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Effect of crop management and weed control systems on the native soil microbial population

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Abstract

The soil quality in a paddy field is the most crucial element for the supply and the production of rice in India. However, the pressure on the paddy field creates a challenge for preventing soil degradation. Soil microflora are most vulnerable to soil pollution, and a decrease or increase of the soil bacteria may reflect the health of soil. In this study, we try to understand the effect of crop management and weed control systems on the native soil bacterial colony. Our study consists of three types of crop management systems, such as zero-tillage, the system of rice intensification (SRI), brown manuring, and three types of weed removal processes, i.e. chemical, integrated and mechanical. In the chemical and integrated treatment, two herbicides were used for weed removal, but in mechanical weeding, a cono-weeder was used. The colony forming unit (CFU) of different soil bacteria (nitrogen fixing and phosphate solubilizing) were measured during different stages of the crop growth. It was observed that the mechanical weeding has the least impact for both soil bacteria, but the chemical treatment showed a decrease of PSB count in all three systems. Whereas, the integrated treatment produced a better result in crop management and soil microbial population.

Keywords: *Azotobacter*, crop management, herbicide, soil bacteria, weed control.

Introduction

Indigenous microbial population of soil is important for maintenance of soil quality. They regulate numerous factors such as - organic content, nutrient cycling, soil aeration, and amount of available nitrogen. Moreover, they influence the growth of the plant through different processes, rhizosphere activity, legume activity, releasing of organic acids, and soil binding are few of them. The fixation and regulation of nutrient through degradation of soil contaminants was performed by diverse soil microorganisms (Hungria et al., 2009). There is a huge demand to produce rice in Asian countries, as rice is one of the major foods for developing countries. Due to a huge pressure, there is a little scope for a farmer to maintain the paddy-field and its microbiota. Retaining crop residue and reduced tillage are practicing conservation techniques, which is useful for treating resources for sustainable use (Ceja-Navarro et al., 2010). The positive effect of these conservation practices directly correlated to aggregated biological, microbial activity and an improved soil quality (Alvear et al., 2005). Farming techniques are important for rice cultivation, and along with it is beneficial to a farmer.—Integrated crop management has multiple benefits to rice cultivation. Crop management system elevates the practice of sustainable agricultural techniques through fulfilling the demand for ecosystem services, securing the food demand of future generation for creating a nourishing society (Tilman et al., 2002). One of the farming techniques is zero-tillage, which reduces disturbance and acts as a carbon sink. This approach reduces soil erosion and increases organic carbon content in arable lands (Ashworth et al., 2017). Moreover, it has other benefits to the traditional technologies such as- suitable conditions for growth, high-quality seedbed, facilitating easy germination (Tarafder et al., 2017). Zero-tillage system promotes bacterial activity in soil, and thus stabilizes the soil, but prolonged use of zero-tillage could change the soil structure, interfere with the oxygen quantity in soil (Dong et al., 2017, Hungria et al., 2009). Nonetheless, zero-tillage system affects the phosphorus distribution, nutrient availability, and crop residues (Shi et al., 2012). While zero-tillage deals with soil conservation, the SRI focuses on increased productivity of rice eliminating the need for inorganic fertilizer. SRI system differs from the conventional tillage system for the use of compost, use of alternative water management, managing of young seedling, and weed management. The standard agricultural method, which requires a large amount of water for rice, is to maintain the seedlings into the submerged water for certain duration in India. Scarcity of water and reduced water table threaten many Indian farmers, along with it, the high electricity cost for irrigation pump is a major burden for farmers. SRI system could fill up this gap by the use of less water and making the seedbed more aerobic to increase the soil organic content and rate of nitrification. The nitrification rate increased due to the use of SRI was studied by Sooksa-Nguan et al., (2009, 2010). A little information was found about the mechanism and regulatory process of SRI. There are majorly two instruments, which play a crucial role in the SRI. The large root system and the diverse number of microorganisms are the main two major factors, which play a crucial role in the SRI. These two interacting factors create a bigger nutrient-based network containing mites, earthworms, arthropods, and other organisms. All these organisms with soil bacteria contribute to increased organic acids in the soil for faster decomposition of organic substances, which increase carbon percentage and nutrient for plants. Compared to a conventional facility, SRI follows a minimum moisture percentage in the field by regular spraying of water (saturated soil culture, SSC) or utilizing alternatively wetting and drying fields (AWD) (Thakur et al., 2014). Substituting the conventional flooding process, these two soil moisture methods provide an advantage for the root-growth and soil aeration (Thakur, 2010).

