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Influence of tillage and crop establishment practices on physical properties of a rice-wheat cropping system in the Indo-Gangetic plain

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Abstract
Rice (*Oryza sativa* L.)-Wheat (*Triticum aestivum* L.) is the major cropping system occupying 13.5 million ha in the Indo-Gangetic Plains. A study evaluated eight treatments (T) involving four tillage methods and four rice establishment methods on soil microbial activity, soil enzyme activities and soil nutrient pools in a rice-wheat rotation. C mineralization were significantly higher in the transplanted plots then least zero tilled plot, Soil dehydrogenases activities were Rotovator tilled plots had the highest dehydrogenase enzyme activity followed by strip tillage, conventional tillage and zero tillage after wheat harvest. Highest urease enzyme activity was observed in zero tilled rice plots followed by puddling treatments. The highest phosphatase enzyme activity was observed in zero tilled wheat plots. The dilute salt extractable carbon (DSEC) was highest in strip tilled plots and lowest in zero tilled plots. Labile carbohydrates in soil had more labile carbohydrates than plots where transplanted rice was grown. Available Nitrogen, phosphorus and potash was significantly higher in conventionally tilled plot, zero tilled plot and rotavator tilled plot observed. Rotovator and conventional sowing generally maintained higher available Zn levels then reduced tillage practices (strip and zero tillage).

Keywords: Tillage, enzyme activity, soil organic carbon, cropping system, soil health

Introduction

Rice and wheat are the major cereal crops of India and is the backbone of food, nutritional security and livelihood for several hundred million people. It is grown in rotation in 12.3 million hectares (Kumar *et al.,* 1998) [3] and cover 50% of the land under rice wheat cropping system (RWCS) in the world. India has been food secure during the last three decades, at a gross level, largely because of this increase in food production. The food security of India and other countries in South Asia is, however, now at a risk due to continuously increasing population which implies a greater demand for food. By 2050, India's population is expected to grow to 1.6 billion people from the current level of 1.0 billion and the cereal requirement of India by 2020 will be between 257 to 296 million tons (Kumar, 1998) [3]. There is also increasing emergence of evidence that continuous cultivation of rice and wheat is lowering soil fertility, organic matter content, depleting ground water resources, exacerbating weed and pest problems and widespread nutrient deficiencies, especially of the micronutrients. An insight into the rice wheat cropping system reveals that it brings together conflicting and complementary practices. Much of the system operates at a low yield because of inadequate nutrient and inappropriate water management. The repeated transitions from anaerobic to aerobic and back to anaerobic growing conditions affect soil structure, microbial population and microbe-nutrient relations, affecting nutrient availability and growth of component crops in the cropping system.

The challenge is to understand crop responses to required combination of practices that also influence microbial activity and nutrient dynamics, so that management systems can be devised for high and sustainable combined yield. Research must attend to existing problems and improve resource use efficiency of existing practices.

Materials and Methods

The study was carried out at initiated in the research farm of the Institute of Agricultural Sciences, Banaras Hindu University. The eastern part of the Indo-Gangetic plain and extends between the parallels of 24⁰43′ and 25⁰35′ N latitude and 82⁰11′ and 83⁰33′ E longitude covering a geographical area of about 1578 km^2. The weather of the district is classified under moisture deficit index of 20 to 40 per cent and falls in semi-arid to sub-humid climatic zone with hot summers and cold winters. The mean summer, winter and soil temperatures are 33.2, 18.9 and 25.8 °C, respectively. The normal rainfall is about 1100 mm and the value of potential evapotranspiration is about 1500 mm. The amount of tillage given to each treatment was further quantified on a 0 to 3 scale (Table-1) with zero tillage being given a tillage degree of zero and puddling being given a score of 3. In wheat conventional sowing was given a score of 3. The scores of the treatment combinations was added up to reach a final tillage degree score as shown here under, with zero tillage in both rice and wheat receiving the lowest score and puddling followed by conventional sowing of wheat receiving the highest score. The treatments were laid out in permanent plots in a split plot design. During kharif season, strips for rice were created and sowing done as per treatment. After kharif season, strips for wheat were created perpendicularly to the rice treatments and superimposed, thereby creating sixteen treatment combinations for the RWCS. Randomization of rice and wheat treatments was done at the initiation of the experiment and thereafter the same pattern is being followed. Soil samples (0-15cm) were collected with a core auger after harvest of rice and wheat crops to represent each treatment. For estimation of bulk density, the soil from the cores were transferred into moisture boxes and brought to the laboratory and weighed immediately. They were then dried in an oven at 105 °C to a constant weight to calculate bulk density.

