Journal of Crop and Weed 8(1): 129-132 (2012)

Effect of herbicides on microbial biomass in relation to availability of plant nutrients in soil

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Received: 28.06.2011, Revised: 25.04.2012, Accepted : 25.05.2012

ABSTRACT

An experiment was conducted under laboratory conditions to investigate the effect of three herbicides, viz., fenoxaprop, pendimethalin and paraquat either separately or in a combination of two, at their field application rates (50 g, 1.0 kg and 1.0 kg a.i. ha^{-1}, respectively) on the changes of microbial biomass carbon, nitrogen and phosphorus as well as transformations of plant nutrients in an alluvial soil collected from Cooch Behar, West Bengal. Application of herbicides significantly increased the microbial biomass carbon, nitrogen and phosphorus which resulted greater availability of plant nutrients in soil. The microbial biomass carbon was highly induced due to the combined application of the herbicides followed by single application of fenoxaprop and paraquat. Pendimethalin alone recorded maximum stimulation to the microbial biomass nitrogen while microbial biomass phosphorus was highly induced under the combined application of fenoxaprop and paraquat followed by single application of paraquat. The highest retention of organic carbon was recorded with pendimethalin when applied alone or in a combination with fenoxaprop while paraquat in combination with fenoxaprop and pendimethalin retained more amount of total nitrogen. The stimulation of available nitrogen (exch. NH_4^+ and soluble NO_3^-) was highest under the combined application of fenoxaprop and pendimethalin followed by the single application of fenoxaprop. In case of availability of phosphorus in soil, the stimulation was highest with the single application of paraquat followed by the combined application fenoxaprop and pendimethalin.

Key words: Herbicides, microbial biomass, plant nutrients, soil

Soil is the repository of all types of chemical inputs including the herbicides. During the application of herbicides, a large portion of these chemicals accumulates in the top layer soil (0-15 cm) where most of the microbiological activities occur (Das and Kole, 2006). Microorganisms degrade a variety of carbonaceous substances including the accumulated herbicides in soil to derive their energy and other nutrients for their cellular metabolism (Das *et al.*, 2003). As a result, amount of microbial biomass increases which favorably influences the transformations of plant nutrients in soil (Das *et al.*, 2003). Reports are also available (Selvamani and Sankaran 1993; El-Ghamry *et al.*, 2001) on the deleterious effect of herbicides on growth and activities of microorganisms in soil. Moreover, the interaction between the herbicides and microorganisms vary depending upon the type of herbicides and microorganisms (Nongthombam *et al.*, 2008). The present study was conducted to investigate the effect of three widely used herbicides *viz.*, fenoxaprop, pendimethalin and paraquat, either alone or in a combination, at their field application rates (50 g, 1.0 kg and 1.0 kg a.i. ha^{-1}, respectively) on the changes of microbial biomass carbon, nitrogen and phosphorus as well as transformations and availability of some plant nutrients in soil.

MATERIALS AND METHODS

For the experiment, an alluvial soil (*Typic orchraqualf*) possessing physic-chemical properties sand 45.6%, silt 43.4%, clay 11%, sandy loam in texture, density 1.01 g cm^{-1}, water holding capacity 55%, pH (1:2.5 w/v) in water 5.2, EC 0.17 dSm^{-1}, CEC 11.3 cmol (p$^+$) kg^{-1}, organic C 4.1 g kg^{-1}, total N 0.61 g kg^{-1}, total P 0.547 g kg^{-1}, exch NH_4^+ 98.3 mg kg^{-1}, soluble NO_3^- 45.4 mg kg^{-1}and $NaHCO_3$ extractable P 33 mg kg^{-1}, was collected from Cooch Behar, West Bengal by taking several thin slices from the surface soil layer (0-15 cm) by means of a spade as outlined by Jackson (1973). The composite soils were air dried up to 20% moisture content (Pepper *et al.*, 2009) in shade and passed through 2mm (4-8 mesh cm^{-1}) sieve. The processed soils were stored in screw-cap jars and were used for the experiment. Three herbicides *viz.*, fenoxaprop (9% EC), pendimethalin (30% EC) and paraquat (25% EC) at rates of 50 g, 1.0 kg and 1.0 kg a.i. ha^{-1}, respectively, were mixed thoroughly either separately or in a combination of two, with 1.0 kg air-dried and sieved soil (2mm) and were placed in polyethylene pots. The water content of the soil was adjusted to 60% of water holding capacity of the soil and maintained throughout the experiment.To avoid photodegradation of the herbicides and evaporation loss of water from the soil, the pots were kept covered with black polyethylene sheet and were incubated in dark at 30 ± 1°C for 60 days. All the treatments were replicated three times. Soil moisture content was measured at each sampling date from the subsamples.

