Indian J. Crop Science, **1**(1-2): 146-150 (2006)

Influence of tillage systems and moisture regimes on soil physical environment, growth and productivity of rice-wheat system in upper gangetic plains of Western Uttar Pradesh

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Abstract

Field studies were conducted in UGP region for 4 crop cycles i.e., rice (cv. Saket-4) and succeeding wheat (cv. HD 2285) crops with the objectives to study the influence of tillage systems and moisture regimes on soil physical environment, root growth and productivity. Higher puddling index and reduction in percolation rate was found with conventional compared to reduced puddling. Root growth of rice was significantly affected by tillage systems and moisture regimes but in succeeding wheat, it was significantly affected by moisture regimes only. Grain yield of rice, wheat and the system was significantly influenced by tillage systems as well as moisture regimes.

Key words: Tillage systems, moisture regimes, puddling Index, percolation rate, rice-wheat system.

Introduction

Rice-wheat is prominent cropping systems of India and a major portion (2.66 m. ha) falls in Upper Gangetic Plains (Yadav *et al.,* 1998). Crop establishment is an exceedingly important factor in improving the productivity of rice-wheat system as this represents a substantial proportion of production cost. A tillage system need to be developed that gives smooth transition between wetland rice soil and dry land arable soil conditions with minimum use of mechanical manpower (Mandal, 1984). Although plenty of literature is available on the tillage and water requirements of individual crops of rice and wheat but scanty information is available on the tillage and water requirement of rice and wheat crops, whenever grown, in a system and the interactive effects of crop establishment methods and irrigation schedules in the systems are also not known. Keeping these in mind, experiments were conducted to evaluate the effects of tillage systems and moisture regimes on the soil physical environment, root growth, and productivity of rice-wheat system in Upper Gangetic Plains of Western Uttar Pradesh.

Materials and Methods

Field experiments with rice (Saket- 4) and wheat (HD-2285) sequence during four crop cycles were conducted at PDCSR, Modipuram, Meerut, Uttar Pradesh in semi-arid sub-tropical climate with an average rainfall of 810 mm in split plot design and replicated four times without disturbing the lay out. Soil of the study area was *Typic Ustochrept*, very deep sandy loam well drained, and with physico-chemical properties of surface layer (0-15 cm): sand 65.3%, silt 18.2%, clay 15.5%, pH 7.8, electrical conductivity 0.179 dS m^{-1}, organic carbon 0.51%, bulk density 1.52 Mg m^{-3} and available water 11.2% (w/w). Treatments comprised of eight tillage systems (main-plot) and two moisture regimes (sub-plot) (Table 1). Rice (direct seeded and transplanted) and succeeding wheat crops were grown with recommended package of practices. Puddling index was estimated as per the procedure of Bhole and Pandya (1964) and percolation/infiltration rate was measured by double ring infiltrometer method. Root samples from an area of 0.20 m x 0.20 m x 0.10 m at flowering stage were collected and root volume was estimated. Pooled data of four seasons was performed to assess the effects of tillage systems and moisture regimes and their interactive influence on various parameters.

Results and Discussion

Soil physical environment

Puddling Index (PI): In puddled rice, substantially higher puddling index (48.8%) was recorded with conventional (0.67) compared to reduced puddling (0.45) indicating more churning action of water and soil by puddling. Consistently increased values of PI were recorded with conventional puddling which were 0.59, 0.69 and 0.72 and lower values of 0.37, 0.48 and 0.50 with reduced puddling in first , second and third years, respectively indicating the increasing trend of PI during the study. This might be because of more and more mixing of soil particles with turbulent water resulting in formation of dense slurry of soil and water containing more volume of soil in per unit volume of water in the slurry which resulted in higher PI values. The depth of puddling of soil might be increasing in successive years, which might have stabilized in few years in medium textured soils. There might be more separation of sand, silt and clay from the soil aggregates in successive years. Pandey *et al.,* (2000) also found that puddling index was highest with conventional as compared to reduced puddling.