Table 1: The treatment details of experiments

Code	Rice	Tillage Degree	Code	Wheat	Tillage Degree
P1	Direct seeding by zero till drill	Least 0	T1	Rotavator till drilling	Moderate 2
P2	Direct seeding of sprouted seed under puddled condition	Least 3	T2	Conventional sowing	Moderate 3
P3	Hand transplanting under puddled condition	Least 3	T3	Strip till drilling	Moderate 1
P4	Transplanting by self-propelled transplanter	Least 3	T4	Zero till drilling	Moderate 0

Results and Discussion

Soil microbial activity

The cumulative C mineralization was measured during a 30 day period after rice and wheat harvest respectively (Table 2 and 03). Although higher cumulative C mineralization rates were observed in zero tilled rice, the values were not significantly higher than in the transplanted plots. The effect of preceding tillage practice was prominent in soils after rice in influencing carbon mineralization. In general higher rate of carbon mineralization was observed in plots with higher tillage intensity i.e. in conventional and rotovator tilled plots. With a decrease in tillage intensity, microbial activity also decreased, which was observed with low C mineralization rages in strip tilled plots. Zero tilled plots however had higher C mineralization rates than strip tilled plots. Zero tilled rice followed by zero tilled wheat plots had highest cumulative C mineralization (microbial activity). But transplanting, in general caused a decrease in cumulative C mineralization rates.

Soil management influences soil microorganisms and soil microbial processes through changes in the quantity and quality of plant residues entering the soil, and its spatial distribution. While in conventional tillage systems, organic matter is more thoroughly distributed than in no tillage systems where crop residues are concentrated on the soil surface. Mulching, generally, increases enzymes activities in soils. With the increasing of mulch there is an increased of the supply of the readily available substrate, such as carbohydrates, for microorganisms as well as soil enzymes. As a consequence, an increase in enzyme activities occur which play a major role in degradation of carbohydrates in soils and the hydrolysis of these enzymes are believed to be important energy sources for the growth of soil microorganisms (Deng and Tabatabai, 1996) [5]. High C mineralization has also been observed in the present study under zero tillage as compared to conventional tillage of wheat.

Table 2: Effect of planting methods and tillage practices on cumulative C mineralization (30 days) after rice (mg CO_2 C kg^{-1} soil)

	Tillage practices				
Planting Methods	T1	T2	T3	T4	Mean
P1	585.00	639.00	618.00	657.00	624.75
P2	639.00	603.00	606.00	606.00	613.50
P3	630.00	543.00	525.00	543.00	560.25
P4	594.00	642.00	570.00	570.00	594.00
Mean	612.00	606.75	579.75	594.00	

LSD	P	T	P X T
P<0.05	NS	13.54	72.92
P<0.01	NS	18.35	109.06

Table 3: Effect of planting methods and tillage practices on cumulative C mineralization (30 days) after Wheat (mg CO_2 C kg^{-1} soil)

	Tillage practices				
Planting Methods	T1	T2	T3	T4	Mean
P1	522.00	558.00	507.00	594.00	545.25
P2	564.00	567.00	555.00	555.00	560.25
P3	519.00	525.00	444.00	540.00	507.00
P4	558.00	498.00	543.00	516.00	528.75
Mean	540.75	537.00	512.25	551.25	

LSD	P	T	P X T
P<0.05	NS	17.77	54.45
P<0.01	NS	24.08	79.39

Soil enzyme activities

Dehydrogenase enzyme activity

Soil dehydrogenases plays an important role in degradation of organic matter and is a general indicator of soil enzymatic activity. The dehydrogenase enzyme activity was measured in soil both after harvest of rice and wheat and expressed as micrograms tri phenyl formazan produced per gram soil per hour, and is presented in (table 4 and 5) respectively. The dehydrogenase enzyme activity was in general lower in rice than wheat probably because of anaerobic nature of rice cultivation. The planting method of rice and preceding tillage practice in wheat both had its effect on dehydrogenase enzyme activity in soil after rice harvest. The lowest dehydrogenase enzyme activity was observed in manually transplanted plots and highest in direct seeded puddled plots. Rice plots previously conventionally tilled had the highest dehydrogenase enzyme activity and those that were rotovator tilled had the lowest.

