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Influence of weed management practices on soil microbial populations, soil nutrient status and biological yield of aerobic rice (*Oryza sativa* L.)

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Abstract

Herbicide application has become a major breakthrough in agricultural productivity in the whole world since its benefit has been overwhelming over the years. Nevertheless, its harmful impact on the non-target soil microorganisms which plays important role in organic matter decomposition, N and nutrient recycling. The herbicides used in rice grown under aerobic condition may affect the biological equilibrium of the soil and thus affect the nutrient status, health and productivity of the soil. To study the effect of herbicides on soil microbial population in aerobic rice cultivation, a field experiment was carried out at the Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bengaluru during 2017 to study the effect of different weed management practices on soil microbial population, soil chemical properties, available soil nutrients and biological yield of aerobic rice. Eleven weed management treatments were attempted*viz.*,stale seedbed techniques, different mulching practices, application of pre and post-emergence herbicides, intercultivation and hand weeding. The results showed that there was no ill effect from different weed management treatments on the soil microbial population *viz.,* fungi, bacteria and actinomycetes after harvest of rice. The reduced weed density and dry weight in the superior treatments reduced the loss of nutrients from soil thus helped in improving the soil available nutrient status after harvest. All weed management practices in combination with herbicides registered markedly higher biological yield over the weedy check.

Introduction

Rice is the most important staple food crop for about half of the world's population, supplying 20 per cent of calories consumed worldwide. By 2035, it is estimated to meet the global rice demand, about 114 MT to meet the rice requirement of increasing population (Kumar and Ladha, 2011). Due to the receding water table, increased costs of labour for transplanting of paddy and the adverse effects of puddling on soil health, aerobic rice system of cultivation known as direct-seeded rice (DSR) is gaining more popularity. But, weeds are the main constraints for farmers practicing aerobic rice cultivation. Hence, the use of herbicides both pre- and post-emergence is required for establishment of a good crop. An unintended consequence of application of herbicides may lead to significant changes in the populations of microorganisms and their activities thereby influencing the microbial ecological balance in soil and affecting the productivity of soils. Generally, chemical herbicides are not harmful when applied to soil at the recommended dosage, but some of them may exhibit certain side effects on non-target organisms including micro-organisms due to their persistence nature (Anoop *et al*., 2016). The increasing reliance on rice cultivation on herbicides has led to concern about their eco-toxicological behaviour in the rice fields. Soil health and microbial diversity have become vital issues for sustainable agricultural practices (Simerjeet *et al*., 2014).

Thus, the present investigation was undertaken to find out the impact of different weed management practices on the soil microbial populations such as total bacteria, fungi and actinomycetes.

Material and Methods

A field trialwas initiated at ZARS, University of Agricultural Sciences,GKVK campus, Bengaluru during 2017 to study the effect of different weed management practices on soil microbial population, available soil nutrients status and biological yield of aerobic rice. The experiment was designed with RCBD with 11 treatments replicated thrice. The treatments are stale seedbed technique, application of straw mulch (rice straw), live mulch with dhaincha, live mulch with horsegram, spray of pre-mergence herbicides namely pendimethalin 30 % EC and pyrazosulfuron ethyl 10 % WP and one early post-emergence herbicide bispyribac sodium 10 % SC, intercultivation and hand-weeding were also practiced and weedy-check as well. Rice seeds were sown directly by dibbling at the rate of 7 kg ha^{-1} by following 25 cm x 25 cm spacing. The aerobic rice variety used wasMAS 946-1. The knapsack sprayer fitted with a flat fan type nozzle (WFN 40) was used for herbicide application, using a spray volume of 750 and 500 litres ha^{-1} in pre- and post-emergence herbicide respectively. The weedy check plot was kept undisturbed for the entire cropping period. The recommended dose of FYM @ 10 t ha^{-1} was applied 15 days prior to sowing and fertilizer dose of 100: 50: 50 kg N, P_2O_5, K_2O ha^{-1} was applied through urea, SSP and MoP, respectively. The 50 per cent of N was applied as basal dose and the remaining 50 per cent was applied in two splits *i.e.,* at tillering and panicle initiation stage. Whereas, SSP and MOP fertilizers were applied as basal dose at the time of sowing.

