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Microbiological properties of soil influenced by weed control methods in maize-pea cropping system under mid hill conditions of Himachal Pradesh

Rajinder Kumar, Dinesh Badiyala, Neelam Sharma, S.S. Rana and Pawan Pathania
Department of Agronomy, Forages and Grassland Management
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur - 176 062, India.
Corresponding author:rajinderkumar226@gmail.com

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Abstract

The present investigation was undertaken in an ongoing experiment on maize-pea cropping system to study the effect of weed control methods on population of soil beneficial bacteria such as Azotobacter, Phosphate solublising microorganisms, basal soil respiration and microbial biomass carbon after the harvest of maize crop over a period of three years from 2010 to 2012. In maize, there were five weed control treatments viz. weedy check; mechanical weedings; atrazine 0.75 kg/ha pre-emergence; atrazine 1.5 kg/ha pre-emergence; atrazine 0.75 kg/ha fb. 2,4-D 0.5 kg/ha) and in pea there were four treatments viz, weedy check; mechanical weeding; pendimethalin 1.0/1.25 kg/ha pre- emergence; pedimethalin 0.75 kg/ha fb mechanical weeding. Weed control treatments in maize resulted in significant variation in the count of Azotobacter and phosphate solublizing microorganisms. Population of Azotobacter was significantly higher under pre-emergence application of atrazine 1.50 kg/ha (14.93x10^4 cfu/g dry soil), mechanical weeding (14.46x10^4 cfu/g dry soil), and atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha (13.70x10^4 cfu/g dry soil) over atrazine 1.0 kg/ha fb hand weeding. Atrazine 1.50 kg/ha and atrazine 1.0 kg/ha fb. 2,4-D resulted in significantly higher count of phosphate solublizing microorganisms over mechanical weeding. Weed control in maize also did not show any significant influence in soil pH, soil organic carbon, microbial biomass carbon and basal soil respiration. Weed control treatment in pea gave significant variation in count of Azotobacter, phosphate solublising microorganisms, basal soil respiration and microbial biomass carbon. Population of Azotobacter was highest under mechanical weeding. Pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding had lower population than mechanical weeding. The population of phosphate solublizing microorganisms was significantly higher under pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding over mechanical weeding alone. Weed control treatments applied in pea did not significantly influence the count of Azospirillum, pH, and organic carbon after the harvest of maize. Pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding had higher microbial biomass carbon over mechanical weeding alone. Pendimethalin had significant decrease in soil respiration after the harvest of maize which is an important indicator of soil biological health.

Key words: Azotobacter, maize-pea cropping system, microbiological properties, weed control methods.

Soil, an important component of the ecosystem, serves as a medium for plant growth through the activity of microbial communities. These soil microbial communities play critical role in litter decomposition and nutrient cycling, which in turn, affect soil fertility and plant growth. A healthy population of soil microorganisms can stabilize the ecological system in soil (Chauhan *et al.* 2006) due to their ability to regenerate nutrients to support plant growth. Any change in their population and activity may affect the cycling and availability of nutrients which indirectly affect productivity and other soil functions (Wang *et al.* 2008). In modern day agriculture, herbicides have a tremendous role in controlling weeds. A judicious and cautious herbicides use helps in sustaining the productivity at higher level while their indiscriminate use leads to serious ecological imbalance. It is important to have knowledge of behavior of herbicides in the soil to avoid soil pollution and their side effect on soil micro-organisms. Microcosms containing soil microfauna of field communities offer higher resolution of ecotoxicological effects of chemicals in soil environments and can provide better understanding of possible response of soil microbes to herbicides. In general, a lot of information is available concerning the influence of herbicides on soil micro flora and fauna in a variety of ecosystems. But information concerning the impact of herbicide applications on soil microbiological properties under maize-pea cropping system in western

Himalaya is required. Therefore, an attempt has been made to assess the effect of herbicidal weed management on some of soil microbiological properties in maize-pea cropping system under mid hill conditions of Himachal Pradesh.

Materials and Methods

The present investigation was carried out in an ongoing experiment on weed control in maize-pea cropping sequence at Palampur during three consecutive years of 2010, 2011 and 2012. The soil of the experimental field classified as Alfisols was silty clay loam in texture, acidic in reaction, medium in organic carbon, available N and P and high in available K. Fifteen treatment combinations constituting of five weed control treatments (viz. weedy check; mechanical weeding 20 and 40 DAS; pre-emergence application of atrazine 1.0 kg/ha fb. mechanical weeding; pre-emergence application of atrazine 1.5 kg/ha; atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha) in maize and four treatments (viz., weedy check; mechanical weeding (30 and 60 DAS); pre- emergence application of pendimethalin 1.2 kg/ha; pre-emergence application of pedimethalin 0.75 kg/ha fb mechanical weeding) in pea were tested in split plot design with three replications. During *kharif*, weed control treatments in maize were assigned to main plot and during *rabi* treatments in pea were allotted to sub plots.