Rotovator tilled plots however the highest dehydrogenase enzyme activity had followed by strip tillage, conventional tillage and zero tillage after wheat harvest. Preceding planting method in rice however had no significant effect on the dehydrogenase enzyme activity in soils after wheat harvest. Zero tilled rice followed by zero tilled wheat had the lowest dehydrogenase enzyme activity after wheat harvest. Nannipieri (1994) [4] concluded that more dehydrogenase activity was found in zero-till soil due to larger proportions of microbial biomass and carbohydrate-C per unit of organic C.

Table 4: Effect of planting methods and tillage practices on dehydrogenase enzyme activity after rice (ug TPF produced g^{-1} soil hr^{-1})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	2.16	2.61	2.36	2.53	2.42
P2	2.63	4.30	4.07	3.30	3.57
P3	1.77	2.28	1.96	1.41	1.86
P4	2.50	3.59	2.73	2.43	2.81
Mean	2.27	3.19	2.78	2.42	

LSD	**P**	**T**	**P X T**
P<0.05	0.85	0.47	NS
P<0.01	1.28	0.64	NS

Table 5: Effect of planting methods and tillage practices on dehydrogenase enzyme activity after wheat (ug TPF produced g^{-1} soil hr^{-1})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	9.34	8.47	8.93	7.38	8.53
P2	11.94	10.17	11.63	9.45	10.80
P3	10.47	9.60	10.46	10.19	10.18
P4	12.41	11.03	9.46	8.83	10.43
Mean	11.04	9.82	10.12	8.96	

LSD	**P**	**T**	**P X T**
P<0.05	NS	0.24	2.53
P<0.01	NS	0.33	3.83

Urease enzyme activity

Urease enzyme activity was measured in soils after wheat harvest and is presented in (table 6). The urease enzyme activity was expressed as micrograms urea hydrolyzed per gram soil per hour. Preceding planting method in rice and tillage treatment in wheat both had its impact on urease enzyme activity in soils after wheat harvest. Highest urease enzyme activity was observed in zero tilled rice plots followed by puddling treatments. It is generally reported that urease enzyme activity is more in zero tillage than conventional tillage (Dick *et al.,* 1997) [1], however Mina *et al.,* (2008) [6] did not find any difference in urease enzyme activity between zero and conventional tillage.

Among the puddled rice treatments, direct seeded plots had the highest urease enzyme activity followed by manual transplanting and them by machine transplanting. Whereas among the tillage treatments, highest urease enzyme activity was observed in rotovator tilled plots followed by zero tilled plots and then by conventional and lowest in strip tilled plots. Among all the tillage treatments in wheat, plots which were previously zero tilled in rice exhibited higher urease enzyme activity than the puddled plots. Among all the tillage treatments in wheat, in plots where direct seeding was followed in preceding rice, urease enzyme activity was in general higher than where transplanting was followed.

Table 6: Effect of planting methods and tillage practices on urease enzyme activity after wheat (ug urea hydrolised g^{-1} soil hr^{-1})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	298.26	290.82	243.67	284.62	279.34
P2	261.04	222.58	192.80	192.80	217.31
P3	145.66	107.20	145.66	144.42	135.73
P4	100.99	77.42	56.33	105.96	85.17
Mean	201.49	174.50	159.62	181.95	

