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Influence of different tillage methods and integrated weed management practices on soil microbial population in wheat under lower gangetic plains

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Abstract
A field experiment was carried out in new alluvial zone of West Bengal under *rabi* season to find out the effect of different tillage methods and integrated weed management practices on survival and population of total bacteria, actinomycetes and fungi in rhizosphere soil of wheat. Two methods of tillage practices were adopted *viz.* conventional tillage and zero tillage under the experiment. Whereas four different integrated weed management treatments namely two hand weeding at 15 and 30 days after sowing (DAS), one hand weeding at 15 DAS followed by application of post-emergence chemical herbicide (ready mixture of sulfosulfuron & metsulfuron methyl) at 30 DAS, one mechanical weeding at 15 DAS followed by application of same post-emergence chemical herbicide at 30 DAS and application of pre-emergence botanical herbicide (1:1 bamboo and parthenium aqua's extract) at 2 DAS followed by one mechanical weeding at 15 DAS were tested along with a weedy check. The result of the present investigation showed that maximum population of different microorganisms were recorder under zero tillage over conventional tillage throughout the experimentation. On the other hand; application of post emergence chemical herbicide suppressed the microbial population between 0 to 7 days after application (DAA), whereas minimum microbial population were observed in between 3 to 15 days after application of botanical herbicide during both the years under the investigation. Two hand weeding treatment produced significantly higher microbial populations over weedy check in most of the cases throughout the investigation.

Keywords: wheat, tillage, herbicide, chemical, botanical, rhizosphere soil, microorganism

Introduction

Wheat is the most important cereals in India after rice. In India, wheat production has increased from 11.0 million tonnes during 1960-61 to 107.59 million tonnes during 2019-20 over an area of 31.45 Mha with an average yield of 3421 kg ha^{-1} (Anonymous 2020-21) [1]. But productivity of wheat is declining day by day through environmental degradation are becoming visible in the form of declining soil fertility, degradation of irrigation water quality, shift in water table, rising salinity and resistance of many pests to pesticides (Singh *et al.* 2010) [18] and therefore concerns should to express through check the environmental degradation which is leading the production system unsustainability (Bhatt *et al.* 2016) [2]. Thus, for sustainable agriculture, agriculture scientists are looking towards the resource conservation strategies, such as zero tillage, bed planting, etc. (Chaudhary and Sharma, 2019) [5]. With regard to zero tillage method, which is characterized by placing of seeds on topsoil (Morris *et al.* 2010) [14], it is necessary to follow an appropriate procedure, to avoid high weed densities and prevent unacceptable problems (Brainard *et al.* 2013) [4]. Uncontrolled weed population in wheat caused 60.5% reduction in wheat grain yield under conventional tillage (CT) and 70% in zero tillage (ZT) conditions (Jain *et al.*, 2007) [11]. Therefore to overcome this problem, herbicides are applied to control weeds in the crop field and have direct or indirect consequences on non-targeted organisms including soil micro flora. It has been reported that some of microorganisms were able to degrade the herbicide, while some others were adversely affected depending on the type of herbicide used (Sebiomo *et al.*, 2011) [17]. Therefore, effects of herbicides on microbial growth, either stimulating or depressive, depend on the chemicals type, microbial species and environmental conditions (Zain *et al.*, 2013) [21]. Therefore, present investigation was framed to assess the influence of different

tillage methods and integrated weed management practices on different rhizosphere soil of wheat under lower Gangetic plains.