Soil samples (0-15cm depth) were collected after the harvest of maize. Population of *Azotobacter* and phosphate solubilising microorganisms was enumerated by plate count technique of Wollum (1982) through serial dilution using Jensen agar and pikovskyas media, respectively (Fig.1). The population of *Azospirillum* was estimated by most probable number (MPN) technique by using nitrogen free malate semi solid medium. The total count of the microorganisms was obtained by multiplying the number of cells per plate by the dilution factor, which was the reciprocal of the dilution. Microbial biomass carbon was determined by using fumigation extraction method of Vance *et al.* (1987). The basal soil respiration was determined based on CO_2 released from the incubated soil as per the method of Alef (1995). The yields were harvested from net plot.

Results and Discussion

Effect of weed control treatments applied in maize

Weed control treatments brought about significant variation in the population of Azotobacter after the harvest of maize during year 2010 and 2012 (Table 1). This may be due to the level of weed control leading to a soil conditions favourable or unfavourable under a particular treatment. On pooled data basis the population of Azotobacter was significantly higher under pre-emergence application of atrazine 1.50 kg/ha (14.93 x 10^4 cfu/gdry soil), mechanical weeding (14.46 x 10^4 cfu/g dry soil), weedy check (14.45 x 10^4 cfu/g dry soil), and atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha (13.70 x 10^4 cfu/g dry soil) over atrazine 1.0 kg/ha fb hand weeding. Ramesh and Nadanassababady (2005) showed no negative impact of atrazine on soil microbial population including soil fungi, bacteria and actinomycetes in rainfed maize field. However, Ayansina and Oso (2006) reported decrease in microbial counts due to higher concentration of atrazine. Similarly Piskorz (1998) and Konstantinovic et al. (1999) reported decrease in Azotobacter population due to atrazine. The negative effect of atrazine on beneficial rhizosphere microorganisms has also been observed by Majid and Mazharuddin (2014).

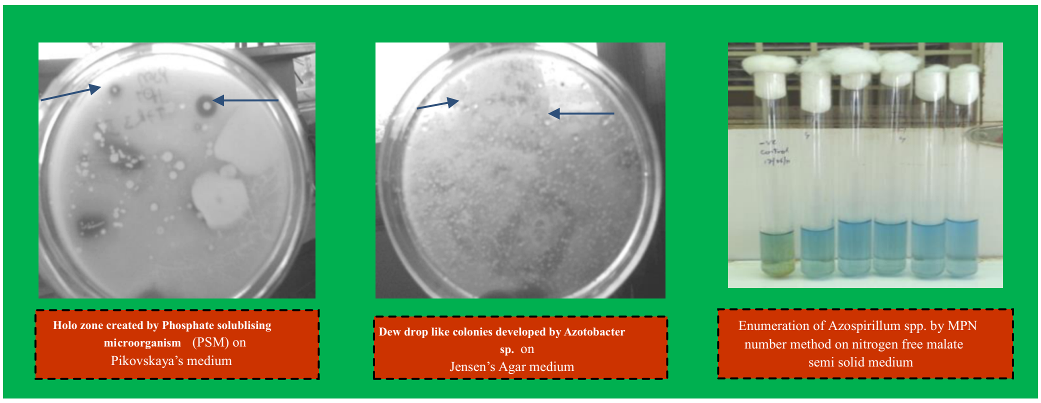

Fig 1. Growth of phosphate solublising bacteria, Azotobacter and Azospirillum bacteria

Weed control treatments in maize gave significant variation in the count of phosphate solublizing microorganisms after the harvest of maize during 2011 and 2012. On pooled basis, atrazine 1.50 kg/ha and atrazine 1.0 kg/ha fb. 2,4-D resulted in significantly higher count of phosphate solublizing micro-organisms over mechanical weeding. However, atrazine fb hand weeding was comparable to atrazine 1.50 kg/ha and atrazine fb 2,4-D in influencing the population of phosphate solublizing micro-organims. Kunc *et al.* (1985) observed rise in microbial count in the atrazine treated soil due to use of herbicide as a energy source.

Though there was large difference in the population of the Azosprillum under the treatments but differences were not significant. Ramesh and Nadanassababady (2005) reported similar results. Weed control in maize also did not significantly influence soil pH, soil organic carbon, microbial biomass carbon and basal soil respiration (Table 2). It was reported that herbicide application to soil causes transient impacts on microbial population growth (Adhikary *et al* .2014) only after 15 days after application. No inhibition was reported 15 days after application until harvest of the crop. Microbial adaptation to herbicides or their degradation (Latha and Gopal 2010) may be the reasons these soil properties remained unaffected under different weed control treatments in maize. Deshmukh and Srikande (1974) reported similar findings.