Soil samples were collected after 75 days of incubation from the replicated pots of each treatment. The subsamples were immediately analyzed to determine microbial biomass C, N and P through fumigation following the standard methods (Jenkinson and Powlson 1978; Brookes *et al.*, 1982; Shen *et al.*, 1984). Soil samples were analyzed to estimate the changes of organic C through Walkley

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and Black method (Nelson and Sommers, 1996), total N through wet oxidation procedure (Kjeldahl method) (Bremner, 1996) and total P by digesting with perchloric acid and quantified colorimetrically following vanadomolybdophosphoric acid method (Kuo, 1996). Available N was measured using 2*N* potassium chloride through distillation technique (Mulvaney, 1996). Water soluble P in soil was extracted in $NaHCO_3$ (Jackson, 1973) and quantified colorimetrically following the method of Olsen and Dean (1982).

RESULTS AND DISCUSSION

Application of herbicides at their field application rates significantly stimulated the activities of microorganisms in soil resulting in greater accumulation of microbial biomass and available plant nutrients in soil (Fig. 1,2 and 3). This pointed out that the active soil microorganisms utilized the herbicides as well as their degraded products for their growth and metabolism. Similar observations were also recorded earlier (Cork and Krueger, 1991; Debnath *et al.*, 2002). It was also revealed that microbial biomass carbon and nitrogen were increased significantly in the herbicides treated soils as compared to control (Fig. 1) and the increment of biomass carbon was maximum under the combined application of the herbicides followed by single application of fenoxaprop and paraquat while the highest response for microbial biomass nitrogen was recorded with the single application pendimethalin. Similar trend was also recorded for the stimulation of microbial biomass phosphorus in soil (Fig. 1) and the highest stimulation was recorded with the combined application of fenoxaprop and paraquat followed by single application of paraquat.

