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Impact of herbicides and nutrient management on soil biological properties in maize (*Zea mays* L.) + cowpea (*Vigna unguiculata* L.) intercropping system

R. Y. P. LOKOSE, S. N. JENA, M. R. SATPATHY AND J. BEHERA

Department of Agronomy, College of Agriculture
Orissa University of Agriculture and Technology Bhubaneswar-751003, Odisha

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ABSTRACT

A field experiment was conducted during 2015-016 and 2016-017 on loamy sand soil to assess the impact of two commonly used herbicides (pendimethalin and oxyfluorfen) and nutrient management on soil microbial populations in maize + cowpea intercropping system. The field experiment was laid out in a split-plot design with three replications. There were altogether 16 treatment combinations having main plot treatments (Nutrient management): F_1= recommended dose of fertilizer (RDF) i.e. 120, 60, 60 kg ha^{-1} N-P_2O_5-K_2O, F_2= RDF+FYM 5 t ha^{-1}, F_3= RDF+ 0.2 Lime requirement (LR), F_4= RDF+FYM 5 t ha^{-1} + Lime 0.2 LR and sub-plot treatments (Weed management): W_1= Pendimethalin 0.75 kg ha^{-1}, W_2= Oxyfluorfen 0.03 kg ha^{-1}, W_3= Farmer practices or hoeing and weeding at 20 days after sowing (DAS), W_4= Weedy check. The results revealed that the herbicide treatments significantly inhibited the development of microbial populations in the soil at the initial stage after application of herbicide. No inhibition was observed after 30 days of application up to 60 DAA. Among the herbicides, oxyflourfen reduced the soil microbial population significantly as compared to pendimethalin at initial crop growth stage. The higher value of microbial population were observed under combined application of recommended NPK+ FYM along with lime as compared to mere application of recommended NPK.

***Keywords*: Bacteria, fungi, herbicides, nutrient management, oxyfluorfen and pendimethalin**

Herbicides are applied to control weeds in the crop field and have direct or indirect consequences on non-targeted organisms including soil microflora. 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). 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). In addition to that recently many multinational companies have released new herbicide molecules which are again open huge scope for studying the influence of these molecules on soil microorganisms.

Although, chemical fertilizers are playing a crucial role to meet the nutrient requirement of the crop, the continued application of chemical fertilizer leads to deterioration of soil health with reduced organic carbon and increased micro-nutrients deficiencies (Nagavani and Subbian 2014) which posing a greater threat to sustainable agriculture. In this endeavor proper blending of organic and inorganic fertilizer is important not only for increasing yield, but also for sustaining soil health. Use of organic manures like FYM in combination with chemical fertilizers, helps in improving physico-chemical properties of the soil and improves the utilization of applied fertilizers resulting in higher yield and quality. Further, it stimulates the activity of microorganisms that makes the plant to get the macro and micro-nutrients through enhanced biological processes, increase nutrient solubility and soil pH (Alabadan *et al.,* 2009).

Effects of herbicides on soil microorganisms in maize + cowpea intercropping system with special emphasis on microbial population in relation to organic and inorganic fertilizers are limited. Therefore the present study was framed to evaluate the effect of commonly used herbicides and nutrient management on soil biological properties in maize + cowpea intercropping system.

MATERIALS AND METHODS

The experiment was conducted during two consecutive *kharif* season of 2015 and 2016 at Agronomy main Research Farm, Central Research Station of the College of Agriculture, OUAT- Bhubaneswar. The site is located at $20^0$15' N latitude, longitude of 85^0 52' E and at an altitude of 25.9 meter above the mean sea level. The soil of the experimental plot was loamy sand in texture, low in available nitrogen (134 kg ha^{-1}), high in available phosphorus (87.5 kg ha^{-1}) and low in available potassium (71.6 kg ha^{-1}), organic carbon 0.24% and pH (4.71), EC dsm^{-1} (046). The field experiment was laid out in a split-plot design with three replications. There were altogether 16 treatment combinations with four main plot treatments (Nutrient management): F_1=RDF (120, 60, 60 kg ha^{-1} N-P_2O_5-K_2O), F_2= RDF+FYM 5 t ha^{-1}, F_3= RDF+ 0.2 Lime requirement (LR), F_4= RDF+FYM 5 t ha^{-1}+ Lime 0.2 LR and four sub-plot

