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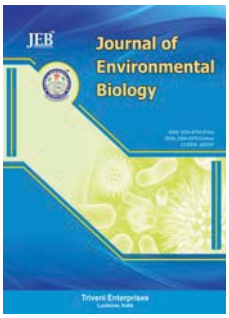

Studies on the effect of day time application of herbicide mesosulfuron-methyl on soil microbial communities of wheat rhizosphere

Authors Info

A. Singh[1]*, M.L. Kewat[1] and S. Sondhia[2]

[1]Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, India

[2]ICAR-Directorate of Weed Research, Jabalpur-482 004, India

*Corresponding Author Email : ashasinghrajpoot@gmail.com

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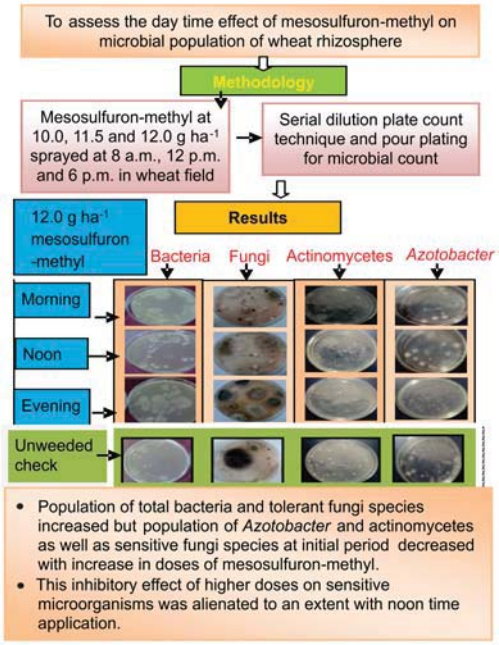
Abstract

Aim : Mesosulfuron-methyl is one of the post emergence sulfonylurea herbicides and biotransformation is major process for its degradation. Persistence of mesosulfuron-methyl in soil mainly depends on temperature and microbial population. When herbicide is applied at different time of a day, it is exposed to different soil environmental factors. This interaction of mesosulfuron-methyl with soil environmental factors may affect microbial population differentially. Hence, the main objective of the study was to find how the day time application of mesosulfuron-methyl at different doses affects the microbial population of wheat rhizosphere.



Methodology : Five weed control treatments, comprising of three doses of mesosulfuron-methyl (10.0, 11.5 and 12.0 g ha^{-1}) including one hand weeding and weedy check as main plot treatments, were superimposed with three day times of herbicide application (8 a.m., 12 p.m. and 6 p.m.) as sub plot treatments and laidout in split plot design with four replications. Soil sample were collected at 5, 10, 30 and 80 days after herbicide application. The developed colonies were counted using serial dilution plate count technique and expressed as colony forming units (cfu) per gram dry soil.

Results : Bacterial population was significantly (14.20 and 16.14%) higher under 12 g ha^{-1} mesosulfuron-methyl application over unweeded check at 10 and 30 days after, respectively. However, competition with dominant bacterial population and toxic effect of herbicide immediately after application inhibited fungal and actinomycete species. But with time, adapted fungal population was increased to 24.77 and 58.13% under 11.5 g ha^{-1}, and 28.77 and 73.40% under12.0 g ha^{-1} application at 30 and 80 days after application, respectively, over 10 days after application. While, the population of actinomycetes and *Azotobactor* was ever less under mesosulfuron-methyl in comparison to non-herbicidal treatments. However, fungal and actinomycetes population survived successfully in case of mesosulfuron application during noon hours even at higher doses due to less residue in soil.

Interpretation : Population of *Azotobactor* and actinomycetes (up to 80 days) as well as fungi (upto 10 days) was affected due to mesosulfuron doses except bacteria. Similarly, fungal and actinomycetes population was affected identically due to morning and evening application of mesosulfuron. On the contrary bacterial and *Azotobactor* population did not vary.