The unwanted growth of the crop field weeds and its competition with crop for nutrients and moisture are a major problem in tropical country like India. The weed management is generally done by applying herbicide and removing the weed manually. The application of herbicides is specific dose dependent and has affected the soil microflora.

There are several literatures available describing the herbicide degradation or assessing chemical parameters of soil, but less investigations focus on the study of soil microorganism as an indicator of the soil health (Kalia & Gosal 2011; Zabaloy et al., 2011; Marin-Morales et al., 2013; Lehman et al., 2015; Prashar & Shah, 2016; Raj & Syriac, 2017). The various physical and chemical techniques for testing soil are time-consuming and not error-free. Further, it takes a long time than microbial assessment. In this regard, soil microbial testing to assess soil health could be a better approach than conventional chemical soil testing. In this study to check the soil health, considered three types of weeding techniques applied to three types of cropping system, zero tillage, SRI, and brown manuring to measure the changes in phosphate solubilizing (PSB) and nitrogen-fixing *Azotobacter* soil bacteria as per the dose of herbicide.

Material and Methods

Herbicide treatment

In this study, two types of herbicides named Pretrilachlor and Pyrazosulfuron ethyl were used. The generic names of these two herbicides are Rifit (Pretrilachlor) and Saathi (Pyrazosulfuron ethyl). Petrilachlor was applied at the rate of 3ml/liter of water, and pyrazosulfuron ethyl was applied at the dilution of 0.55gm/liter of water. Three types of weed management; chemical, integrated, and hand weeding or mechanical weeding were applied. Pre-emergence herbicide, Pretrilachlor was applied at second day after transplanting, and the second herbicide, Pyrazosulfuron ethyl was used in the field at 35 days after sowing. The chemical treatment used only two types of herbicide applied. Whereas, in an integrated process, at first, Pretrilachlor was applied on the second day and with the combination of cono-weeder applied at 35 days after sowing. Another method was hand weeding, where mechanical weeding was applied at 15 and 35 days.

Collection and Preparation of sample

The composite soil samples of different treatment system were collected from the rhizosphere and stored in a refrigerator before the preparation of samples. 1 gm of soil sample was diluted into 10 ml of sterile water serving as a stock sample. Soil sample was prepared by serial dilution, where stock sample was marked as 10^{-1}, and subsequent samples were prepared from the stock upto 10^{-5} dilution. The suitable Pikovskaya's media was used for phosphate solubilizing bacteria, and *Azotobacter* specific media was used for nitrogen-fixing bacteria. All the agar media were prepared aseptically for poured plate sampling of soil samples. All the microbial works were made in a laminar air-flow maintaining an aseptic condition.

Study of soil bacterial population

About 100μl of soil suspension from the 10^{-5} dilution was poured into the pre-marked sterilized petri-dish. The suitable sterile medium poured aseptically in each petri-plate, and the plates was rotated gently for mixing. All the samplings were made in triplicate for representative results. Afterward, the plates were placed in an incubator at the temperature of 37.5^{0}C for 48 hrs. The colony character of bacterial growth was checked regularly. The colony forming units (CFU) of the specific bacteria were calculated at following the standard method.