Weed control treatments applied in maize resulted in significant variation in grain yield of maize during all the three years and the combined of the three years. The effective control of weeds under herbicidal and mechanical weeding resulted in significantly higher yield over weedy check. Several researchers reported improvement in yield of maize with effective control of weeds (Rana *et al.* 1998; Kumar *et al.* 2011; 2012). However, weed control treatments in maize were comparable in influencing the pooled maize grain yield. Weeds in weedy check reduced the grain yield of maize by 38.5%. Weed control treatments in maize also had significant influence on green pod yield during all the years of experimentation. All weed control treatments in maize were significantly superior to weedy check in influencing green pod pea yield. Being a legume requiring aeration in the rhizosphere, mechanical weeding had higher green pea yield. This was followed by atrazine 1.50 kg/ha. Weeds reduced green pea yield by 33.4% over mechanical weeding in maize.

Effect of weed control treatments applied in pea

Weed control treatments applied in pea resulted in significant variation in the count of Azotobacter after harvest of maize during 2010 and 2011 and the combined count of all the three years (Table 1). Population of Azotobacter was highest under mechanical weeding. Pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding had lower population than mechanical weeding but were comparable to weedy check. Oyeleke *et al.* (2011) also reported lower microbial count at higher rate of pendimethalin. The population of phosphate solublizing microorganisms was significantly higher under pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding over mechanical weeding alone. Sathiyavani *et al.* (2015) and Adhikary *et al.* (2014) reported similar findings. Weed control treatments applied in pea did not significantly influence the count of Azospirillum, pH, and organic carbon (Table 2.) after the harvest of maize. However, pooled microbial biomass carbon and basal soil respiration were significantly varied under weed control treatments. Pendimethalin 1.20 kg/ha and pendimethalin 0.75 kg/ha fb mechanical weeding had higher microbial biomass carbon over mechanical weeding alone. However, application of pendimethalin had significant decrease in soil respiration after the harvest of maize which is an important indicator of soil biological health (Shetty and Magu 1997).

Weed control methods in pea brought about significant variation in maize grain and green pea yield in all the three reporting years and the mean of the three years (Table 3). All treatments were significantly superior to weedy check in increasing the maize grain and pea green pod yield. Increase in pea yield with herbicidal treatments has been reported by several workers (Chadha *et al.* 2004; Rana et al. 2013; Mawalia *et al.* 2016). All weed control treatments were statistically at par with each other in influencing maize grain yield. However, pendimethalin fb mechanical weeding and mechanical weeding alone remaining at par gave significantly higher green pea yield over pendimethalin 1.20 kg/ha. Weeds in weedy check reduced maize grain and pea pod yield by 13.7 and 45.6% respectively, over pendimethalin fb mechanical weeding.

Conclusion

The application of atrazine helped in increasing the population of Azotobacter, Phosphate solublising microorganisms and Azospirillum while pendimethalin caused detrimental effect on Azotobacter and Azospirillum population.. The present investigation agreed with the study of Domsch and Grams (1983), that the general rise in microbial counts could be due to the fact that the microorganisms benefits from the transformation of the herbicide, since in the process of decomposition of the

Table 1. Effect of treatments on beneficial soil microbe population in maize-pea cropping system

Treatment	Azotobacter ($\times 10^4$ cfu/g dry soil)				Phosphate Solublising microorganisms ($\times 10^4$ cfu/g dry soil)				Azospirillum ($\times 10^4$ MPN/g dry soil)			
	2010	2011	2012	Pooled	2010	2011	2012	Pooled	2010	2011	2012	Pooled
Weed control methods in maize												
Weedy check	8.11	26.5	8.74	14.45	8.57	3.75	8.39	6.90	32.2	52.9	32.5	39.2
Mechanical weeding	7.61	27.8	7.97	14.46	7.19	4.22	8.03	6.48	31.6	36.2	34.1	33.96
Atrazine 1.0 kg/ha fb. HW	6.06	21.2	6.29	11.18	8.68	2.89	9.33	6.96	25.2	62.8	34.8	40.93
Atrazine 1.5 kg/ha	6.89	30.3	7.61	14.93	9.49	4.84	8.92	7.75	24.2	47.5	31.1	34.27
Atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha	9.05	23.2	8.86	13.70	9.65	3.39	10.0	7.68	23.1	43.7	28.5	31.76
CD (P=0.05)	1.29	NS	1.41	1.4	NS	1.11	1.06	1.06	NS	NS	NS	NS
Weed control methods in pea												
Weedy check	7.91	23.8	7.88	13.2	8.66	3.26	8.59	6.84	30.1	49.3	37.3	38.9
Mechanical weeding	6.67	36.2	7.30	16.7	7.83	3.74	8.06	6.54	33.5	57.9	32.9	41.43
Pendimethalin 1.2 kg/ha	7.53	21.2	7.87	12.2	9.07	4.19	9.54	7.60	23.7	48.0	42.8	38.17
Pendimethalin 0.75 kg/ha fb. mechanical weeding	8.07-	22.0	8.53	12.9	9.33	4.08	9.57	7.66	21.7	46.3	33.5	33.83
CD (P=0.05)	1.04	2.5	NS	1.7	NS	1.97	0.8	0.88	NS	NS	NS	NS