Introduction

Crop protection plays a key role in sustaining the crop productivity against pests like weed, insect, disease and rodents. Among all these pests, weeds cause identical reduction in the productivity of irrigated wheat (Ryan *et al*., 2009; Smith *et al*., 2010). But these days, due to higher labourer wages for manual weeding in wheat, the farmers are relying completely on herbicides as these are cost effective. Mesosulfuron-methyl (Methyl2-[[[[(4,6 dimethoxy-2-pyrimidinyl) amino] carbonyl] amino] sulfonyl] -4- [[(methylsulfonyl) amino] methyl] benzoate) is one of the post emergence sulfonylurea herbicides, which is mainly used for controlling grassy weeds and some broad leaf weeds in wheat by inhibiting acetolactate synthase enzyme (Yuan *et al*., 2013). However, when herbicide is applied to the field, it not only control target weeds, directly or indirectly reaches the soil and later subjected to various processes viz., sorption, degradation and transport from the site of application. It is important to note that the members of this group are highly persistent in soil and even at low concentration cause residual effect on succeeding or rotational crops after winter wheat (Walker and Brown, 1982; Singh *et al*., 2003; Sondhia *et al*., 2013, 2016). However, mesosulfuron-methyl exhibit very high to medium mobility, hence it is highly liable to leach to ground water or reach surface water by runoff and consequently, contaminate both surface and groundwater bodies. Hence, information on fates and behaviour of herbicide is most important aspect for maintaining the sustainable agriculture production system and healthy environment. There are two pathways for breakdown of sulfonylureas, first one is hydrolysis which occurs rapidly under acidic conditions but another is microbially mediated break down in neutral or alkaline soil (Brown and Cotterman, 1994). In general, these herbicides degraded in soil primarily by chemical hydrolysis and then microbial metabolism but some researcher illustrated the relative importance of microbial degradation (Ismail and Lee, 1995; Ye *et al*., 2003). While, the photolysis and volatilization are relatively minor processes for degradation of sulfonylurea group members in soil (Sondhia, 2008). Mesosulfuron-methyl is degraded in soil and water via hydrolysis and O- demethylation reactions and major metabolites (which represent to more than 10% of the applied radioactivity) of its degradation are mesosulfuron acid; 4,6-dimethoxypyrimidine-2-yl-urea; 2-amino-4,6-dimethoxypyrimidine. The all transient intermediate metabolites are also degraded to final products *viz*., non-extractabled residues (59.2%) and CO_2 (32.1%) at day 120 (EFSA, 2016). Since, in case of mesosulfuron, biotransformation is the major pathway of degradation, hence its persistence varies with microbial population and temperature in non-sterile aerobic soil. According to EFSA (2008), with the decrease in temperature from 20^0C to 10^0C, half life of mesosulfuron-methyl increased upto 154 from 49.1 days. Studies of Sebiomo *et al*. (2011) also revealed that some microorganisms are able to degrade herbicide, while others are adversely affected depending on the application rates and type of herbicide used. However, at recommended rate, herbicides have no short or long-term effect on microbial populations (Bollen, 1961). But injudicious use of herbicides to achieve higher weed control efficacy may also have ill effects on public health and environment. Whitcomb (1999) also reported that herbicides which inhibit acetolactate synthase enzyme, affect many species of higher plants as well as bacteria, fungi, yeasts and algae. Since photodegradation, photolysis and volatilization processes are not significant for mesosulfuron-methyl, hence instead of increasing its rate only, change in time of application during day hours (morning, noon and evening) could be taken into consideration so as to enhance activity of mesosulfuron-methyl against weeds even with lower dose. But when it applied at different time of the day, herbicide interact with different climatic factors (air temperature, relative humidity, light intensity, dew and wind velocity), edaphic factors (soil temperature and soil moisture) and plant morphology which are varied throughout the day, may not only have influence on the efficacy of herbicide but also affect the amount of herbicide going in the soil, sorption and rate of degradation. Sondhia *et al*. (2013) and Zain *et al*. (2013) reported that herbicides affect microbial growth, either positively or negatively; depending on chemicals (class and concentration), microbial species and environmental factors such as temperature, moisture and pH etc. Hence, interaction of different doses of mesosulfuron-methyl with day time applications may influence soil microbial population differently. However, information on how day time application of mesosulfuron-methyl at three rates affects the most important groups of soil microorganisms *viz*., bacteria, fungi, actinomycetes and *Azotobactor* in field condition, is not available in literature. Hence, keeping these facts in view, the present study was undertaken to find suitable time of day for mesosulfuron-methyl application and its suitable dose for recommendation, which have less or no adverse effect on microbial communities of wheat rhizosphere soil of Kymore Plateau and Satpura hills zone of Madhya Pradesh.