The composite soil was sampled before sowing and after harvesting of rice to analyse soil chemical reactions, soil nutrient status and microbial populations. Four samples of soil under each treatment were taken from 0-30 cm soil depth and mixed to have a representative sample of the treatment. The viable microbial counts were analysed by standard dilution plating technique. The bacterial population was estimated by counting colony growth on soil extract agar medium (James 1958 and Allen 1957). The fungal population was estimated by using Martin's Rose Bengal agar medium (Parkinson *et al*., 1971), the actinomycetes population was estimated by using Kuster's agar medium (Wellingtonn & Toth, 1963 and Küster & Williams, 1964). After incubation under suitable conditions for 3-8 days, the colonies were counted and the number of viable bacteria, fungi and actinomycetes were expressed as colony forming units (cfu) per gram of dry weight of soil.

Weed density and dry weight were recorded at 30, 60, 90 DAS and at harvest. Weed density was recorded in 0.5 m × 0.5 mquadrate randomly at one spot in each plot. Weeds were uprooted, washed with tap water, sun-dried, oven-dried at 65°C for 48 hours. After attaining the constant weight, the samples were weighed and expressed in grams per m^2.The plants from net plot were cut at two inches above the ground, sun-dried for three days and threshed. The grain and straw dry weight from the net plot was recorded and expressed askg ha^{-1}. The square-root transformation of original data of weeds was done for statistical analysis, the statistical significance of the treatment effects on different parameters was determined for the least significant difference (LSD) at 5 % level using analysis of variance as described by Cochran and Cox (1957).

Results and Discussion

General weed flora of the experimental field, weed density and weed dry weight: The infestation by different weed groups was observed in the experimental site. The analysis of the relative proportion of monocots, dicots and sedges weeds to total weed counts in weedy check was worked out during the crop growth period.The density of monocot weed count was higher than that of sedges and dicot weeds. Among the monocot weeds: *Eragrostis pilosa, Eleusine indica, Echinochloa cruss-galli, E. colona, Digitaria marginata, D. sanguinalis* and *Dactyloctenium aegyptium* were predominant. Among the dicot weeds: *Achyranthes aspera, Borreria hispida, Portulaca oleracea*, *Oldenlandia corymbosa, Commelina benghalensis, Acanthospermum hispidum, Cleome monophylla, C. gynandra, Ipomoea sepiaria, I. carnea, Sida cordifolia, Parthenium hysterophorus, Amaranthus viridis, Cassia tora* and *Crotalaria pallid* and *Cyperus rotundus* among sedges. All the treatments resulted in significant reduction in total weed density and total weed dry weight over the weedy check during the course of the field experiment (Table 1).

During the crop growth period, significantly lower total weed density and weed dry weight at 60 DAS (29.33 and 7.53 g m^{-2}) and 90 DAS (36.00 and 24.20 g m^{-2}) were found with stale seedbed technique *fb* bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as early PoE + one IC at 40 DAS, followed by straw mulch at 6 t ha^{-1}*fb*bispyribac sodium 10 % SC at 30 ml a.i. ha^{-1} as PoE at 60 DAS (33.33 and 8.51 g m^{-2}) and 90 DAS (40.00 and 26.17 g m^{-2}).

The significant reduction in total weed density and dry weight might have originated from the efficient control of the weeds at all stages of crop growth period. Nevertheless, significantly higher weed density, total dry weight of grasses, broad leaved and sedges weeds observed in a weedy check plot. The results are relatively similar to the findings of Nadeem *et al*., 2011; Arun *et al*., 2017, Praneeth *et al*., 2017 and Nivetha *et al*., 2017.