LSD	**P**	**T**	**P X T**
P<0.05	13.35	1.74	13.68
P<0.01	20.23	2.36	20.60

Phosphatase enzyme activity

The phosphatase enzyme activity was measured by reduction of di-sodium para-nitro phenyl phosphate tetra-hydrate into para-nitro phenol and is presented in (table 7). The Phosphatase enzyme activity was influenced by the tillage methods in wheat and not by the planting methods in preceding rice. Among the tillage methods, conventionally tilled wheat plots showed the highest phosphatase enzyme activity followed by strip tillage and then by rotovator tillage. However the highest phosphatase enzyme activity was observed in zero tilled wheat plots. In the zero tilled rice plots, the highest phosphatase enzyme activity was observed in zero tilled/strip tilled rice, i.e. where tillage intensity was reduced. Conventional or rotovator tilled plots had comparatively lower phosphatase enzyme activities. Higher phosphatase enzyme activity has also been reported by Balota *et al.,* (2004) [7] in no tillage wheat as compared to conventional tillage in tropical Brazil. Mina *et al.,* (2008) [6] also reported that the activities of acid and alkaline phosphatase activities were significantly higher in zero-tillage than in conventional tillage treatments.

Table 7: Effect of planting methods and tillage practices on alkaline phosphatase enzyme activity after Wheat (ug PNP produced g^{-1} soil hr^{-1})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	34.72	36.37	44.33	43.51	39.73
P2	43.15	31.19	41.28	36.61	38.06
P3	37.77	48.55	36.75	37.12	40.05
P4	42.39	44.78	36.58	48.08	42.96
Mean	39.51	40.22	39.74	41.33	

LSD	**P**	**T**	**P X T**
P<0.05	NS	0.15	3.47
P<0.01	NS	0.20	5.26

Soil nutrient pools

Carbon stock in soil

The carbon stock in soil was calculated from the data of bulk density and total organic carbon over a depth interval of 5 cm and the summed up to 15 cm soil depth. The data on carbon stock to 15 cm soil depth is presented separately for soils after rice and wheat in tables 8 and 9 respectively.

Table 8: Effect of planting methods and tillage practices on C stock (0-15 cm) in soil after rice (kg m^{-2})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	1.43	1.30	1.29	1.39	1.35
P2	1.28	1.35	1.26	1.30	1.30
P3	1.30	1.44	1.33	1.39	1.37
P4	1.39	1.24	1.29	1.31	1.31
Mean	1.35	1.33	1.29	1.35	

LSD	**P**	**T**	**P X T**
P<0.05	NS	0.04	0.09
P<0.01	NS	0.06	0.14

Table 9: Effect of planting methods and tillage practices on C stock (0-15 cm) in soil after wheat (kg m^{-2})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	0.75	0.84	0.69	0.71	0.75
P2	0.87	0.73	0.82	0.71	0.78
P3	0.74	0.86	0.93	0.84	0.84
P4	0.77	0.82	0.82	0.75	0.79
Mean	0.78	0.81	0.81	0.75	

LSD	**P**	**T**	**P X T**
P<0.05	NS	0.03	0.10
P<0.01	NS	0.04	0.14

There are two strategies or mechanisms of C sequestration:

1. Increasing stable proportion of macro-and micro-aggregates.
2. Deep placement of SOC in the sub-soil horizons with sub-surface incorporation of biomass (Lal and Kimble, 1997) [2].

Carbon stock in soil after rice harvest was not influenced by the planting methods followed for rice cultivation, but was influenced by the preceding tillage method in wheat. There was not much variation in carbon stock among the tillage practices with lowest stock observed in strip tillage.

Carbon storage in soil after wheat was in general much lower than after rice and this could be because of rapid oxidation of organic carbon during aerobic cultivation of wheat. Tillage method had significant influence on carbon storage after wheat. Higher carbon storage was observed in conventional/rotovator/strip tillage over zero tillage in spite of residue retention under zero tilled plots. This is probably because the residue retained in preceding crop is not incorporated into soil by tillage and acts as surface mulch only. Whereas the little residue that is left over in other tillage systems are incorporated in soil and form organic matter thereby resulting in higher carbon stock. This fact is better borne out from the data of zero tilled rice plots. In the zero tilled rice plots, higher carbon storage was observed in conventionally tilled plots, followed by rotovator and then by strip tillage. This highlights the fact that mixing of the residue into soil is necessary for converting residue carbon into soil carbon.