Results and discussion

Bacterial population in zero tillage

The colony forming unit (CFU) was counted after three types of treatments in zero tillage system, and data collected at four different periods. The mechanical weeding had the maximum bacterial count for before herbicide application (BHA), and chemical treatment had the second highest number. Surprisingly, integrated treatment, which produced the lowest count, affects *Azotobacter* population most, for all three treatments. Figure 1a described *Azotobacter* population in zero tillage. At harvesting period, the bacterial population was increased by 15% after mechanical weeding. Nonetheless, bacterial population increased at harvesting for all the three treatments. After second time application of herbicide, *Azotobacter* bacterial population reduced for the chemical treatment up to 25%, but it reduced for the integrated treatment up to 15% (Figure 1a). Similar to *Azotobacter*, data for PSB population was collected for four different periods (Figure 1b). Unlike previous data, bacterial population was higher for before herbicide application (BHA) but not at the harvesting. At the BHA level, mechanical and integrated weeding showed lower value, which was opposite of the *Azotobacter* result. There was a little change for PSB population after second treatment compared to first treatment for mechanical weeding (Figure 1b). Further, mechanical weeding had a little effect on the removal of PSB population compared to other treatments. Among other two treatments, PSB population was affected strongly by chemical treatment than integrated treatment. PSB population reduced by 25% after first chemical treatment and increased to 50% after the second chemical treatment (Figure 1b). Brenner & Corson, (1974) studied the effect of herbicide and insecticides decrease the *Azotobactor* population in soil.

From the result for *Azotobacter* population, it was observed that chemical treatment effective than integrated treatment. It was suggested that zero-tillage organized the soil to support bacterial growth, and when herbicide was applied after stabilization of soil, it removed the bacteria with a strong efficiency (Banerjee et al., 2019). Due to the stabilization, bacteria collected all the necessary nutrients for growth, thus we see a higher number of nitrogen-fixing colonies were observed than PSB. One of the reason could be the zero disturbance at no-tillage, that could lead to improve the soil physicochemical property and increase of availability of nutrients (Dong et al., 2017). For the PSB, the removal rate was as high as 50% after second chemical treatment. The removal rate for PSB was higher than the removal rate of *Azotobacter*, and the reason could be the role of zero-tillage in phosphate management (Dong et al., 2017). Probably, the outcome was controlled by the treatment availability and transfer of phosphate to soil, and thus after second treatment, it reached to highest removal rate.

Bacterial population in system of rice intensification

Previous study design was applied for SRI, and data was collected at the same interval. The population of *Azotobacter* and PSB after three treatments in SRI showed in Figure 2a and b. It was observed that after the first treatment, the bacterial count increased for mechanical weeding (Figure 2a). Probably, the water conservation and the weed management were responsible for increasing bacterial count. The *Azotobacter* count was same between second treatment and at harvesting for mechanical weeding (Figure 2a). After second application, *Azotobacter* bacterial removal rate for chemical treatment reached to 38%, but integrated treatment reached to higher percentage of 41%. Randriamiharisoa et al. (2006) studied on the soil biological contributions to SRI. The integrated system produced the higher bacterial count compared to mechanical weeding for PSB population (Figure 2b). Moreover, the chemical treatment showed the least bacterial count, and it was indicated that PSB population was sensitive to the chemical treatment. There was a small increase of bacterial colony for the integrated treatment after second herbicide application (Figure 2b). However, no change was observed in bacterial colonies for mechanical weeding between first and second application. It was observed, from the figure 2b, that bacterial colonies were increased at the harvesting stage for all treatments. The efficacy for chemical treatment reached to 50% after second application, but it reached to meager 16% for integrated treatment. Effect of weed control methods on rice cultivars under the SRI was detailed studied by Pandey, (2009).

The study showed that the chemical treatment affected the PSB population but not *Azotobacter* population. Whereas, integrated treatment has affected most of the *Azotobacter* population. Elimination of inorganic fertilizer could be one of the reasons that chemical treatment worked better for PSB because this elimination could increase the phosphate content on the soil, and thus the bacteria increased and its removal (Roy et al., 2015). Although, *Azotobacter* population was responded to integrated treatment. A combination of chemical and mechanical weeding stirred the soil well initially. In the integrated process, mechanical weeding followed by chemical weeding and this sequence removed the unnecessary particles from soil to facilitate and increase oxygen quantity. This process allowed the nitrogen specific bacteria to colonize the soil robustly. Thus, removal rate was high for integrated treatment.

Bacterial population in brown manuring

The population of *Azotobacter* and PSB after different treatments in brown manuring showed in Figure 3a and b. The study design was no different from the SRI system, and data was collected at four different intervals. It was observed that chemical treatment was resulted the highest bacterial count at BHA level, but afterward, mechanical weeding produced the highest bacterial count for *Azotobacter* population (Figure 3a). The mechanical weeding did not affect strongly on the *Azotobacter* population. But when mechanical weeding was combined with chemical treatment, it was resulted the maximum removal rate (Figure 3a). Bacterial colony was high for chemical treatment at BHA level, but it reduced at harvesting (Figure 3a). The efficiency was reached to 55% for the chemical treatment after the second application, but integrated treatment, which showed a rapid decrease of the colony at the beginning, reached 33%. For the PSB population, mechanical weeding process was inactive at the beginning, but it increased the bacterial population at harvesting (Figure 3a).

