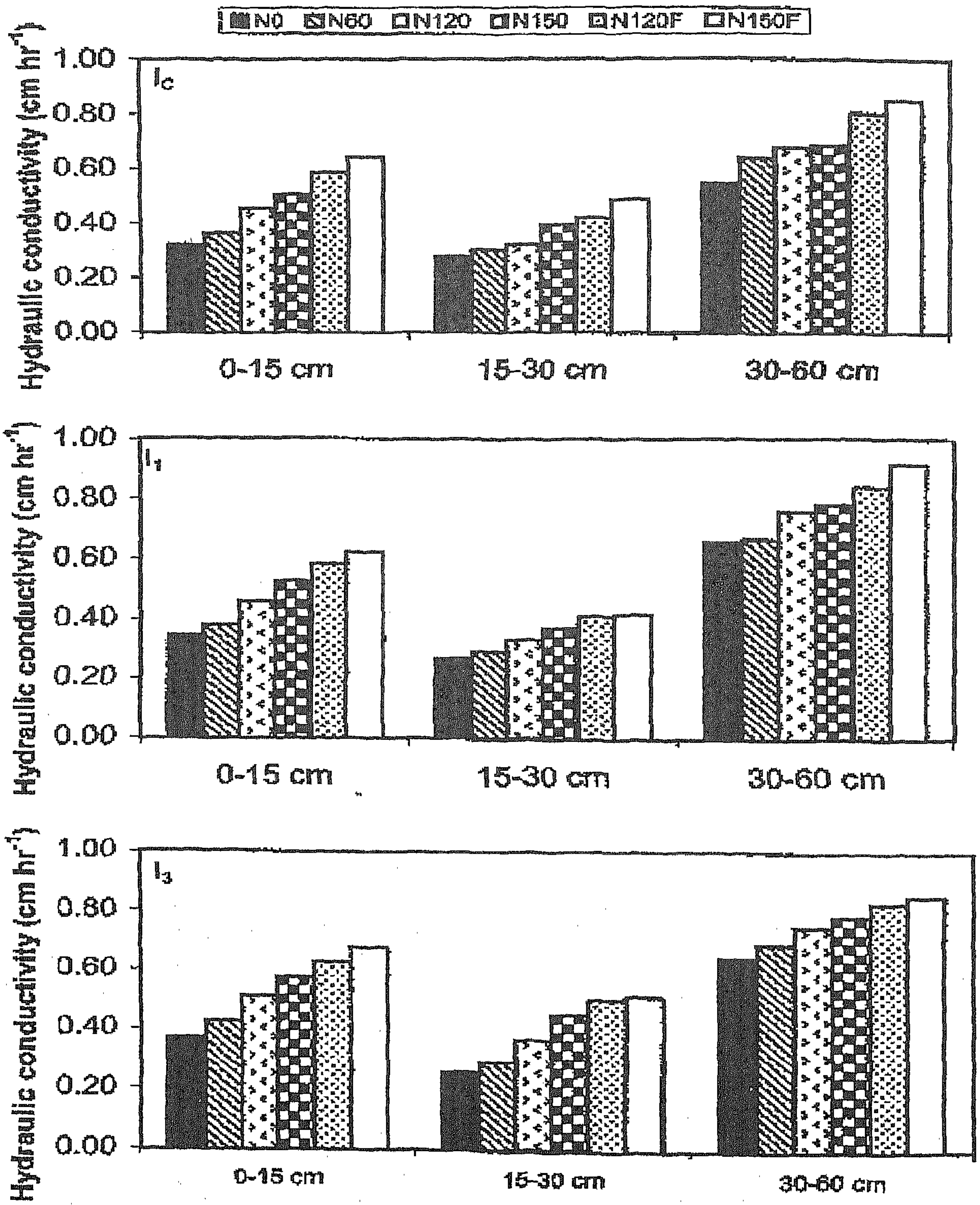

Fig 2: Effect of water, N and FYM on soil hydraulic conductivity (average of two years)

I_c: continuous submergence, I_1 and I_3: irrigation one day and three days after drainage, respectively; CD (I)=0.0221, CD (F)=0.0365; CD (I): critical difference at 5%level of significance for water regimes, CD (F): *critical difference at 5 % level of significance for nitrogen levels*