Labile Carbon in soil

The dilute salt extractable carbon (DSEC) (Table 10) was estimated as a measure of the labile carbon in soil and was measured by extracting fresh soil with 0.5M solution of K_2SO_4 (1:5 wt/vol). Tillage practices in wheat had a significant effect on the dilute salt extractable carbon content in soils after wheat. DSEC was highest in strip tilled plots and lowest in zero tilled plots. Both conventional and rotovator tilled plots had similar DSAC values which were intermediate between the two extreme values. Among the zero tilled wheat plots, highest DSEC was observed in plots which had direct seeded rice planted under puddled condition. Lower labile C in zero tilled plots might be because it is utilized by microbes which are reflected in higher cumulative C mineralization in zero tilled wheat plots.

Table 10: Effect of planting methods and tillage practices on dilute salt extractable C after wheat (ug C g^{-1})

	Tillage practices				
Planting Methods	**T1**	**T2**	**T3**	**T4**	**Mean**
P1	615.16	606.24	615.69	557.21	598.44
P2	624.07	561.66	688.52	706.41	645.17
P3	590.16	788.06	734.33	564.18	669.18
P4	707.46	600.00	555.22	559.70	605.60
Mean	634.21	638.99	648.31	596.87	

LSD	**P**	**T**	**P X T**
P<0.05	NS	15.60	62.24
P<0.01	NS	21.15	92.16

Labile carbohydrate in soil

Labile carbohydrates in soil are also a measure of labile carbon and were estimated by autoclaving at 121 ^{o}C for 1 hour with a strong acid, and measuring the amount of carbohydrate released. The preceding planting method in rice and tillage treatments in wheat, both influenced the amount of labile carbohydrate in soil (Table 11). Among the preceding planting methods in rice, direct seeded plots always had more labile carbohydrates than plots where transplanted rice was grown. Zero tilled rice however had highest labile carbohydrate content. An increase in soil CHO content in zero-tillage practice has been reported earlier (Arshad *et al.*, 1990; Kapusta *et al.*, 1996) [8, 9]. Soil CHO is an important source of energy for micro-organisms, therefore zero tillage is suggested to promote biological activity in the soil.

Among the tillage practices tested in wheat, significantly higher labile carbohydrates were observed in strip tilled plots. Rest of the tillage treatments had similar labile carbohydrate contents. Among the zero tilled wheat plots, rice plots where direct seeding was the practice had higher labile carbohydrate compared to transplanted rice plots. The trend was similar in conventional and rotovator tilled plots also. Highest labile carbohydrate was observed in zero tilled rice followed by either zero or rotovator tilled wheat and also in direct seeded rice in puddled soil followed by strip tilled wheat.

Table 11: Effect of planting methods and tillage practices carbohydrates labile after wheat (ug glucose C g^{-1} soil)

Planting Methods	Tillage practices T1	T2	T3	T4	Mean
P1	652.15	590.76	526.15	603.87	593.23
P2	581.61	549.48	644.07	561.87	584.26
P3	499.58	536.92	549.12	512.15	524.44
P4	443.41	477.33	625.41	465.48	502.91
Mean	544.78	538.62	586.19	535.84	

LSD	P	T	P X T
P<0.05	NS	12.20	55.41
P<0.01	NS	16.54	82.46

Available nitrogen in soil

Available N was estimated by oxidation with alkaline permanganate and is presented in table 12. The available N status of soil after wheat was influenced by tillage practices in wheat. Highest available N content was observed in conventionally tilled plots followed by strip tillage and then by zero tillage. Rotovator tilled plots recorded the lowest available N content. Among any of the tillage treatments, plots which were previously zero tilled in rice recorded higher available N content.

Differences in available N among tillage systems have generally been reported. Soil N content was also significantly increased under zero or minimum tillage (Martin-Rueda *et al.*, 2007) [10]. Higher available N in zero tillage is generally attributed to less loss through immobilization, volatilization, denitrification, and leaching (Malhi *et al.*, 2001) [11]. The climate being dry, such losses of nitrogen is negligible and consequently higher N content in conventional tillage has been reported.