Percolation Rate: Under puddled condition, considerably lower (27.8%) percolation rate of water (0.0810 m sec^{-1}) was recorded with conventional as compared to reduced puddling (0.1119 m sec^{-1}) indicating the increase in water storage pores (micro) and decrease in water transmission pores (elongated-macro) which resulted in more retention of soil water under conventionally puddled soils. Aggrawal et al. (1995) also observed that percolation decreased from 14 mm d^{-1} with low puddling to 10 mm d^{-1} with high puddling. A continuous decline in percolation rate was observed i.e. 0.1042, 0.0810 and 0.0579 m sec-1 with conventional puddling and 0.1389,0.1157 and 0.0810 m sec^{-1} with reduced puddling in 1995, 1996 and 1997, respectively indicating the decreasing trend of percolation rates over a period of three years. This might be because of effective churning and mixing of soil in successive years. A gradual decrease over years in water intake rate of soil was reported by Sur *et al.* (1981). In direct seeded rice , percolation rate was 1.2731 m sec^{-1}. The percolation rates were reduced by 9,11 and 16 times with reduced puddling and 12,16 and 22 times with conventional puddling during 1995, 1996 and 1997, respectively compared to direct seeding indicating drastic reduction in percolation losses due to puddling.

Root growth

Rice: Root volume of rice crop was significantly affected by tillage systems and moisture regimes (Table 2). Significantly higher root volume was recorded under puddled (30.8 cc) compared to direct seeded condition (25.6 cc). This may be because of enhanced root proliferation due to reduced percolation rate under intensive puddling (Aggrawal et al., 1999). Bajpai and Tripathi (2000) also observed that the puddling alone in rice enhanced root length density (RLD) by 12% and root growth (RLD) of rice in puddled treatment was significantly higher than in non-puddled treatment and the major portion of roots was concentrated in 0-0.10 m soil depth. Highest root volume was found with conventional puddling (31.9 cc) and lowest with reduced tillage (24.5 cc) indicating the favourable effect of puddling on root growth in puddled layers. Significantly higher root volume was obtained under saturation to submergence as compared to irrigations at initiation of soil cracking.

Wheat: It was found that root volume of wheat grown either after puddled and direct seeded rice was significantly affected by tillage systems as well as by moisture regimes and the interactions were significant (Table 2). Significantly higher root volume was observed under direct seeded (31.2 cc) compared to puddled (27.4 cc) condition indicating the adverse effect of puddling. Significantly higher root volume was recorded under well-watered compared to limited water condition indicating favourable effects of irrigation schedules on root growth of wheat. Significantly higher root volume was obtained when wheat crop was grown after direct seeded (31.2 cc) compared to puddled rice (27.4 cc) indicating the adverse effect of crop establishment methods of preceding rice crop on succeeding crop of wheat which might be because of poor soil physical condition. Puddling in rice has adversely affected the wheat crops and minimized root length by 28% (Bajpai and Tripathi, 2000). Relatively higher root volume was recorded with conventional (31.4 cc) compared to reduced tillage (31.0 cc) when grown after direct seeded rice indicating favourable affects of preceding crop establishment methods on succeeding wheat crop. Comparatively lower root volume was recorded when wheat crop was grown after conventional (26.9 cc) compared to reduced (27.7 cc) puddling which indicates the adverse effect of intensive puddling on root volume of succeeding crop of wheat.

Productivity

Rice: Grain yield of rice, wheat and the system was significantly affected by tillage systems as well as moisture regimes and the interactions were significant (Table 3). Considerably higher (70.9%) grain yield was recorded under puddled (4.00 Mg ha^{-1}) compared to direct seeded (2.34 Mg ha^{-1}) condition which might be due to reduced percolation losses of water and nutrients puddled rice. Gill (1994) also reported that the rice transplanted after puddling can give 20- 50% more yield than direct seeded rice. Significantly higher grain yield was recorded with conventional (4.13 Mg ha^{-1}) compared to reduced (3.88Mg ha^{-1}) puddling. Singh *et al.* (2000) also found that rice grain yield increased significantly with increase in levels of puddling in loamy sand, sandy loam and silty clay loam. In direct seeded rice, significantly higher grain yield was obtained with conventional (2.49 Mg ha^{-1}) compared to reduced (2.19 Mg ha^{-1}) tillage. Significantly higher grain yield was recorded with saturation to submergence compared to irrigations at initiation of soil cracking.