Materials and methods

The present experiment was conducted during two consecutive *rabi* seasons of 2013-14 and 2014-15 at RRSS farm of BCKV, Chakdaha, Nadia, W.B. being situated at New Alluvial Zone (NAZ) of West Bengal (23^0 5.3' N latitude and $83^0$5.3' E longitude with an elevation of 9.75 m above MSL). The soil of the experimental field was sandy clay loam in texture having pH 7.20, organic carbon 0.67%, available N 165.63 kg ha^{-1}, available P 16.26 kg ha^{-1} and available K 126.41kg ha^{-1}. The experiment was laid out in a split plot design with two levels of different tillage methods (T_1 - Conventional Tillage, T_2 - Zero Tillage) in main plots and five levels of IWM practices [M_1 - Weedy check, M_2 - Hand weeding at 15 and 30 DAS, M_3 - Hand weeding at 15 DAS *fb* application of post-emergence chemical herbicide (ready mixture of Sulfosulfuron & Metsulfuron methyl) at 30 DAS, M_4 - Mechanical weeding at 15 DAS *fb* application of post-emergence chemical herbicide (ready mixture of Sulfosulfuron & Metsulfuron methyl) at 30 DAS, M_5 - Application of pre-emergence botanical herbicide (Parthenium and Bamboo aqua's extract) at 2 DAS *fb* mechanical weeding at 15 DAS] in sub plots and replicated thrice. Wheat variety PBW-343 was used under the experiment. As per recommendation ready mixture of Sulfosulfuron 75 % WG & Metsulfuron methyl 20% WP was applied in the wheat field @ 40 g ha^{-1} at 30 DAS as Post-emergence herbicide. Whereas in case of botanical herbicide 5% (50 g powder in 1000 ml water) 1:1 (25 g powder for each) Bamboo and Parthenium aqua's extract was applied as pre-emergence to the respective plots of the experimental field. For mechanical weeding "wheel hoe" was used and recommended dose of fertilizer (RDF) was used for r*abi* wheat i.e. N:P:K::120-60-40 kg ha^{-1} during both the years of field trial.

Soil samples were collected from rhizosphere of wheat crop in the upper 0-15 cm soil profile from each of the experimental plot at 0 (fore spraying as initial), 3, 7, 15 and 30 DAA and at harvest in both of the year. The samples were properly tagged, sealed and carried out from the field to the laboratory for analysis. The enumeration of the microbial population for total bacteria, Actinomycetes and Fungi were done on agar plants containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt, 1965) [15]; plates were incubated at 30^0C. The counts were taken at 5^{th} day of incubation. The results were reported as number of cells per gram of soil. For counting total number of viable bacteria, actinomycetes and fungi; Thornton's agar medium, Jensen's nitrogen free medium (Jensen 1951) and Rose-Bengal agar medium (Martin 1950) [12] were used respectively.

Results and discussion

Effect of tillage

The result revealed that the population of total bacteria (CFU x 10^6 g^{-1} of soil), actinomycetes (CFU x 10^5 g^{-1} of soil) and fungi (CFU x 10^4 $g^{-1}$of soil) in rhizosphere soil of wheat were differed significantly with the variation of different tillage methods at all the observations under the investigation (Table 1 and 2). In this study, it has been found that the maximum population of total bacteria was higher under zero tillage method (T_2) over conventional tillage method (T_1). The highest population of total bacteria (189.73 CFU x 10^6 g^{-1} of soil) was recorder under zero tillage method (T_2) at harvest. Similarly highest population of actinomycetes (127.90 CFU x 10^5 g^{-1} of soil) was observed under zero tillage method (T_2) at harvest. Similar trend was also observed in case of fungal population and therefore highest population of fungi (18.80 CFU x 10^4 $g^{-1}$of soil) was found under zero tillage method (T_2) at harvest stage of the crop over conventional tillage method (T_1) throughout the experimentation. Consequently the minimum population of total bacteria (120.30 CFU x 10^6 g^{-1} of soil), actinomycetes (59.13 CFU x 10^5 g^{-1} of soil) and fungi (8.20 CFU x 10^4 $g^{-1}$of soil) were recorded under conventional tillage method (T_1) at 3 DAA during both the years under the study. Similar findings were also observed by Younesabadi *et al.* (2014) [20] and Govindan and Chinnusamy (2014) [7]. Higher microbial population under zero tillage method (T_2) may be due to the presence of residues of preceding crop, caused more accumulation of organic matter in the upper layer of soil profile which increased the abundance of microbial population (Groenigen *et al.* 2010; Mathew 2012; Bhatt and Kukal 2015) [13, 3]. In addition of this, zero tillage method significantly reduces physical disturbance in upper soil profile and hence improves soil biological health, which helps to increase the population of soil microorganisms (Guo *et al.* 2015, Guo *et al.* 2019) [9]. On the contrary, Younesabadi *et al.*, (2014) [20] reverse mechanism is true in case of conventional tillage where it has been done without any crop residues of previous crops and whatever a small quantity of crop residues left over after harvesting of the preceding crop, was incorporated in the soil and later decomposed by the organism. Therefore, the microbial population was found less under conventional tillage method (T_1) as compare to zero tillage method (T_2) during the present investigation.