Table 12: Effect of planting methods and tillage practices on available N after wheat (kg ha^{-1})

Planting Methods	Tillage practices T1	T2	T3	T4	Mean
P1	235.20	235.16	203.84	235.20	227.35
P2	156.80	235.20	219.52	188.16	199.92
P3	219.52	188.16	203.84	172.48	196.00
P4	188.16	203.84	219.52	235.20	211.68
Mean	199.92	215.59	211.68	207.76	

LSD	P	T	P X T
P<0.05	NS	1.65	38.13
P<0.01	NS	2.24	57.72

Available phosphorus in soil

The water soluble P content was however influence both by the tillage practices in wheat and preceding planting method in rice (Table 13). Preceding direct seeded rice plots had lower water soluble P content, whereas transplanted plots had higher water soluble P. Among the tillage treatments, zero tilled wheat plots had higher water soluble P, followed by strip tilled plots and then by conventionally tilled plots. Rotovator tilled plots had lowest water soluble P content. Within a given tillage treatment also, plots previously directly seeded in rice (whether puddled or zero tilled) had lower water soluble P content. Higher available P in zero tilled soil was also reported by Mina *et al.*, (2008) [6] wherein they ascribed it due to higher organic matter and or redistribution.

Table 13: Effect of planting methods and tillage practices on water soluble P after wheat (ppm)

Planting Methods	Tillage practices T1	T2	T3	T4	Mean
P1	7.04	7.81	8.96	10.58	8.60
P2	7.33	8.24	9.39	12.93	9.47
P3	13.89	19.11	13.46	14.61	15.27
P4	15.90	14.03	18.20	16.09	16.06
Mean	11.04	12.30	12.50	13.55	

LSD	P	T	P X T
P<0.05	0.52	0.15	0.58
P<0.01	0.79	0.20	0.86

Available potassium in soil

The available K content after wheat was influence by planting methods only and is presented in table 14. There was no significant difference between conventional/strip/zero tilled plots so far as available K content is concerned after wheat. The available K content in the rotovator tilled plots was however significantly greater in rotovator tilled plots. Zero tilled rice followed by strip tilled wheat recorded the lowest available K content. Highest available K was found in mechanically transplanted rice plots followed by rotovator tillage.

Table 14: Effect of planting methods and tillage practices on available K after wheat (kg ha^{-1})

Planting Methods	Tillage practices T1	T2	T3	T4	Mean
P1	101.92	106.02	92.88	106.79	101.90
P2	100.43	125.74	100.43	112.75	109.83
P3	132.53	104.53	118.35	108.64	116.01
P4	141.87	109.01	114.99	107.15	118.25
Mean	119.19	111.33	106.66	108.83	

LSD	P	T	P X T
P<0.05	NS	6.50	33.94
P<0.01	NS	8.81	50.72

Available zinc in soil

The available zinc status of all the treatments was for below the critical limit of Zn availability (Table 15), in the absence of Zn fertilization and will probably be a major causes of yield decline in future in all the plots. The available zinc content ranged from 0.18 to 0.30 ppm in the 0-15cm soil layer. Rotovator and conventional sowing generally maintained higher available Zn levels then reduced tillage practices (strip and zero tillage). This is probably because tillage causes intimate mixing of residue with soil which enhancing organic matter decomposition which in turn maintain higher available Zn level. Available Zn level in plots is a function of difference between Zn addition and uptake. In the absence of Zn addition and with continuous Zn uptake the Zn level in soils are maintained by mineralization of roots and stubbles, and is thus not adequate to maintain optimum Zn levels in soil. Among all the planting methods, generally higher zinc levels were observed in rotovator tilled plots (except direct seeding under transplanted condition).

Table 15: Effect of planting methods and tillage practices on DTPA extractable Zn after wheat (ppm)

Planting Methods	Tillage practices				
	T1	T2	T3	T4	Mean
P1	0.26	0.23	0.23	0.23	0.24
P2	0.18	0.29	0.24	0.24	0.23
P3	0.30	0.27	0.25	0.25	0.27
P4	0.26	0.22	0.23	0.23	0.24
Mean	0.25	0.25	0.24	0.24	

LSD	P	T	P X T
P<0.05	NS	0.01	0.05
P<0.01	NS	NS	0.07

Relationship between tillage and soil microbial properties

The relationship between tillage and soil microbial properties vis-à-vis nutrient availability have been brought out by multiple correlation analysis carried out between these parameters and are discussed below:

Relationship between tillage and soil microbiology

Dehydrogenase enzyme activity is a general indicator of microbial activity in soil. Tillage significantly influenced the dehydrogenase enzyme activity after wheat (r= 0.69*) but not after rice. With increase in tillage intensity in wheat cultivation, soil was more disturbed and hence microbes became more active, which might have resulted in increase in dehydrogenase enzyme activity. Tillage also influence the urease enzyme activity after wheat (r= -0.55*), but there was no influence of tillage on the phosphatase enzyme activity. Cumulative respiration after rice or wheat was however not influenced by tillage intensities. Rice yield was influenced by dehydrogenase (r=0.55*) and urease (r=-0.87*) enzyme activities. Wheat yield was not affected by any of the enzyme activities, but total grain yield of the cropping system was influenced by urease enzyme activity only (r= -0.76*).

