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Improvement of Soil Physical Environment for Increasing Productivity of Rice-Wheat Cropping Sequence in Vertisols

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ABSTRACT

Field experiment conducted from 1991 to 1995 at the Experimental Station, J.N. Krishi Vishwa Vidyalaya, Jabalpur, M.P, revealed that puddling of Vertisols increased the bulk density and penetration force and reduced the hydraulic conductivity and basic infiltration rate as compared to direct seeded paddy. *Rabi* tillage treatments reduced the bulk density and penetration force and increased the hydraulic conductivity and basic infiltration rate. Data averaged over 5 years indicated that transplanted paddy produced significantly higher grain yield as compared to lehi and direct seeded paddy. Although in some of the years grain yield of direct seeded paddy plots was at par with transplanted paddy. Zero till plots produced significantly higher grain yield of wheat as compared to mould board plough or cultivator + disc harrow till plots. Direct seeded paddy plots produced significantly higher grain yield of wheat as compared to puddled paddy or lehi system of rice cultivation. Increasing levels of phosphorus from 0 to 80 kg P_2O_5 ha^{-1} significantly increased the grain yield of paddy and wheat. Total productivity of paddy and wheat was higher in direct seeded plots as compared to puddled paddy plots.

Introduction

Puddling is a traditional practice in lowland rice cultivation. It brings about destruction of natural soil structure and causes dispersion of soil particles. The aggregates and peds are destroyed into soft mud by the thorough mixing of soil in standing water (Sharma and DeDatta, 1986). Repeated puddling develops workability and trafficability problems in paddy fields (Kisu, 1978). These problems are more serious in Vertisols which are used for growing paddy and wheat (Tomar *et al.*, 1996). Continuous submergence of clay soils and progressive deterioration of soil structure by puddling have made soils very hard and creating problems after rice. The disaggregation and dispersion of soils result in increased bulk density and reduce aeration porosity to the minimum. Following drying of the puddled soils, ploughing for subsequent upland crops leads to a cloddy seed bed that adversely affects the establishment of wheat after paddy.

Research information from the field experiments that describe the effect of puddling on nutrient use efficiency, growth and yield of paddy and wheat is scanty. Therefore, there is need to find out suitable method of rice cultivation, tillage requirement for subsequent crop and nutrient management in rice-wheat cropping sequence in Vertisols.

Materials and Methods

A field experiment was conducted on Vertisols (deep fine textured montmorillonitic family of Typic Haplusterts) at the experimental station, J.N. Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India from 1991-1995. The soil (56% clay, 24% silt and 20% sand) has pH 7.5, $CaCO_3$ 3.5% and organic carbon 0.5 per cent. The 1/3 bar and 15 bar volumetric moisture percentage were 36 and 18 per cent, respectively. Surface bulk density of soil was 1.16 Mg m^{-3} and increased with depth and ranged from 1.16 to 1.60 Mg m^{-3}. A split-plot design consisting of four replications and having 108 plots was used. The main plot had three tillage treatments viz. T_0 : zero tillage, T_1 : cultivator + disc harrow and T_2 : Mould board plough. Each main plot was sub-divided into three sub-plots as system of paddy cultivation viz. M_0 : direct seeded paddy, M_1 : lehi system of cultivation and M_2 : puddled transplanted paddy and three sub-sub-plots as phosphorus levels viz. P_0 : no phosphorus, P_1 : 40 kg P_2O_5 ha^{-1} and P_2 : 80 kg P_2O_5 ha^{-1}. Tillage treatments were imposed during last week of June for paddy and in 2nd week of November for wheat after harvest of paddy. The plot size was 6m x 5.5m for paddy and wheat with inter-plot distance 1.5 m between tillage and systems of rice cultivation and 1m in between phosphorus levels.

Paddy (*Oryza sativa* L.) cultivar Ratna was planted during last week of June to first week of July in direct seeding and lehi system and transplanting was done in 2nd week to 3rd week of July in different years. After harvest of paddy, tillage treatments were imposed and wheat (*Triticum aestivum*) cultivar Lok-1 was planted in

third week of November of each year. Paddy and wheat crops were fertilized with 120 kg N as urea, phosphorus as per treatment as 30 kg K_2O ha^{-1} as muriate of potash. Basal doses of phosphorus and potassium and 40 kg N was applied at the time of planting of paddy and wheat and remaining nitrogen was applied as top dressing in two equal split doses in both the crops.

Soil physical properties such as bulk density , penetration force, infiltration rates and hydraulic conductivity were measured at flowering stage of paddy and wheat. Bulk density was determined using core sampler and penetration force was measured with the help of needle penetrometer. Basic and cumulative infiltration were determined using the double ring infiltrometers. Hydraulic conductivity was measured by constant head method. Both the crops were harvested at physiological maturity.