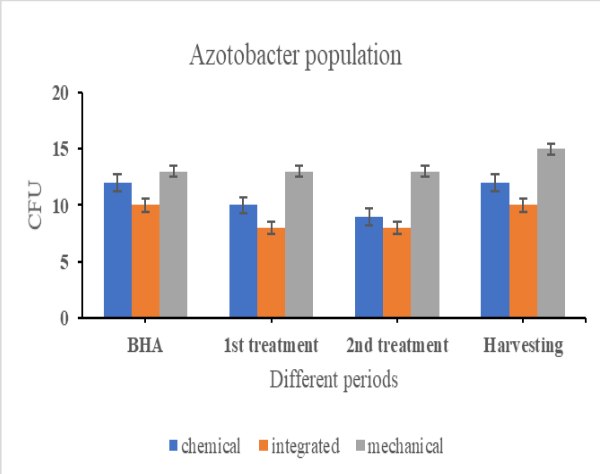

Fig. 1a. Population of *Azotobacter* after three treatments in zero tillage (mean ± SD).

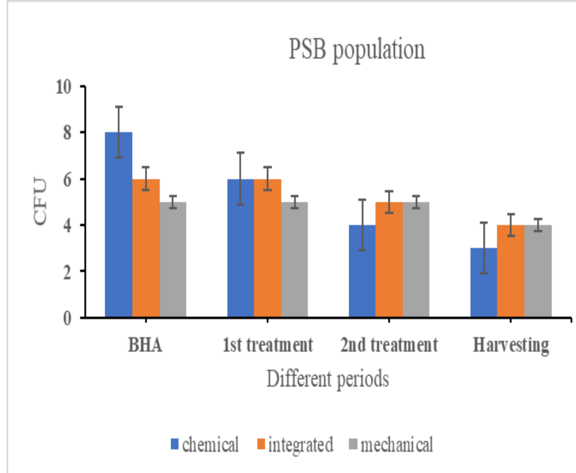

Fig. 1b. Population of PSB after three treatments in zero tillage (mean ± SD).

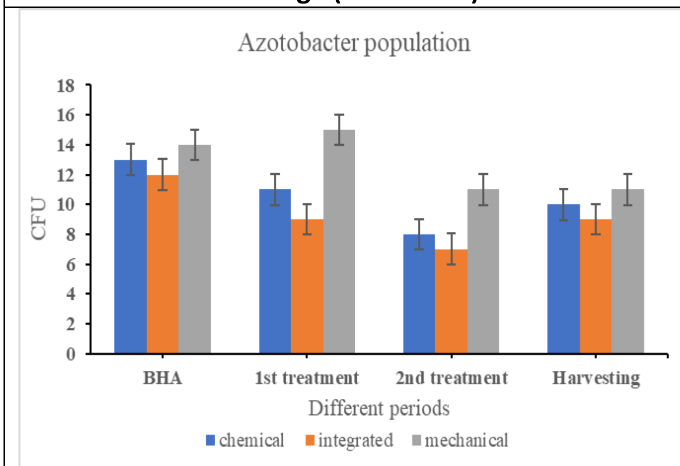

Fig. 2a. Population of *Azotobacter* after three treatments in SRI (mean ± SD).

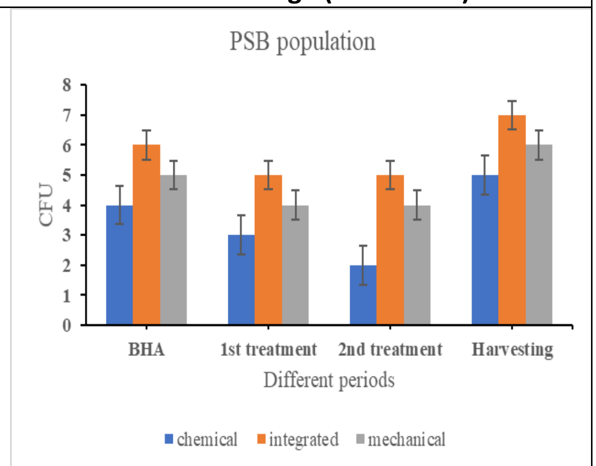

Fig. 2b. Population of PSB after three treatments in SRI (mean ± SD).