Effect of integrated weed management

The results of integrated weed management (IWM) practices (Table 1 and 2) envisaged that the application of herbicides suppressed the microbial population at initial stage after application and later on it was increased gradually towards harvest. Before spraying of herbicides, population of total bacteria, actinomycetes and fungi did not differ significantly with different weed management practices. After application of post-emergence chemical herbicide the bacterial population in rhizosphere soil decreased and produced lowest value (56 CFU x 10^6 g^{-1} of soil) at 3 DAA. Later on *i.e.* from 7 DAA, the population of total bacteria started to increase and reached at maximum level at harvest. Similar trend were also followed in case of actinomycetes and fungal population under the study, where minimum population of actinomycetes (16.50 CFU x 10^5 g^{-1} of soil) and fungi (1.92 CFU x 10^4 g^{-1} of soil) were recorded at 3 DAA. The decreasing trend was comparatively differed in case of botanical herbicide as compared to chemical ones. After application of pre-emergence botanical herbicide (5% 1:1 bamboo and parthenium aqua's extract), lowest population of total bacteria (120.50 CFU x 10^6 g^{-1} of soil) was observed at 3 DAA; whereas minimum population of actinomycetes (25.50 CFU x 10^5 g^{-1} of soil) and fungi (2.92 CFU x 10^4 g^{-1} of soil) were recorded at 7 DAA (Table 1). Among different kind of microorganism, the reduction of bacterial population is higher in comparison to

actinomycetes and fungi in case of post-emergence herbicidal application. Among different IWM practices, treatment M_4 *i.e.* hand weeding at 15 DAS *fb* application of post-emergence chemical herbicide (Sulfosulfuron + Metsulfuron methyl) at 30 DAS; recorded highest population of total bacteria (174.58 CFU x 10^6 g^{-1} of soil), actinomycetes (122.17 CFU x 10^5 g^{-1} of soil) and fungi (16.25 CFU x 10^4 g^{-1} of soil) at harvest, though it was found statistically at per with other IWM treatments including weedy check throughout the investigation. Radivojevic *et al.,* (2004) reported that, chemical herbicides have toxic effects on micro-organisms, reducing their abundance, activity and, consequently, the diversity of their communities. Research has shown that there is no universal pattern of herbicidal effect on soil microorganisms. The toxic effects of herbicides are normally most severe immediately after application, when their concentration in soil is highest. Later on, microorganisms take part in a degradation process, and herbicide concentration and its toxic effect decrease. Ghosh *et al.,* (2012) [6] reported that the botanical herbicides after application also reduced the population of soil microorganisms up to three weeks after application and after that degradation of botanical herbicides increase the population. Sokolova and Gulidova (2010) [19] stated that the application of chemical herbicides have no negative effects on soil microorganisms.

Table 1: Periodical population of total Bacteria (CFU x 10^6 g^{-1} soil); Actinomycetes (CFU x 10^5 g^{-1} soil) and Fungi (CFU x 10^4 g^{-1} soil) at 0, 3 and 7 DAA in rhizosphere soil of wheat as influenced by different tillage methods and integrated weed management practices (pooled data of two years)

Treatments	Days after application (DAA)								
	0			3			7		
	TB	Act	Fun	TB	Act	Fun	TB	Act	Fun
Tillage method of wheat (T)									
Conventional Tillage (T_1)	129.23	82.93	8.50	81.80	48.43	4.70	93.60	53.37	5.30
Zero Tillage (T_2)	165.40	94.57	14.70	120.30	59.13	8.20	145.20	67.00	9.23
SEm (+)	0.39	0.25	0.27	0.001	0.10	0.08	0.002	0.12	0.10
CD ($p \leq 0.05$)	1.54	0.99	1.05	0.003	0.38	0.32	0.006	0.45	0.41
Integrated weed management (M)									
Weedy check (M_1)	147.00	88.83	11.00	158.00	95.67	11.42	161.00	100.50	12.17
Hand weeding at 15 and 30 DAS (M_2)	147.75	88.67	12.00	160.50	103.25	12.50	162.25	107.67	12.92
Hand weeding at 15 DAS *fb* chem. her. App.** at 30 DAS (M_3)	146.75	88.83	11.58	57.75	20.00	2.42	87.00	35.83	4.42
Mechanical weeding at 15 DAS *fb* chem. her. App.** at 30 DAS (M_4)	147.75	89.08	11.67	56.00	16.50	1.92	84.25	31.42	3.92
Botanical her. app # at 2 DAS *fb* mechanical weeding at 15 DAS (M_5)	147.33	88.33	11.75	73.00	33.50	4.00	102.50	25.50	2.92
SEm (+)	0.07	0.04	0.08	0.002	0.23	0.19	0.001	0.25	0.12
CD ($p \leq 0.05$)	NS	NS	NS	0.007	0.67	0.56	0.004	0.71	0.34