Email : lokose1984@gmail.com

treatments (Weed management): W_1= Pendimethalin 0.75 kg ha^{-1}, W_2= Oxyfluorfen 0.03 kg ha^{-1}, W_3= Hoeing and weeding (Farmer practices) at 20 DAS, W_4= Weedy check. Tested varieties were Hybrid maize (PAC 751) and Cowpea (Kashi Kanchan). Urea, single super phosphate and potash were the sources of nitrogen, phosphorous and potassium, respectively.

The soil microbial population (heterotrophic bacteria and fungi) was determined by serial dilution and spread plate technique at initial, 15, 30, 45 and 60 DAA. One (1) g of the collected soil samples were added to each of ten tubes containing 9 ml distilled water thoroughly mixed and spread over petriplates containing Nutrient Agar and Potato Dextrose Agar for enumeration of total heterotrophic bacteria and fungi population respectively. The plates were incubated at 30°C for 24 hours for bacterial isolation and at 30°C for 48 hrs for growth of fungi and observations were made in terms of counting of number of colonies $plate^{-1}$ as below-

$$\text{CFU ml}^{-1} = \frac{\text{No.of colony} \times \text{inverse of dilution taken}}{\text{Vol. of inoculum taken}}$$

RESULTS AND DISCUSSION

Microbial population of bacteria and fungi

Microbial population composition and density is an important attribute of soil organic matter quality, as it provides an indication of a soil's ability to store and recycle nutrients and energy. It also serves as a sensitive indicator of change and future trends in organic matter level. The effect of herbicide treatments on soil microbial population was determined based on the growth of fungal and bacterial colonies in each treatment media. The growth of the microbial population showed different