Materials and Methods

Experimental details : A field experiment was conducted during *Rabi* seasons of 2014-15 and 2015-16 at Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur (M.P.) to assess the effect of day time application of mesosulfuron-methyl on microbial population of wheat rhizosphere. The soil of the experimental field was sandy clay loam in texture, neutral in reaction (pH 7.0), electrical conductivity (0.33dS m^{-1}), medium in organic carbon (0.62%), available N (393 kg ha^{-1}) and available P (17.44 kg ha^{-1}) but high in available K (296 kg ha^{-1}). Fifteen treatments comprising of three doses of mesosulfuron-methyl (10, 11.5 and 12 g ha^{-1}) including one hand weeding (30 DAS) and unweeded check as main plot treatments and were superimposed with three day times of herbicide application (8 a.m., 12 p.m. and 6 p.m.) as sub plot treatments and laid out in a split plot design with four replications. Wheat variety GW 273 was sown in the experimental field with recommended package of practices. Half of nitrogen (60 kg ha^{-1}) and full quantity of P_2O_5 (60 kg ha^{-1}) and K_2O (40 kg h^{-1}) was applied as basal through urea, single super phosphate and muriate of potash. The remaining quantity of nitrogen was applied

in the two splits (30 and 55 DAS). The herbicide was sprayed as post emergence using a spray volume of 500 l ha^{-1} with a knapsack sprayer fitted with flat fan nozzle.

Enumeration of microorganisms : Soil sample were collected from 0-15 cm surface soil from all the plots at 5, 10, 30 and 80 days after herbicide application during both the years. The soil samples were soaked into 90 ml deionized water @ 10 g, later this mixture was shaken for 10 min and kept for 5 min. Thereafter, 1 ml of the supernatant was diluted twice and incubated in diluted water at constant temperature of 30^0C. All samples were performed in triplicate, and were used for enumeration of microorganisms. The viable microbial counts were analyzed by standard technique of serial dilution and pour plating. Enumeration of bacteria and fungi was carried out in soil extract by Nutrient Agar medium (James, 1958) and Rose Bengal Agar medium (Parkinson *et al*., 1971) respectively. Kenknight's Agar medium (Wellingtonn and Toth, 1963) and Ashbys Mannitol Agar medium (Rao, 1977) were used for enumeration of actinomycetes and *Azotobactor*, respectively. After allowing for development of discrete microbial colonies during incubations period of 48 hrs for bacteria, 48–72 hrs for fungi, 7 days for actinomycetes and 5 days for *Azotobacter*, the colonies were counted and the number of viable bacteria, fungi actinomycetes and *Azotobactor* [expressed as colony forming units (cfu)] per gram dry weight of soil was estimated by taking into account soil dilutions.

Statistical analysis : The data obtained on microbial counts were tabulated and subjected to statistical analysis as per method of analysis of variance appropriate for split plot design as suggested by Snedecor and Cochron (1967). The influence of treatment was tested with F test values significant over the tabulated value, the differences between the treatments were further compared with critical difference at 5% level of probability.

Results and Discussion

It is evident from the data given in Table 1 that total bacterial population was minimum at 5 days after its application, which increased correspondingly with time being maximum at 80 days after its application under all the treatments, irrespective of doses of mesosulfuron-methyl and day time applications, suggesting that wheat rhizosphere is beneficial for the growth and reproduction of bacteria regardless of mesosulfuron-methyl doses and its application time. Similar view has been endorsed by Tamilarasi *et al*. (2008). The bacterial population at 5 days after application did not differ significantly in plots receiving mesosulfuron-methyl at different doses and was same to that of hand weeded and weedy check plots. But, at 10 and 30 days after its application numerically higher population was recorded when it was applied at highest dose (12 g ha^{-1}) in comparison to lower doses (10.0 and 11.5 g ha^{-1}). However, bacterial population was 1.47 and 3.32% higher at 30 days after application under lowest dose (10 g ha^{-1}) in comparison to hand weeding, which was further increased with corresponding increase in its dose of application being maximum (13.33 and 21.71%) in plots receiving mesosulfuron-methyl at highest dose (12 g ha^{-1}) during 2014-15 and 2015-16, respectively. It may be attributed that bacteria relies on this herbicide as a source of nutrients and energy. Henceforth, the bacterial population was maximum under mesosulfuron-methyl at highest dose (12 g ha^{-1}). Ratcliff *et al*. (2006) also did not observe any change in microbial abundance in soil treated with glyphosate dose of 50 mg kg^{-1}, but microbial counts increased in response to a 100-fold increase in herbicide dose. While at 80 days after application, the population was normalized and was almost in same range under all the treatments during 2014-15, but it was numerically higher in weedy check plots (26.67 X 10^6 cfu g^{-1}) closely followed by hand weeding as compared to mesosulfuron-methyl application even at lowest dose (24.00 X 10^6 cfu g^{-1}) due to higher root biomass as well as more surface of

Table1 : Effect of day time application of mesosulfuron-methyl on bacterial population (X 10^6 cfu g^{-1})