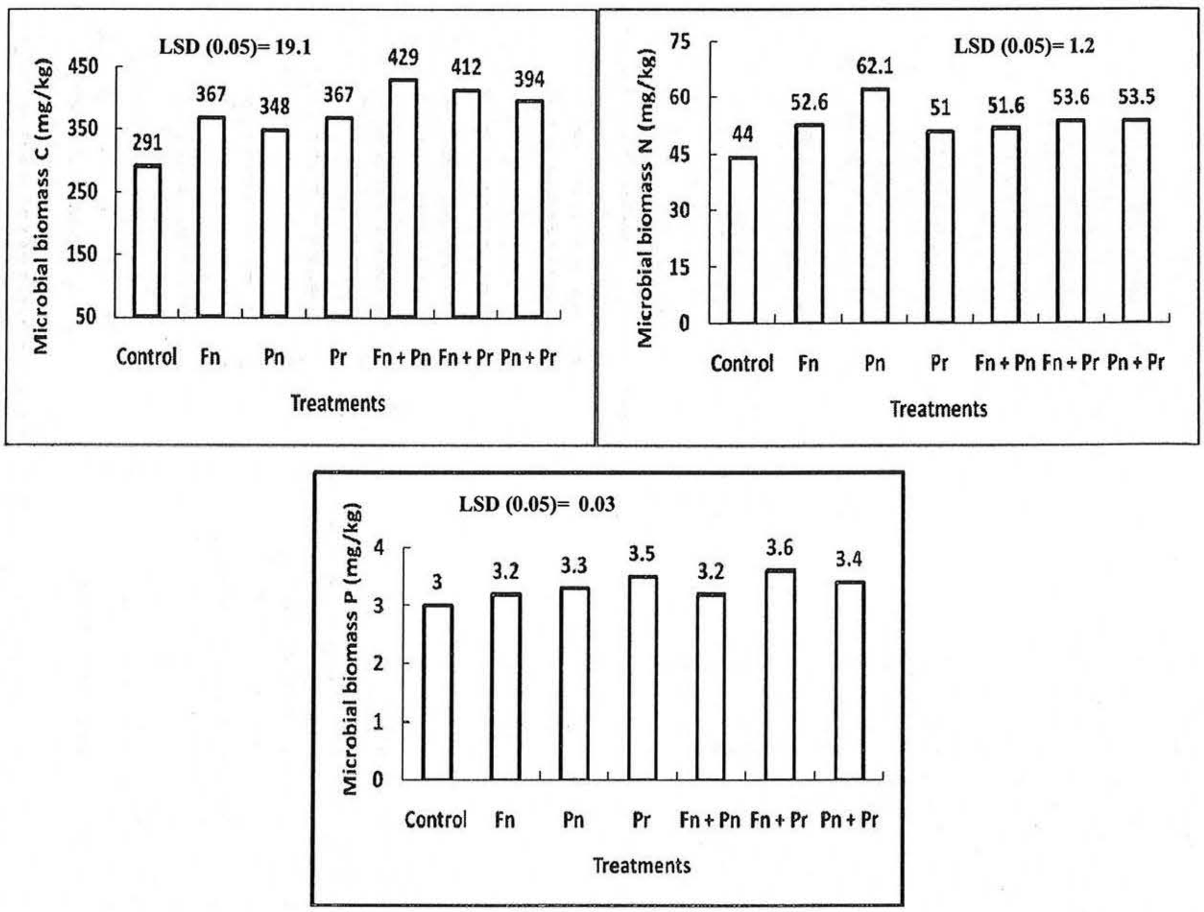

Fig. 1: Effect of herbicides on microbial biomass carbon, nitrogen and phosphorus after 75 days of incubation in soil. Treatments: Control (untreated); Fn, fenoxaprop; Pn, pendimethalin; Pr, paraquat

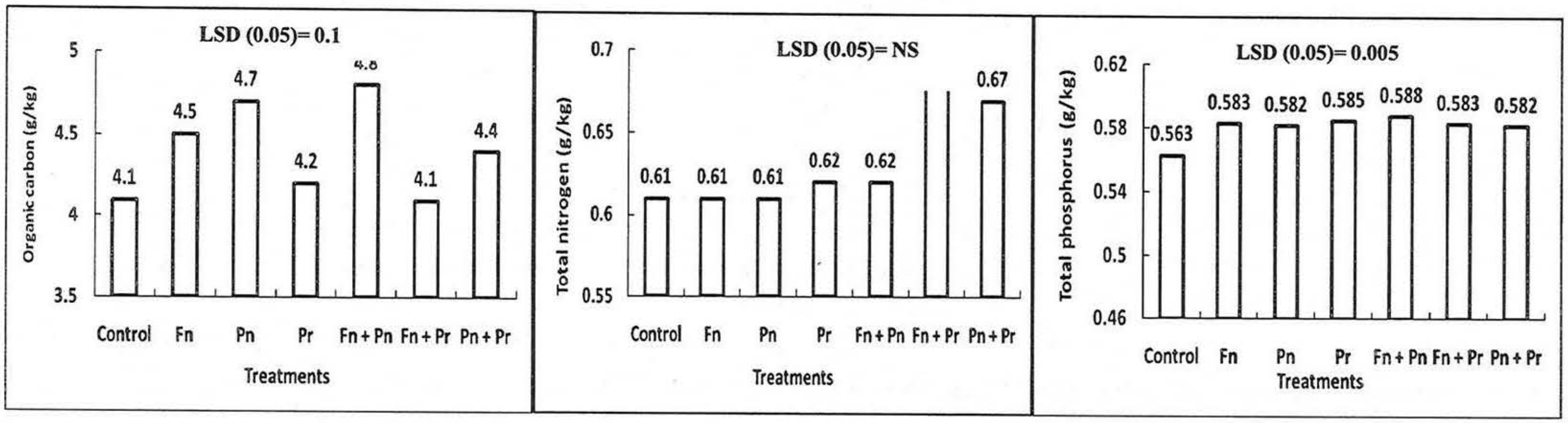

Fig. 2: Effect of herbicides on the changes of carbon, nitrogen and phosphorus after 75 days of incubation in soil