Results and Discussion

Soil physical properties : Irrespective of growth period and tillage treatments the bulk density and penetration force values increased with soil depth in both the crops(Tables 1 & 2) . At flowering stage of paddy direct seeded plots (unpuddled) had lower bulk density than lehi and transplanted (puddled) system of rice cultivation . Similar trends were observed in penetration force data. Puddled plots had lower hydraulic conductivity as compared to unpuddled (direct seeded) plots. Similarly puddled plots had lower basic infiltration rate than the unpuddled plots. The effect of *rabi* tillage on infiltration rate was more pronounced under puddled plots as compared to unpuddled plots (Table 2). The results revealed that due to close packing of soil particles in puddled soil, the saturated hydraulic conductivity and percolation rate of these soils were low.

Tilling of clay soils after paddy reduced the bulk density and penetration force at all the depths of measurement and also increased the saturated hydraulic conductivity and basic infiltration rate (BIR)during the growth of wheat crop. Lowest bulk density and penetration force values were recorded in mould board plough treated plots followed by cultivator and highest in zero till plots. Perusal of the data revealed that there is less deterioration in soil structure under direct seeded paddy. Creation of rabi tillage after paddy particularly under M.B. plough resulted in more and bigger clods in puddled plots and less and smaller clods in direct seeded paddy plots. It was difficult to break these clods by disc harrow even by two or three operations.

Germination of wheat : As the intensity and depth of tillage increased, the germination of wheat significantly reduced (Table 3). Highest germination of wheat was recorded in direct seeded paddy plots which was significantly higher than lehi and transplanted paddy plots. Zero till plots also had significantly higher germination of wheat. Cloddy nature of seed bed in puddled plots significantly affected the germination of wheat .

Table 1. Effect of methods of rice cultivation and tillage on the soil physical properties at flowering stage of paddy in Vertisols

Properties	Soil depth (cm)	Method of cultivation			Tillage		
		Direct seeded	Lehi system	Transplanted rice	No. tillage	Shallow* tillage	Deep* tillage
Bulk density (Mg m^{-3})	0-10	1.16	1.23	1.25	1.26	1.17	1.20
	10-20	1.23	1.30	1.30	1.32	1.28	1.23
	20-30	1.31	1.36	1.36	1.38	1.35	1.34
Penetration force (kg cm^{-2})	5	7.05	7.52	8.18	8.54	7.44	6.78
	10	8.36	11.52	13.27	12.92	11.57	10.98
	15	14.04	15.95	15.95	17.32	16.35	14.53
Hydraulic conductivity (mm hr^{-1})	0-10	3.09	2.04	1.82	1.56	2.34	2.78
Basic infiltration rate (mm hr^{-1})		2.71	2.55	1.71	1.81	2.55	2.36

* Shallow tillage : cultivator + Disc harrow, deep tillage : M.B. plough + disc harrow

Table 2. Effect of tillage and methods of rice cultivation on the soil physical properties at flowering stage of wheat in Vertisols

Properties	Soil depth (cm)	Method of cultivation			Tillage		
		Direct seeded	Lehi system	Transplanted rice	No. tillage	Shallow* tillage	Deep* tillage
Bulk density (Mg m^{-3})	0-10	1.17	1.22	1.26	1.25	1.22	1.18
	10-20	1.27	1.33	1.38	1.36	1.33	1.28
	20-30	1.36	1.43	1.45	1.4	1.43	1.41
Penetration force (kg cm^{-2})	5	5.36	8.23	10.12	8.22	8.21	8.11
	10	7.13	10.90	12.85	10.47	10.27	10.13
	15	12.47	13.33	14.69	10.13	12.36	13.35
Hydraulic conductivity (mm hr^{-1})	0-10	3.52	3.11	2.65	3.04	3.11	3.32
Basic intilgration rate (mm hr^{-1})		2.88	2.53	2.35	2.39	2.45	2.90

* Shallow tillage : cultivator + Disc harrow, deep tillage : M.B. plough + disc harrow

Table 3. Effect of tillage and system of rice cultivation on percent germination of wheat under rice wheat cropping sequence in different years

Treatment	System of rice cultivation			Average
	Direct seeded paddy	Lehi system	Transplanted paddy	
No - Tillage				
1993-94	72.10	63.20	49.60	61.63
1994-95	74.75	59.55	53.55	62.61
1995-96	78.30	65.10	52.65	65.36
Average	75.05	62.60	51.93	63.19
Cultivator + Disc harrow				
1993-94	55.80	53.80	41.00	50.20
1994-95	67.80	47.05	44.75	53.20
1995-96	71.45	47.80	37.35	52.20
Average	59.01	46.53	45.55	50.70
C.D. 4%		1993-94	194-95	1995-96
Tillage		7.221	8.56	8.59
Method of cultivation		2.06	4.41	8.83
Tillage x method of cultivation		NS	NS	4.11

Grain yield : Grain yield data averaged over 5 years are presented in table 4 revealed that transplanted paddy produced about 10 and 11 percent higher yield as compared to direct seeded paddy and Lehi system of rice cultivation , respectively. Higher grain yield of paddy in puddled plots may be due to better weed management and uniform spacing. During crop growth it was also observed that direct seeded and Lehi plots had significantly less number of tillers and smaller earhead length (data not included) which might have affected the grain yield of paddy in these plots.