CFU- Colony forming unit, *fb*- followed by, DAS- Days after sowing, TB- Total Bacteria, Act- Actinomycetes, Fun- Fungi, **ready mixture of Sulfosulfuron & Metsulfuron methyl (Total) @ 40 g ha^{-1}, # 5% 1:1 Bamboo and Parthenium aqua's extract, NS- Non significant

Table 2: Periodical population of total Bacteria (CFU x 10^6 g^{-1} soil); Actinomycetes (CFU x 10^5 g^{-1} soil) and Fungi (CFU x 10^4 g^{-1} soil) at 15 and 30 DAA and at harvest in rhizosphere soil of wheat as influenced by different tillage methods and integrated weed management practices (pooled data of two years)

Treatments	Days after application (DAA)								
	15			30			At harvest		
	TB	Act	Fun	TB	Act	Fun	TB	Act	Fun
Tillage method of wheat (T)									
Conventional Tillage (T_1)	152.80	91.53	9.10	153.57	109.83	11.27	158.40	113.63	11.77
Zero Tillage (T_2)	186.00	113.20	15.60	189.50	122.47	18.30	189.73	127.90	18.80
SEm (+)	0.38	0.18	0.10	0.12	0.25	0.21	0.03	0.29	0.21
CD ($p \leq 0.05$)	1.50	0.72	0.38	0.45	0.99	0.82	0.11	1.13	0.82
Integrated weed management (M)									
Weedy check (M_1)	167.25	110.92	13.33	171.50	115.83	13.92	173.50	121.50	15.17
Hand weeding at 15 and 30 DAS (M_2)	171.67	119.25	14.33	171.50	116.08	14.50	174.00	121.75	16.25
Hand weeding at 15 DAS *fb* chem. her. App.** at 30 DAS (M_3)	173.58	105.08	12.58	171.50	116.58	15.75	174.50	122.13	13.00
Mechanical weeding at 15 DAS *fb* chem. her. App.** at 30 DAS (M_4)	170.17	98.75	12.00	171.75	115.92	15.00	174.58	122.17	16.25
Botanical her. app # at 2 DAS *fb* mechanical weeding at 15 DAS (M_5)	164.33	77.83	9.50	171.42	116.33	14.75	173.75	121.83	15.75
SEm (+)	0.10	0.13	0.09	0.15	0.04	0.09	0.04	0.03	0.09
CD ($p \leq 0.05$)	0.27	0.38	0.27	0.43	0.11	0.26	NS	NS	NS

CFU- Colony forming unit, *fb*- followed by, DAS- Days after sowing, TB- Total Bacteria, Act- Actinomycetes, Fun- Fungi, **ready mixture of Sulfosulfuron & Metsulfuron methyl (Total) @ 40 g ha^{-1}, # 5% 1:1 Bamboo and Parthenium aqua's extract, NS- Non significant

Conclusion

From the present investigation it can be concluded that zero tillage method enhances the soil microbial population over conventional method of tillage in rhizosphere soil of wheat. Integrated weed management practices including application of chemical and botanical herbicides do not reduce the population of soil microorganisms. Among different IWM practices treatment M_4 i.e. mechanical weeding at 15 DAS *fb* application of post-emergence chemical herbicide (ready mixture of sulfosulfuron & metsulfuron methyl) at 30 DAS was found safe and produced highest soil microbial population in rhizosphere soil of wheat under the study. Therefore zero tillage method can be adopted to mitigate the environmental degradation and weed problem can be solved through IWM practices including application of chemical and botanical herbicide without hampering the soil

microbial activity towards higher productivity of wheat under lower Gangetic plains.

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