Biological yield and harvest index of rice as influenced by different weed management practices: The highest biological yield (15930 kg ha^{-1})wasfound instale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DASwhich was statistically at par with straw mulch at 6 t ha^{-1} *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE (15854 kg ha^{-1}), pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE (15820 kg ha^{-1}), pendimethalin 30 % EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE (15774 kg ha^{-1}) and pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (15766 kg ha^{-1}). However, the least biological yield was found in weedy check (1360 kg ha^{-1}). Similarly, the lowest harvest index (o.35) was found in a weedy check while the highest harvest index (0.38) was recorded with stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS followed by pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (0.38). The harvest index of rice paddy crop was not significantly different among different weed management treatments (Table 1). Increased biological yield parameter and harvest index in these practices might be due to the lesser crop weed competition, better soil microbial activity which were resulted to the better growth, yield and yield attributes of rice (Ahmed *et al*. 2015; Praneeth *et al*. 2017; Arun*et al*. 2017 and Nadeem *et al*. 2011).

Effect of herbicide residues on soil microbial population: The impact of different weed management practices on soil microbial population was determined by standard dilution plating technique. There were no significant differences in the initial population of bacteria. However, slight significant differences were observed inthe initial populations of fungi and actinomycetes in different treatments (Table 2).

Till the time of harvest of the crop, the microbial populations within all the weed management practices attained the level which was superior to the original level of population in all the treatments. The trend was similar with bacteria, fungi and actinomycetes. This indicates that, there were no long-term adverse effects of tested herbicides on the beneficial soil microbial populations. Nevertheless, a higher number of bacteria was found in live mulch with dhaincha @ 25 kg ha^{-1} (58.67 CFU x $10^5 g^{-1}$ soil) which was at par with straw mulch @ 6 t ha^{-1}*fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE(58.33CFU x $10^5 g^{-1}$ soil) and live mulch with horsegram @ 30 kg ha^{-1} (58.33 CFU x $10^5 g^{-1}$ soil). A similar trend was also observed with fungi and actinomycetes populations (Table 2).

The present findings of the research are in confirmation with the reports of Ghosh *et al*. (2012) and Bera*et al.* (2013) who have reported that microorganisms are able to degrade herbicides and utilize them as a source of biogenic elements for their own physiological processes. However, before degradation, herbicides have toxic effects on microorganisms, reducing their abundance, activity and consequently the diversity of their communities. The toxic effects of herbicides are normally more severe immediately after application. Later on, microorganisms take part in a degradation process and then degrade the organic herbicides molecules that serve as carbon source for multiplication of microorganisms in the rhizosphere.

Besides, it is also revealed that the herbicide application to soil causes transient impacts on the growth soil microorganisms when applied at recommended field application rate (Adhikary*et al*., 2014; Michael *et al.,* 2016 and Shashank*et al.,* 2018).

Soil chemical properties and status of available soil nutrients after harvest of rice: The soil pH was within the range of 6.76 to 7.18.The electrical conductivity (0.28-0.34 dSm^{-1}) and organic carbon (0.47-0.56 %) were found to be non-significant after harvest of aerobic rice.

Among the various weed management practices, significantly lower soil available nitrogen (271.00 kg ha^{-1}), available phosphorus (18.33 kg ha^{-1}) and available potassium (133.67 kg ha^{-1}) were found in weedy check plots after the harvest of paddy compared to all other treatments. The higher density of weeds in this treatment resulted in weeds ability to grow much faster and denser than rice crop also, removingmuch of the nutrients from soil. It is obviously indicated that reducing the weed density is much important to retain soil fertility.

Significantly, higher soil available nitrogen (315.67 kg ha^{-1}) was found in stale seedbed technique *fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS and was on par withpyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE (315.33 kg ha^{-1}), pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE +one IC as per package of practice (PoP) (314.67 kg ha^{-1}) and straw mulch @ 6 t ha^{-1}*fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE(314.33 kg ha^{-1}).