Table 2. Effect of herbicides on physico - chemical properties of soil in maize-pea cropping system

Treatment	pH				Organic carbon				Microbial Biomass Carbon				Basal soil respiration			
	2010	2011	2012	Mean	2010	2011	2012	Mean	2010	2011	2012	Mean	2010	2011	2012	Mean
Weed control methods in maize																
Weedy check	5.15	5.26	5.16	5.19	1.22	1.20	1.15	1.19	923.7	738.5	722.8	795.0	0.495	0.61	0.748	0.62
Mechanical weeding	5.29	5.26	5.19	5.25	1.21	1.19	1.18	1.19	776.1	1293.1	672.7	914.0	0.385	0.52	0.445	0.45
Atrazine 1.0 kg/ha fb. HW	5.16	5.25	5.17	5.19	1.14	1.13	1.15	1.14	898.2	852.6	740.4	830.4	0.343	0.71	0.703	0.59
Atrazine 1.5 kg/ha	5.13	5.25	5.22	5.20	1.18	1.20	1.13	1.17	888.6	1108.4	796.4	931.1	0.413	0.72	0.593	0.58
Atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha	5.22	5.27	5.21	5.23	1.2	1.21	1.23	1.21	930.6	1207.9	735.4	958.0	0.651	0.85	0.647	0.53
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed control methods in pea																
Weedy check	5.19	5.19	5.20	5.19	1.26	1.25	1.24	1.25	954.2	914.2	780.4	882.9	0.506	0.506	0.671	0.56
Mechanical weeding	5.19	5.19	5.18	5.19	1.19	1.21	1.15	1.18	825.6	865.4	686.2	792.4	0.506	0.525	0.6	0.54
Pendimethalin 1.2 kg/ha	5.17	5.17	5.21	5.18	1.14	1.24	1.15	1.18	896.7	880.7	743.3	840.3	0.345	0.410	0.589	0.45
Pendimethalin 0.75 kg/ha fb. mechanical weeding	5.19	5.19	5.18	5.19	1.17	1.27	1.14	1.19	873.2	893.2	724.1	830.2	0.473	0.564	0.648	0.56
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.2	NS	NS	NS	0.52

Table 3. Effect of treatments on yield of maize (kg/ha) and pea

Treatment	Maize				Pea			
	2010	2011	2012	Mean	2010	2011	2012	Mean
Weed control methods in maize								
Weedy check	3175	3250	3680	3368	4547	4180	4100	4276
Mechanical weeding	4986	5500	5590	5359	7213	7158	4900	6424
Atrazine 1.0 kg/ha fb. HW	4526	5920	5970	5472	5692	5592	5800	5695
Atrazine 1.5 kg/ha	5087	4890	5300	5092	7474	7326	3400	6067
Atrazine 1.0 kg/ha fb. 2,4-D 0.5 kg/ha	4026	5790	6200	5339	5795	5648	4700	5381
CD (P=0.05)	1303	480	350	705	351	342	370	354
Weed control methods in pea								
Weedy check	3883	4690	4910	4494	3853	3978	3400	3744
Mechanical weeding	4058	5230	5490	4926	7383	7388	5300	6690
Pendimethalin 1.2 kg/ha	4816	5050	5360	5075	4347	4912	4200	4486
Pendimethalin 0.75 kg/ha fb. Mechanical weeding	4683	5310	5630	5208	7598	7645	5400	6881
CD (P=0.05)	604	410	320	440	254	281	280	272

complex nitrogen containing molecules, many genera benefits, as the proteinaceous material provides the organism with both nitrogen and carbon. While the general decline in count agreed with the work of Taiwo and Oso (1997), who suggested that this decline in microbial counts must have been due to the fact that the microbial population that were tolerant of the treated pesticides were susceptible to the products of soil-pesticide interactions which could have possibly been bactericidal or fungicidal. This study has evidently shown that herbicides do have inhibitory effect on soil microbial community, while there was no effect on the yield of the planted crop. The yield was affected largely by the presence of weeds at the critical period of crop-weed competition, their density and duration of competition.

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