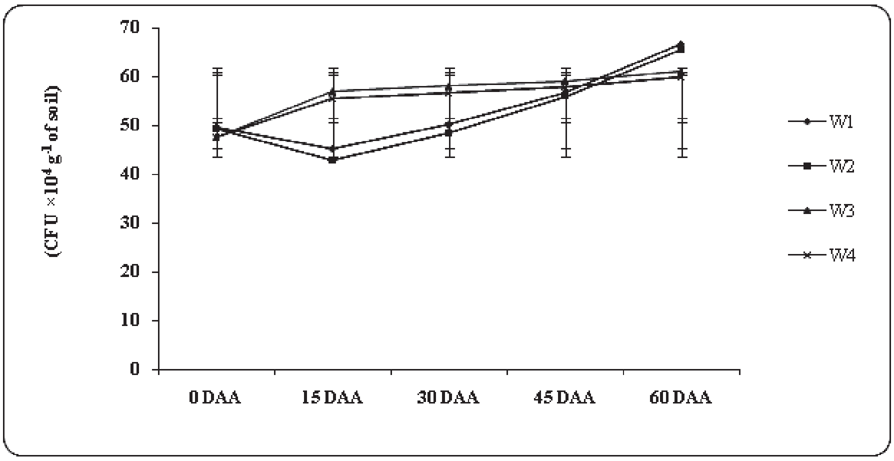

Fig. 1: Bacterial population as influenced by pre-emergent herbicides

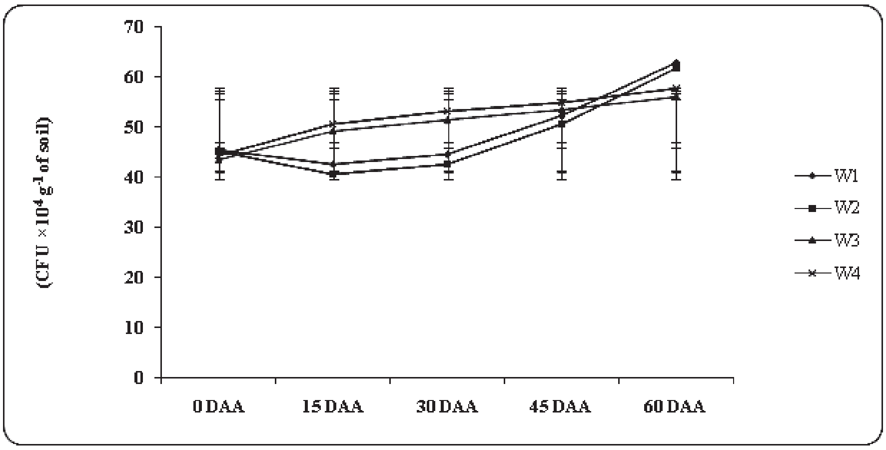

Fig. 2: Influence of pre-emergent herbicides on fungi population

Note: W_1= Pendimethalin @ 0.75 kg ha^{-1}, W_2= Oxyfluorfen @ 0.03 kg ha^{-1}, W_3= Farmer practices at 20 DAS, W_4= Weedy check, DAA= Days after application

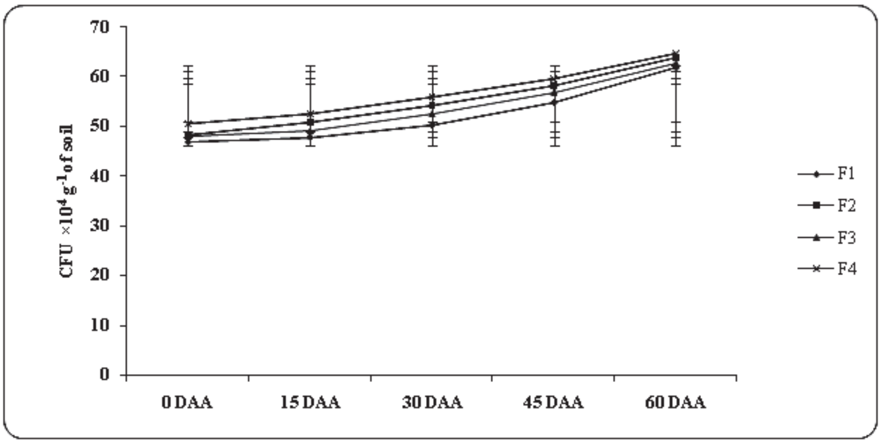

Fig. 3: Effect of nutrient management on total bacteria population

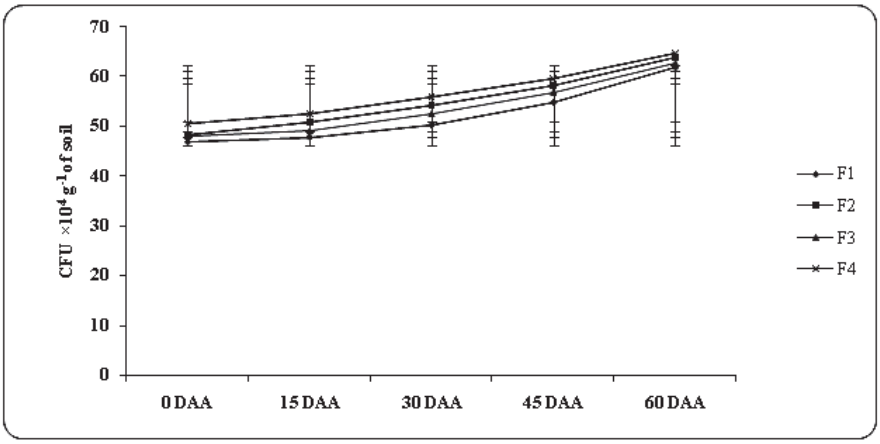

Fig. 4: Fungal population as influenced by nutrient management practices

Note: F_1= recommended dose of fertilizer (RDF), F_2= RDF+FYM 5 t ha^{-1}, F_3= RDF+ 0.2 Lime requirement (LR), F_4= RDF+FYM 5 t ha^{-1}+ Lime 0.2 LR, DAA= Days after application

degree of sensitivity to the herbicide compounds at different sampling dates (exposure periods).