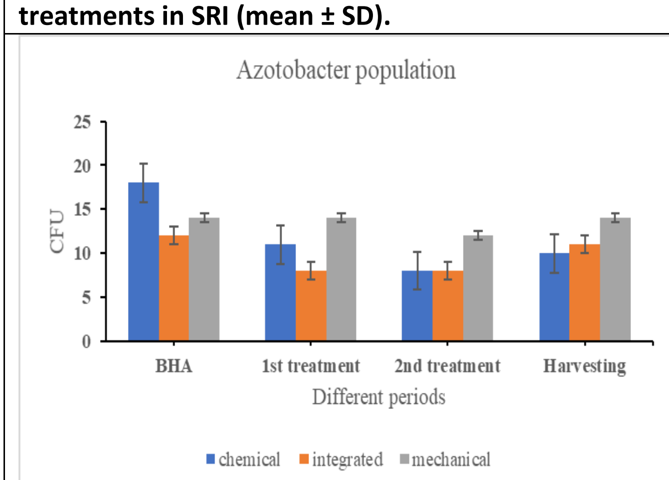

Fig. 3a. Population of *Azotobacter* after three treatments in brown manuring (mean ± SD).

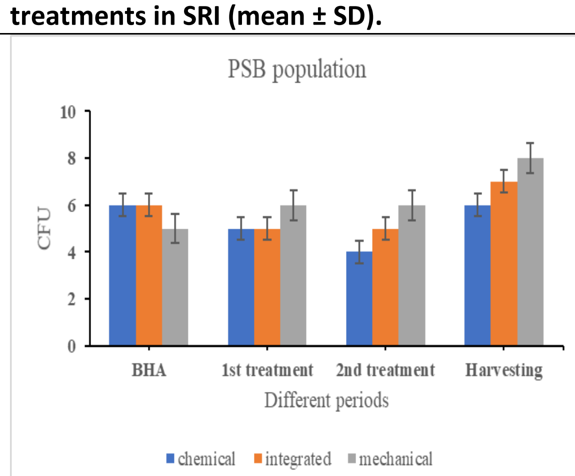

Fig. 3b. Population of PSB after three treatments in brown manuring (mean ± SD).

It was observed that chemical treatment reduced the bacteria afterward (Figure 3b). But, there is no changes were observed in colony count of the integrated treatment system (Figure 3b). The removal efficiency for chemical treatment was reached 33%, and for integrated treatment, it was half of the chemical treatment. The Effect of Brown manuring on Soil Properties was studied by Iliger et al., (2017).

The bacterial count at the harvesting was the maximum irrespective of treatments, and it might suggest that PSB population remained unaffected at harvesting stage (Roy et al., 2015). Although chemical treatment was not as strong as integrated, it reached the same bacterial count as integrated. It was indicated *Azotobacter* responded slowly against studied herbicide in brown manuring. It further strengthens the point that *Azotobacter* colony reacts slowly in brown manuring system. Maitra & Zaman, (2017) reviewed on Brown manuring and stated that it is an effective technique for yield sustainability and weed management of cereal crops.

Conclusion

The study concluded that the herbicide is effective against the decrease of native soil bacterial population in all three types of crop systems. The major inherent soil bacterial population was decreased by chemical application for all the three treatments. The integrated treatment found better results for *Azotobacter* population in zero-tillage and SRI system. For brown manuring, chemical and integrated treatments develop equal results for *Azotobacter* population. The studied herbicides have less effect on *Azotobacter* compared to Phosphate solubilizing bacteria. Moreover, the chemical application decreases the PSB population for all three treatments, which indicates that chemical treatment have negative effect on soil health. In this study, it can be recommended that the integrated treatment, keeping good soil health, may be substituted the chemical treatment for future weed management.

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Conflict of interest:

The authors declare that they have no conflict of interests.

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