Wheat: Significantly higher grain yield of wheat was recorded when grown after direct seeded (4.06 Mg ha^{-1}) compared to puddled (3.85 Mg ha^{-1}) rice. Grain yield of wheat was significantly lower in puddled rice plots than in non-puddled rice plots. This may be due to sub surface compaction (Bajpai and Tripathi, 2000). The crop establishment practices adopted in preceding rice crop has significantly affected the grain yield of succeeding crop of wheat in RWS. Grain yield of wheat grown after puddled rice was significantly affected by tillage systems but it was not significantly affected in

Table 1. Treatments details of the experiment

Rice	Wheat
Tillage systems (main-plot)	
Puddled	
T_1-Conventional puddling (4 passes of puddler)	Conventional tillage (2 harrow + 2 cultivator)
T_2-Conventional puddling (4 passes of puddler)	Reduced tillage (1 harrow + 1 cultivator)
T_3- Reduced puddling (2 passes of puddler)	Conventional tillage (2 harrow + 2 cultivator)
T_4- Reduced puddling (2 passes of puddler)	Reduced tillage (1 harrow + 1 cultivator)
Direct seeded	
T_5-Conventional tillage (2 harrow + 2 cultivator)	Conventional tillage (2 harrow + 2 cultivator)
T_6-Conventional tillage (2 harrow + 2 cultivator)	Reduced tillage (1 harrow + 1 cultivator)
T_7-Reduced tillage (1 harrow + 1 cultivator)	Conventional tillage (2 harrow + 2 cultivator)
T_8-Reduced tillage (1 harrow + 1 cultivator)	Reduced tillage (1 harrow + 1 cultivator)
Moisture regimes (sub-plot)	
Well watered	
Saturation to submergence (5 ± 2.5 cm)	Recommended irrigations (five) at all physiological growth stages
Limited water	
Irrigations at initiation of soil cracking	Three irrigations at crown root initiation (CRI), late jointing and milk stages

Table 2. Effect of tillage systems and moisture regimes on root volume (cc) of rice and wheat

Tillage systems	Rice			Wheat		
	WW	LW	Mean	WW	LW	Mean
T_1	33.3	31.3	32.3	28.0	26.8	27.4
T_2	32.0	30.7	31.4	27.6	25.2	26.4
T_3	31.3	28.7	30.0	28.4	27.6	28.0
T_4	30.7	28.0	29.4	27.5	27.0	27.3
T_5	28.7	25.3	27.0	33.1	31.0	32.1
T_6	28.3	24.7	26.5	32.7	30.7	31.7
T_7	26.3	23.0	24.7	31.6	29.5	30.6
T_8	25.8	22.5	24.2	31.3	29.3	30.3
Mean	29.6	26.8		30.0	28.4	

LSD(P=0.05)	Rice	Wheat
Tillage system (TS)	1.8	1.2
Moisture regimes (MR)	1.3	0.8
TS x MR	3.2	2.0

the same way when grown after direct seeded rice indicating the adverse effects of puddling in rice crop on succeeding wheat (Table 3). Levels of puddling in rice has also significantly influenced the grain yield of succeeding wheat which was (3.80 Mg ha^{-1}) and (3.90 Mg ha^{-1}) when grown after conventional and reduced puddling respectively indicating more adverse effect of conventional compared to reduced puddling on the yield. found that Puddling treatments in rice exhibited residual effects on the yield of following wheat crop. Yield of wheat with intense puddling was significantly lower than at lower level of puddling (Singh *et al.,* 2000). After direct seeded rice, levels of tillage did not significantly affect the grain yield of wheat, which was 4.09 and 4.03 Mg ha^{-1} with conventional and reduced tillage respectively. After puddled rice, the levels of tillage have significantly influenced the grain yield of succeeding wheat which, under conventionally puddled rice, was 3.84 and 3.75 Mg ha^{-1} with conventional and reduced tillage respectively and under reduced puddled rice, was 3.94 and 3.85 Mg ha^{-1} with conventional and reduced tillage respectively. It implies that for getting the higher yields of succeeding wheat, after puddled rice, it requires conventional tillage for proper crop establishment and performance of the wheat crop while the same can be grown with reduced tillage for getting the similar yields after direct seeded rice. Irrigation schedules have also significantly affected the grain yield of wheat, which was 4.08 and 3.83 Mg ha^{-1} with recommended and reduced irrigations, respectively.

System: Significantly higher productivity of the system (rice+wheat) was found under puddled (7.84 Mg ha^{-1}) compared to direct seeded (6.40 Mg ha^{-1}) condition. Highest productivity (7.97 Mg ha^{-1}) was recorded with conventional puddling (T_1) followed by conventional tillage in wheat and the lowest productivity (6.17 Mg ha^{-1}) was recorded with reduced tillage in rice followed by reduced tillage in wheat (T_8). Significantly higher productivity was recorded under well-watered as compared to limited water condition. In rice-wheat system, the increased yield of wheat after direct seeded rice could not compensate for the increased yield of preceding rice under puddled conditions.