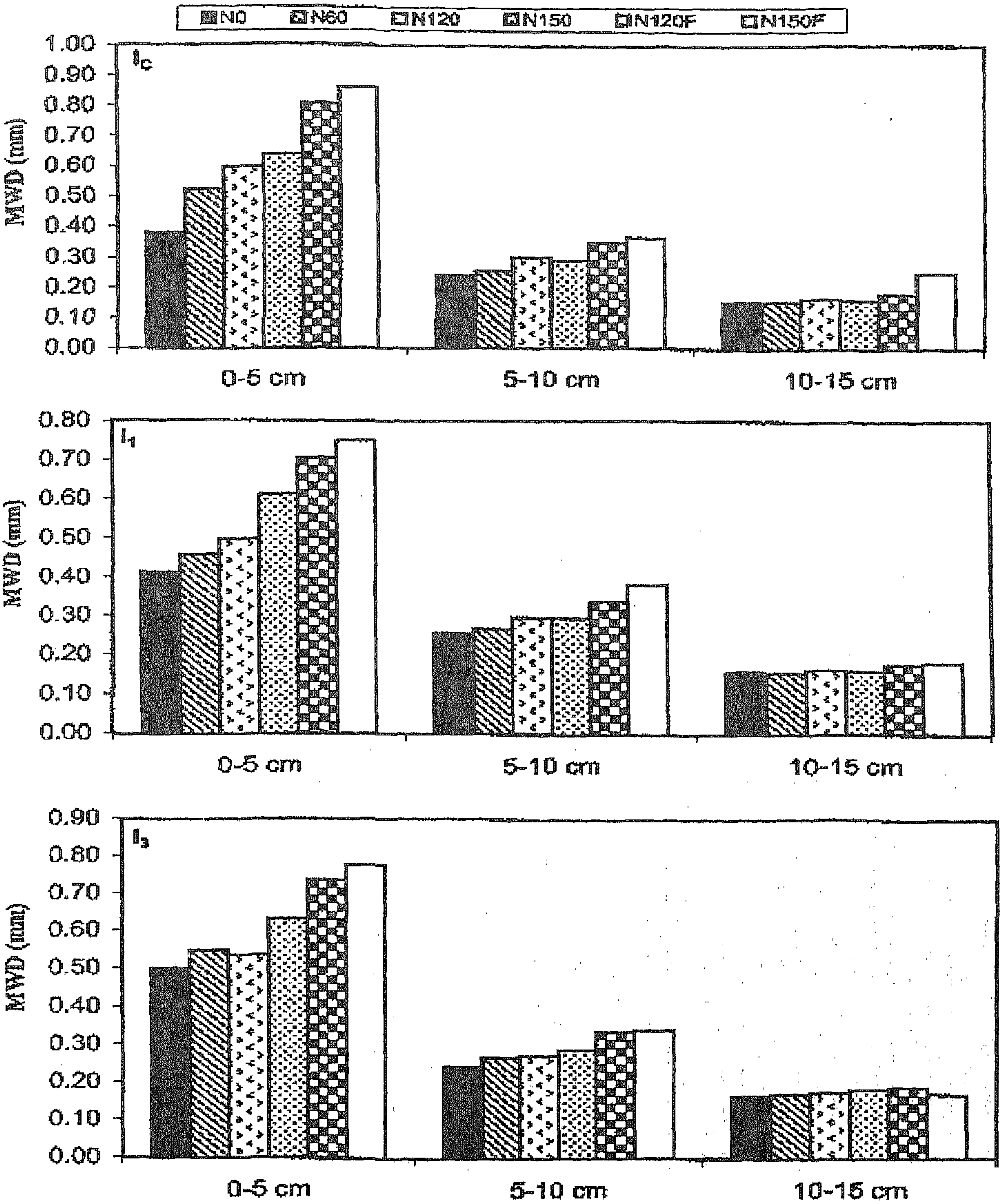

Fig 3. Effect of water, N and FYM on soil mean weight diameter (MWD) (average of two years)

I_c: continuous submergence, I_1 and I_3: irrigation one day and three days after drainage, respectively; CD (I)= *0.017, CD (F)=0.0274; CD (I): critical difference at 5% level of significance for water regimes, CD (F): critical* difference at 5 % level of significance for nitrogen levels

Conclusion

Addition of FYM to substitute a part of the required N improved all the physical properties, which was reflected in a decrease in bulk density, increase in hydraulic conductivity and water retention at field capacity. Continuous submergence degraded the physical properties of soil and resulted in an increase in bulk density, reduction in *Ks* and water retention. Thus, it may be suggested to adopt irrigation one day after disappearance of ponding water instead of continuous submergence, along with highest N level i.e. N_{150} and substitution of 50 % N through FYM for improving soil physical properties which are essential for achieving sustainability in rice based cropping systems.

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