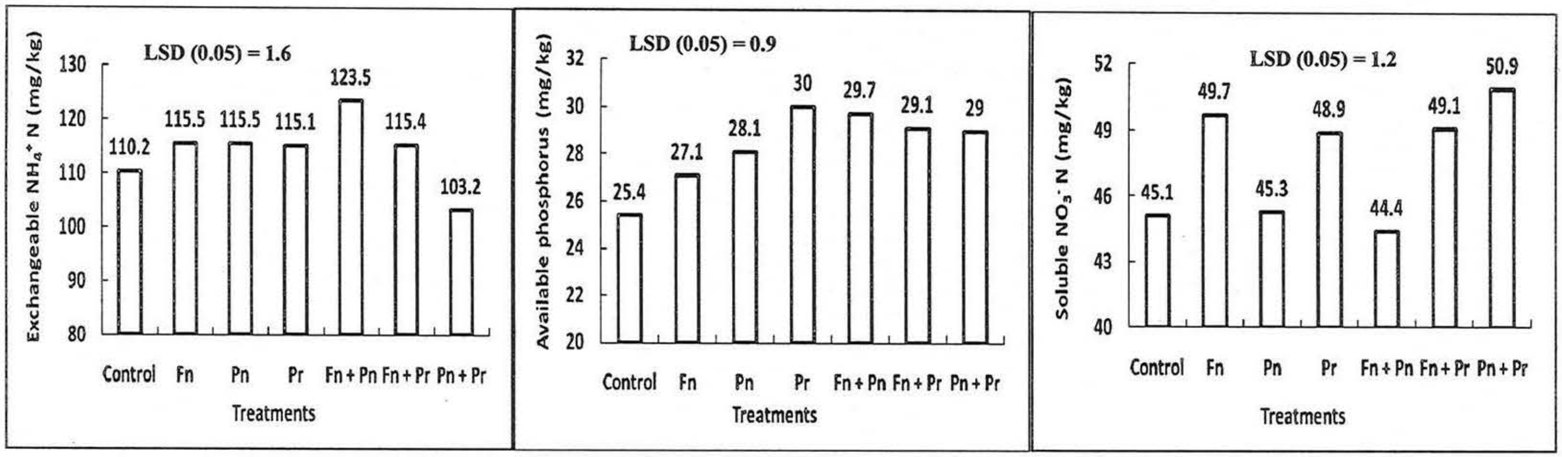

Fig. 3: Effect of herbicides on the changes of available nitrogen and phosphorus after 75 days of incubation in soil Treatments: Control (untreated); Fn, fenoxaprop; Pn, pendimethalin; Pr, paraquat

Sustaining the earlier report (Nongthombam, *et al.*, 2008), the enhanced microbial activities due to application of herbicides stimulated the availability of plant nutrients in soil (Fig. 2 and 3). The highest retention of organic carbon was recorded with pendimethalin when applied alone or in a combination with fenoxaprop (Fig. 2). The similar response was also recorded with the herbicides treatments for the changes in total nitrogen in soil. It was revealed that the combined application of the herbicides retained more amount of total nitrogen as compared to their single application. Among the treatments, the highest response was recorded with paraquat when it was applied with fenoxaprop and pendimethalin. The available nitrogen (exch. NH_4^+ and soluble NO_3^-) content of the soil was highest under the combined application of fenoxaprop and pendimethalin followed by the single application of fenoxaprop (Fig. 3). In case of availability of phosphorus in soil, the stimulation was highest with the single application of paraquat followed by the combined application fenoxaprop and pendimethalin. In general, the combined application of the herbicides released more amount of available phosphorus as compared to their single application.

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