The higher amount of soil available phosphorus (30.67 kg ha^{-1}) was found to be significantly superior in stale seedbed technique *fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS and was found to be on par with straw mulch @ 6 t ha^{-1}*fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE(30.33 kg ha^{-1}), pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb*bispyribacsodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE (30.00 kg ha^{-1}) and pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (PoP) (29.67 kg ha^{-1}).

Soil available potassium varied significantly among the various weed management practices. Stale seed bed technique *fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS recorded significantly higher amount of available potassium (194.33 kg ha^{-1}). However, it was on par with straw mulch @ 6 t ha^{-1}*fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE (192.67kg ha^{-1}), application of pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb*bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE (191.67 kg ha^{-1}) and pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice (PoP) (189.00 kg ha^{-1}) (Table 3).

The reduced weed flora in these treatments also reduced the loss of nutrients from soil thus helped to improve soil available nutrient status. The results of this research are in confirmation with the findings of Sudhalakshmi*et al.* (2006); Sarwar *et al.* (2008) and Mizuhiko, (2016).

Conclusion

The outcome of this research indicated that application of stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS was found to be superior in increasing the biological yield of rice, reducing the weed density and weed dry weight which increased the competitive ability of rice crop to suppress the weeds and also maintaining the microbial population and nutrient status in the soil.

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Table 1 : Total weed density (no.), weight (g m^{-2}) at different stages, Biological yield and Harvest Index in rice as influenced by weed management practices

Weed management practices	60DAS		90DAS		Biological yield (kg ha^{-1})	Harvest Index
	Weed density	Weed dry weight	Weed density	Weed dry weight		
T_1: Stale seedbed technique *fb* two IC @ 15 and 30 DAS	7.90 (62.67)	5.37 (28.33)	9.11 (82.67)	6.55 (42.44)	13155	0.36
T_2: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early post-emergent spray	8.37 (70.67)	5.55 (30.33)	9.54 (92.00)	6.99 (48.41)	12990	0.36
T_3: Stale seedbed technique *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE + one IC @ 40 DAS	5.41 (29.33)	2.83 (7.53)	6.04 (36.00)	4.97 (24.20)	15930	0.38
T_4: Straw mulch at 6 t ha^{-1} *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as PoE	5.81 (33.33)	2.99 (8.51)	6.18 (40.00)	5.16 (26.17)	15854	0.37
T_5: Live mulch with dhaincha @ 25 kg ha^{-1}	9.34 (90.67)	6.08 (36.49)	10.31 (108.00)	7.31 (53.07)	12523	0.36
T_6: Live mulch with horsegram @ 30 kg ha^{-1}	8.63 (74.67)	5.84 (33.75)	8.44 (76.00)	7.12 (50.23)	12650	0.37
T_7: Pendimethalin 30 % EC @ 1.5 L ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	7.15 (50.67)	3.19 (9.69)	7.60 (57.33)	5.25 (27.14)	15774	0.37
T_8: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE *fb* bispyribac sodium 10 % SC @ 30 ml a.i. ha^{-1} as early PoE	6.36 (40.00)	3.08 (9.03)	6.79 (46.67)	5.21 (26.84)	15820	0.37
T_9: Pyrazosulfuron ethyl 10 % WP @ 35 g a.i. ha^{-1} as PE + one IC as per package of practice	7.22 (52.00)	3.30 (10.40)	8.11 (66.67)	5.41 (28.80)	15766	0.38
T_{10}: Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	16160	0.38
T_{11}: Weedy check	20.36 (415.00)	9.78 (95.32)	22.47 (505.33)	16.78 (281.96)	1360	0.35
S.Em.±	0.15	0.08	0.14	0.08	284.25	NS
CD at 5%	0.45	0.24	0.42	0.25	838.57	NS

Values in parentheses are original values; data analyzed using transformation $\sqrt{x+0.5}$

Table 2 : Soil microbial populations in rice field as influenced by weed management practices.