Treatment	Exposure time (Days after application)							
	2014-15				2015-16			
	5	10	30	80	5	10	30	80
Main plot (Herbicide dose)								
Mesosulfuron-methyl 10 g ha^{-1}	17.17	18.67	22.83	23.33	23.67	25.00	26.17	23.00
Mesosulfuron-methyl 11.5 g ha^{-1}	17.00	21.17	23.83	23.83	23.00	27.33	28.67	24.67
Mesosulfuron-methyl 12 g ha^{-1}	17.00	22.50	25.50	23.67	22.00	28.50	30.83	23.83
Hand weeding (30 DAS)	18.17	20.17	22.50	23.00	24.83	25.17	25.33	26.00
Unweeded check	18.00	18.33	22.67	23.17	24.67	25.33	25.83	26.67
LSD (P=0.05)	NS	0.80	1.87	NS	NS	2.04	2.67	NS
Sub-plot (day time of spray)								
Morning (8 a.m.)	17.60	20.20	23.30	23.60	23.50	26.70	27.70	25.00
Noon (12 p.m.)	17.50	20.30	23.40	23.60	23.70	25.80	27.20	25.20
Evening (6 p.m.)	17.30	20.00	23.50	23.00	23.40	26.30	27.20	23.70
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2 : Effect of day time application of mesosulfuron-methyl on fungal population (X 10^4 cfu g^{-1})

Treatment	Exposure time (Days after application)							
	2014-15				2015-16			
	5	10	30	80	5	10	30	80
Main plot (Herbicide dose)								
Mesosulfuron-methyl 10 g ha^{-1}	17.67	17.33	20.83	22.67	23.00	22.33	25.67	31.17
Mesosulfuron-methyl 11.5 g ha^{-1}	15.33	16.50	21.33	25.67	22.17	22.50	27.33	37.00
Mesosulfuron-methyl 12 g ha^{-1}	15.00	16.83	22.17	27.50	21.00	22.00	27.83	39.83
Hand weeding (30 DAS)	18.00	18.50	20.67	20.83	23.33	23.83	22.33	28.17
Unweeded check	18.33	18.83	20.83	22.00	24.33	24.00	21.50	27.50
LSD (P=0.05)	NS	NS	NS	3.09	NS	NS	2.35	3.87
Sub-plot (day time of spray)								
Morning (8 a.m.)	17.10	17.90	22.20	24.10	22.40	23.00	24.40	33.10
Noon (12 p.m.)	17.80	18.50	20.50	23.60	23.80	23.30	25.80	33.00
Evening (6 p.m.)	16.00	16.30	20.80	23.50	22.10	22.50	24.60	32.10
LSD (P=0.05)	1.14	1.93	NS	NS	1.23	NS	NS	NS

Table 3 : Effect of day time application of mesosulfuron-methyl on actinomycetes population (X 10^4 cfu g^{-1})

Treatment	Exposure time (Days after application)							
	2014-15				2015-16			
	5	10	30	80	5	10	30	80
Main plot (Herbicide dose)								
Mesosulfuron-methyl 10 g ha^{-1}	24.17	26.17	33.33	39.83	33.33	34.00	36.33	36.83
Mesosulfuron-methyl 11.5 g ha^{-1}	23.67	24.67	33.00	38.00	31.33	32.00	36.33	35.67
Mesosulfuron-methyl 12 g ha^{-1}	22.00	21.00	32.17	35.83	30.83	31.50	36.00	35.83
Hand weeding (30 DAS)	24.83	26.00	35.33	40.83	39.00	39.33	40.00	46.83
Unweeded check	24.50	27.17	36.50	41.17	42.00	42.00	42.83	55.33
LSD (P=0.05)	NS	2.48	2.64	3.26	6.84	6.62	4.36	7.78
Sub-plot (day time of spray)								
Morning (8 a.m.)	23.70	24.90	34.50	39.40	35.40	35.70	38.60	42.30
Noon (12 p.m.)	24.40	26.60	35.60	39.60	35.70	36.20	40.80	42.70
Evening (6 p.m.)	23.40	23.50	32.10	38.40	34.80	35.40	37.00	40.90
LSD (P=0.05)	NS	1.85	1.24	NS	NS	NS	2.12	NS

soil is covered with plant material of wheat and weeds in case of weedy plots. This helps in maintaining the soil temperature and soil moisture even when air temperature rises upto 41.5 ^{0}C during 2015-16 (Fig.1), which are more favourable for microbial growth in comparison to high soil temperature and over dried soil (Lovieno and Baath, 2008). While, day time application of mesosulfuron-methyl had no marked influence on the bacterial population during both the years, however, 80 days after application highest counts were found under mesosulfuron application during noon time.