The total bacterial population development in soil was affected significantly after application of pendimethalin and oxyfluorfen (Fig.1). After the application of herbicides the bacterial populations were sharply decreased at 15 DAA as compared to the observation before spraying. However, oxyfluorfen caused the maximum suppression through growth inhibition of the bacterial colony development at faster rate (15 DAA) than pendimethalin. But after 15 DAA, the population increased significantly in the treated plots as compared to control plots. This might be due to utilization of the herbicides including their degraded fractions by microorganism to derive energy, carbon and other nutrients for their growth and metabolism in soil. Similar observations were also reported by Chen *et al.* (2015) and Jeevan *et al.* (2016). The decrease in the population of total bacteria was due to competitive influence and the toxic effect as well as different persistence periods of different chemical herbicides in soil ecosystems. On the other hand, the increase may be due to recovery of microbial population after initial inhibition and microbial adaptation to these chemicals or their degradation. It can also be due to microbial multiplication on increased supply of nutrients available in form of microorganisms killed by herbicides or due to the proto-cooperative influence of various microorganisms on total bacteria in the rhizosphere of maize + cowpea. For all the cases of herbicidal treatments, total bacteria recovered from initial loss and exceeded the initial counts. Ghosh *et al.*, 2012 also reported similar results.

The inhibition of fungal colony development by the herbicides relative to the control (without herbicide treatment) was shown in (Fig. 2). The population of fungi decreased at 15 DAA as compared to the observation before spraying of herbicidal treatments and then it recovered at later stages. This might be due to the toxic effect of the chemicals applied or competitive influence of various microorganisms on the population of fungi in the rhizosphere of maize + cowpea. Sapundjieva *et al*. (2008) reported similar findings. After 30 DAA, the population again significantly increased in all the treatments because the chemicals were degraded at that time and no toxic effect in the soil remained after the persistence period of the applied herbicides. But in case of farmers' practices and un-weeded control, it showed slow and steady increase in fungi population. Pendimethalin @ 0.75 kg ha^{-1} and oxyfluorfen @ 0.03 kg ha^{-1} could be considered as only moderately toxic to the fungal colony development, causing moderate inhibition of 15.61 and 19.96 per cent respectively. The fungal colonies therefore, showed their ability to recover from the toxic effect by 15 DAA and at 30 DAA, no further inhibition or full colony recovery was observed. Bera and Ghosh (2013) 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 most severe immediately after application when their concentrations in soil are the highest. Later on, microorganisms take part in a degradation process of herbicide concentration and its toxic effect gradually decline up to half-life. Then the degraded organic herbicides provide carbon rich substrates which in turn maximize the microbial population in the rhizosphere.

Maximum population of total bacteria and fungi count was noted under RDF+ FYM+LR and RDF +FYM (Fig. 3, 4). The recommended dose of fertilizer alone (RDF) resulted in lower values of microbial populations than in combination with organic manure. The increase in microbial population with the combined application of inorganic fertilizers and organic manure might be due to stimulated growth and activities of soil microorganism with more carbon addition and changes in physico-chemical properties of soil. Similar result was reported by Kumar *et al.* (2014).

The application of recommended dose of inorganic fertilizer and manures along with lime and RDF + FYM if adopted properly, can lead to many-fold improvement of microbial population of bacterial and fungal of soil used for growth of maize + cowpea intercropped on acidic soil and thus application of oxyfluorfen @ 0.03 kg $ha^{-1}$and pendimethalin @ 0.75 kg ha^{-1} to soil cause transient impacts on microbial population growth.

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