It can be concluded that the tillage requirements in succeeding wheat grown after puddled rice might not be reduced from conventional tillage as it has significantly reduced the grain yield. However, it can be reduced when wheat crop is grown after direct seeded rice, which reduces the cost of production and saves the precious energy resources without significant reduction in the yield. Puddling in preceding rice crop has significantly reduced the yields of succeeding wheat crop in the system. For achieving the highest productivity of the system (8.15 Mg ha^{-1}), conventional puddling and saturation to submergence in rice and conventional tillage and five irrigations is essentially required in succeeding wheat crop in rice- wheat system.

Table 3. Effect of tillage systems and moisture regimes on grain yield of rice, wheat and system

Tillage systems	Grain yield (Mg ha^{-1})								
	Rice			Wheat			System		
	WW	LW	Mean	WW	LW	Mean	WW	LW	Mean
T_1	4.20	4.07	4.14	3.95	3.73	3.84	8.15	7.79	7.97
T_2	4.18	4.04	4.11	3.88	3.61	3.75	8.06	7.65	7.86
T_3	4.02	3.79	3.91	4.05	3.83	3.94	8.06	7.62	7.84
T_4	3.98	3.72	3.85	3.98	3.71	3.85	7.96	7.43	7.70
T_5	2.69	2.27	2.48	4.23	3.98	4.11	6.92	6.25	6.59
T_6	2.72	2.28	2.50	4.18	3.92	4.05	6.90	6.20	6.55
T_7	2.42	2.01	2.22	4.19	3.95	4.07	6.60	5.97	6.29
T_8	2.36	1.96	2.16	4.14	3.87	4.01	6.50	5.83	6.17
Mean	3.32	3.02		4.08	3.83		7.39	6.84	

LSD (P=0.05)	Rice	Wheat	System
Tillage system (TS)	0.06	0.07	0.09
Moisture regimes (MR)	0.04	0.03	0.05
TS x MR	0.09	NS	0.13

References

Aggrawal G.C., Sidhu A.S., Sekhon N.K., Sandhu K.S and Sur H.S. 1995. Puddling and N management effects on crop response in a rice-wheat cropping systems. *Soil & Tillage Research*, 36:129-139.

Aggrawal P., Garg R.N., Das D.K and Sharma A.M. 1999. Puddling, soil physical environment and rice growth on a *typic ustochrept*. *J. Indian Soc. Soil Sci.*, 47:355-357.

Bajpai R.K. and Tripathi R.P. 2000. Evaluation of non-puddling under shallow water tables and alternative tillage methods on soil and crop parameters in a rice-wheat system in Uttar Pradesh. *Soil & Tillage Res.,* 55:99-106.

Bhole N.C. and. Pandya A.C. 1964. Measurement of quality of puddlers. *Journal of Ag, Engg.,* 1:27-30.

Gill K.S. 1994. Sustainability issues related to rice-wheat production system in Asia. In: *Sustainability of rice-wheat production system in Asia* (Eds. R.S.Paroda, T, Woodhead and R.B. Singh), RAPA, Publication: 1994/11:33-60.

Mandal L.N. 1984. Soil research in relation to rice. *J.Indian Soc. Soil Sci*., 32:575-582.

Pandey D.S., Rath B.S., Misra R.D., Prakash A. and Singh V.P. 2000. Effect of puddling and method of wheat sowing on soil health of *Acqic Hapludoll* soil. In International conference on "*Managing Natural Resources for sustainable Agricultural Production in the 21st Century- Development and Conservation"* Feb. 14-18, New Delhi :1481.

Singh R., Gajri P.R., Gill K.S and Chaudhary M.R. 2000. Soil and fertilizer N management for sustainable rice-wheat production. Intl. Conf. "*Managing Natural Resources for Sustainable Agricultural Production in the 21st Century- Development and Conservation"* Feb. 14-18, New Delhi : 1358-1359.

Sur H.S., Prihar S.S. and Jalota S.K. 1981. Effect of rice-wheat rotations on water transmission and wheat root development in sandy loam soil of Punjab, India. *Soil & Tillage Research*, 1:361-371.

Yadav R.L., Prasad K. and Gangwar K.S. 1998. Analysis of eco-regional production constraints in rice-wheat cropping system. Bulletin No. 98-2, PDCSR Modipuram, India, 68 pp.