Significantly higher grain yield of wheat was recorded in direct seeded paddy plots than the puddled and lehi system of rice cultivation in all the years except in 1994 (Table 4). Poor yield of wheat in puddled and lehi system plots may be because of poor physical conditions (Table 1) observed in these plots as compared to direct seeded paddy plots. As discussed earlier higher bulk density and penetration force and cloddy nature of seed bed in puddled paddy plots affected

Table 4. Effect of tillage and methods of rice cultivation on the grain yield (kg ha^{-1}) of paddy and wheat in Vertisols of Jabalpur

Treatment	Average											
	1991	1992	1993	1994	1995	Av.	1991	1992	1993	1994	1995	Av.
Methods of rice cultivation												
Direct seeded	4209	3502	4688	3229	2898	3705	3712	3523	4473	3981	3754	3889
Lehi system	3464	2667	5548	3122	3374	3675	3448	3434	4277	3572	3417	3629
Transplanted	4913	2715	5560	3300	3940	4085	3796	3368	4137	3445	3216	3592
Tillage												
No-tillage	4311	3042	5219	2930	3378	3776	3871	3545	4421	4221	4112	4036
Shallow tillage	4182	2922	5413	2931	079	3699	3807	3137	4302	3582	3270	3619
Deep tillage	4092	2919	5165	2885	2670	3546	3275	3646	4096	3196	3005	3443
Average	4195	2961	5265	2915	3032	3673	3651	3441	4276	3666	3462	3699
C.D. 5%												
Method of cultivation	417	353	562	NS	116	-	292	115	161	160	289	-
Tillage	NS	NS	NS	NS	139	-	251	418	194	101	267	

Table 5. Effect of phosphorus levels on the grain yield of paddy and wheat in Vertisols

P_2O_5 level (kg ha^{-1})	Paddy (kg ha^{-1})				Wheat (kg ha^{-1})			
	91-92	92-93	93-94	Av.	91-92	92-93	93-94	Av.
0	3948	2867	4787	3867	3338	3281	4037	3552
40	4742	3001	5276	4183	3639	3432	4397	3822
80	4366	3015	5731	4370	3980	3617	4601	4066
CD 5%	189.0	NS	185	-	297	287	128	-

the germination and stand of wheat in these plots. Data presented in table 4 further revealed that creation of deep tillage after paddy reduced the grain yield of wheat significantly in different years except in 1992 season. Summer tillage treatments created for paddy did not have significant effect on the grain yield of paddy. Zero till wheat after direct seeded and transplanted paddy produced about 7 and 8 percent higher grain yield than Cultivator + Disc harrow and M.B. plough tilled plots, respectively. Better grain yield of wheat in zero till plots may be due to better germination and stand (Table 3) of the crop in these plots . Deep tilled plots produced cloddy seedbed which affected the germination and stand of wheat as compared to shallow till and zero till plot. Interactive effect of tillage x method of rice cultivation on the grain yield of paddy and wheat were not significant. Increasing levels of phosphorus significantly increased the grain yield of paddy and wheat. The significantly higher yield of rice and wheat was recorded in P_{30} level of phosphorus than P_0 and P_{40} levels of phosphorus (Table 5).

These results revealed that no-till wheat after puddled transplanted and direct seeded paddy provide better seedbed for germination, stand and establishment of wheat and are found advantageous in saving time and sowing cost compared to conventional methods of seed bed preparation and sowing of wheat. Data presented in table 4 further indicated that average total productivity under paddy-wheat cropping in zero till system was about 7812 kg ha^{-1} which was higher than the shallow till (7318 kg ha^{-1}) and deep till plots (6985 kg ha^{-1}).

References

Kisu, M. 1978. Tillage properties of wet soils. In : Soils and Rice, International Rice Research Institute, LosBanos, Philippines, pp 307-316.

Sharma, P.K. and DeDatta, S.K. 1986. Physical properties and process of puddled rice soils. *Adv. in Soil Sci.* 5 : 139-178.

Tomar, S.S.; Tembe, G.P.; Sharma, S.K.; Bhadauria,U.P.S. and Tomar, V.S. 1996. Improvement of physical conditions of black soils of Madhya Pradesh. Dept. of Soil Science & Agril. Chemistry, JNKVV, Jabalpur, M.P., India. pp 93+