Weed management practices	Before sowing			After harvest		
	Bacteria ($CFUx10^5g^{-1}$ soil)	Fungi ($CFUx10^4g^{-1}$ soil)	Actinomycetes ($CFUx10^3g^{-1}$ soil)	Bacteria ($CFUx10^5g^{-1}$ soil)	Fungi ($CFUx10^4g^{-1}$ soil)	Actinomycetes ($CFUx10^3g^{-1}$ soil)
T_1: Stale seed bed technique fb two IC @15&30DAS	51.33	21.00	15.00	56.67	24.33	18.00
T_2: Stale seed bed technique fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1} as early post-emergent spray	51.67	20.00	15.33	53.33	23.33	16.33
T_3: Stale seed bed technique fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1} as early PoE+one IC@40DAS	49.00	19.67	16.33	55.67	24.00	16.67
T_4: Straw mulch @ 6 t ha^{-1} fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1} as PoE	51.67	20.00	15.00	58.33	25.67	19.33
T_5: Live mulch with Dhaincha @ 25 kg ha^{-1}	51.00	20.33	14.00	58.67	26.00	19.67
T_6: Live mulch with Horsegram @ 30 kg ha^{-1}	49.67	21.33	15.00	58.33	25.33	19.67
T_7: Perdimethalin 30%EC @ 1.5 L ha^{-1} as PE fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1} as early PoE	50.33	19.33	15.33	56.00	24.00	18.00
T_8: Pyrazosulfuron ethyl 10%WP@ 35 g a.i. ha^{-1} as PE fb Bispyribac sodium 10%SC @ 30 ml a.i ha^{-1} as early PoE	50.00	20.67	14.33	56.33	24.33	18.33
T_9: Pyrazosulfuron ethyl 10%WP @ 35 g a.i. ha^{-1} as PE +one IC as per package of practice (PoP)	51.00	20.67	14.00	56.67	24.67	18.67
T_{10}: Weed free	51.33	20.33	16.00	58.67	26.00	19.67
T_{11}: Weedy-check	51.00	20.67	15.33	55.00	24.00	17.67
S.Em.±		0.31	0.33	1.10	0.54	0.39
CD @ 5%	NS	0.91	0.97	3.25	1.59	1.15

Table3 : Soil chemical properties &available soil nutrient status as influenced by weed management practices after harvesting aerobic rice.

Weed management practices	pH	EC (dSm^{-1})	OC (%)	Nitrogen (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1: Stale seed bed technique fb two IC @15&30DAS	7.06	0.33	0.51	312.33	28.67	179.33
T_2: Stale seed bed technique fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1}as early post-emergent spray	6.76	0.32	0.49	308.67	28.00	178.00
T_3: Stale seed bed technique fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1}as early PoE–one IC@40DAS	6.96	0.33	0.50	315.67	30.67	194.33
T_4: Straw mulch @ 6 t ha^{-1}fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1}as PoE	7.00	0.28	0.54	314.33	30.33	192.67
T_5: Live mulch with Dhaincha@ 25 kg ha^{-1}	7.18	0.32	0.53	301.67	24.67	172.00
T_6: Live mulch with Horsegram@ 30 kg ha^{-1}	7.10	0.29	0.56	303.33	25.33	173.33
T_7: Pendimethalin 30%EC @ 1.5 L ha^{-1}as PE fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1}as early PoE	6.84	0.32	0.47	313.67	29.33	187.00
T_8: Pyrazosulfuron ethyl 10%WP@ 35 g a.i. ha^{-1} as PE fb Bispyribac sodium 10%SC @ 30 ml a.i. ha^{-1}as early PoE	6.87	0.28	0.48	315.33	30.00	191.67
T_9: Pyrazosulfuron ethyl 10%WP @ 35 g a.i. ha^{-1} as PE +one IC as per package of practice (PoP)	6.93	0.31	0.48	314.67	29.67	189.00
T_{10}: Weed free	7.06	0.34	0.56	317.33	32.00	197.33
T_{11}: Weedy-check	7.12	0.33	0.54	271.00	18.33	133.67
S.Em.±				4.83	0.46	2.97
CD @ 5%	NS			14.27	1.38	8.76