Relationship between nutrient availability and soil enzymes

Various enzymes release specific plant nutrients form soil organic matter and their activity correlates with the fertility status of the soil, as related to the availability of that nutrient. Available N was influenced by dehydrogenase enzyme activity (r= -0.56*), whereas available P was influenced by urease enzyme activity (r= -9.0*) and C mineralization (r= -0.54*) but not with phosphatase enzyme activity. Lack of correlation between acid and alkaline phosphatase activities with extractable P, which is consistent with other studies (Baligar *et al.,* 1999; Baloto *et al*., 2004) [14]. Phosphatases are stimulated when phosphate levels are low in soils. This lack of correlation between phosphatases and extractable P may be due to the suppression of soil phosphatase activity from long-term application of phosphate fertilizer (120 kg P_2O_5 per ha per year) as suggested by Haynes and Williams (1992) [13]. Available K and Zn availabilities were not correlated to any biological parameters.

Conclusion

Soil microbial activity

Higher microbial activity (cumulative C mineralization rates) were observed in zero tilled rice than in the transplanted plots. The effect of preceding tillage practice was prominent in soils after rice in influencing carbon mineralization. In soils after wheat, cumulative carbon mineralization was significantly affected by tillage practices and higher tillage intensity had higher rates of C mineralization and reduction of C mineralization was noticed with reduction in tillage. Zero tillage however had the highest cumulative C mineralization rate. Among the zero tilled wheat plots, highest microbial activity was observed in those plots which were also zero tilled during rice.

Soil enzyme activities

The dehydrogenase enzyme activity was in general lower in rice than wheat. The lowest dehydrogenase enzyme activity was observed in manually transplanted plots and highest in direct seeded puddled plots. In wheat, rotovator tilled plots had the highest dehydrogenase enzyme activity followed by strip tillage, conventional tillage and zero tillage. Zero tilled rice followed by zero tilled wheat had the lowest dehydrogenase enzyme activity after wheat harvest.

Highest urease enzyme activity was observed in zero tilled rice plots followed by puddling treatments (direct seeded > manual transplanting > machine transplanting). Whereas among the tillage treatments in wheat, highest urease enzyme activity was observed in rotovator tilled plots followed by zero tilled plots and then by conventional and lowest in strip tilled plots.

The highest phosphatase enzyme activity was observed in zero tilled wheat plots followed by conventionally tilled and then by strip tillage and then by rotovator tillage. In the zero tilled rice plots, the highest phosphatase enzyme activity was observed where tillage intensity was reduced.

Soil nutrient pools

Carbon stock in soil after rice harvest was not influenced by the planting methods followed for rice cultivation, but was influenced by the preceding tillage method in wheat. Carbon storage in soil after wheat was in general much lower than after rice and tillage method had significant influence on carbon storage after wheat. Higher carbon storage was observed in conventional/rotovator/strip tillage over zero tillage which highlights the fact that mixing of the residue into soil is necessary for converting residue carbon into soil carbon.

Highest available N content was observed in conventionally tilled plots followed by strip tillage, zero tillage and rotovator tillage. Direct seeded rice plots had lower water soluble P content, whereas transplanted plots had higher water soluble P. Among the tillage treatments, zero tilled wheat plots had higher water soluble P, followed by strip tilled plots and then by conventionally tilled plots. The available K content after wheat was influence by planting methods with no significant difference between conventional/strip/zero tilled plots so far as available K content is concerned after wheat. The available zinc status of all the treatments was for below the critical limit of Zn availability but rotovator and conventional sown plots generally maintained higher available Zn levels then reduced tillage practices (strip and zero tillage).

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