The fungal population was significantly influenced by mesosulfuron-methyl doses at later period both the years of experimentation (Table 2). The fungi population at 5 and 10 days after application was numerically higher when mesosulfuron-methyl was applied at lowest dose (10 g ha^{-1}) but it decreased with the increase in doses of mesosulfuron-methyl being the minimum when it was applied at highest dose (12 g ha^{-1}) during both the years 2014-15 and 2015-16. Whereas population was maximum under weedy check closely followed by hand weeding. But reverse was true at 30 and 80 days after application in case of mesosulfuron-methyl applied at highest and lower doses, as mesosulfuron-methyl 12 g ha^{-1} registered maximum fungal counts during both years. This is attributed to moderately toxic effect on fungi during early period but colonies recovered from toxic effect at 30 days after application. Studies of Sondhia *et al*. (2013) also indicated that at 0 day (2 hours after application), the concentration of pyrazosulfuron-ethyl was high, as it was not utilized by fungi immediately after application but fungal growth was increased with time and

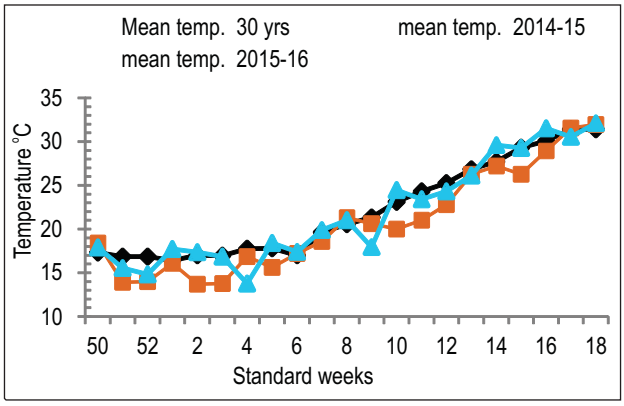


Fig.1 : Mean temperature during Rabi season 2014-15 and 2015-16

utilized pyrazosulfuron-ethyl successively. While at 30 days after application, degree of change in fungal counts was increased as the dose of herbicide increased during the both years. And fungal colony at 80 days after application was 7.59 and 13.35% higher with 10 g ha^{-1}, whereas it was 12.14 and 34.55% in plots receiving mesosulfuron-methyl at 11.5 g ha^{-1} being 25.00 and 44.88% higher under highest dose (12 g ha^{-1}) over unweeded check during 2014-15 and 2015-16, respectively. These results showed that fungi are well adapted to mesosulfuron-methyl. Similar results have been reported by Ahtiainen *et al*. (2003). A stimulatory effect of increased dose of herbicides on fungal counts was observed by several workers *viz*., Sondhia *et al*. (2016) on penoxsulam at a dose of 25 g ha^{-1}, Crouzet *et al*. (2010) on mesotrione applied to soil at 0.45 to 45 mg kg^{-1} and Zabaloy *et al*. (2010) on 2,4-dichlorophenoxyacetate applied in soil at 1 to 10 mg kg^{-1}. While in case of day time applications, fungal population was significantly higher when mesosulfuron applied during noon at 5 and 10 days after application (17.60 X 10^4 and 18.50 X 10^4 cfu g^{-1}) during first year and on 5th days (23.30 X 10^4 cfu g^{-1}) during second year of experimentation in comparison to morning and evening time application. Suggesting that noon time application of mesosulfuron-methyl did not have inhibitory effect on fungal population upto 10 and 5 days after application during first and second year, respectively. European Food Safety Authority (2008 and 2016) reported that temperature and microbial activity are major factors affecting the mesosulfuron-methyl degradation. However, the microbial activity is not started immediately after application of herbicide, then temperature becomes a major factor for its degradation. Henceforth, higher air temperature (20 and 22.6^{0}C during 2014-15 and 2015-16, respectively) during noon time application caused faster degradation and left relatively lower residues of mesosulfuron-methyl in soil. As a consequence, the fungal population was higher during noon time application in comparison to morning as well as evening time application where air temperature was comparatively lower (ranges 9.6 to 18.6 ^{0}C), which caused more accumulation of residues in soil and finally reduced the fungal population identically. However, day time application of mesosulfuron-methyl did not cause significant variation on the fungal population at 30 and 80 days after application during both the years.

Actinomycetes population was significantly influenced by doses of mesosulfuron-methyl at 10, 30 and 80 days after application during 2014-15 and at all the time periods during 2015-16 in wheat rhizosphere (Table 3). During first year, actinomycetes population steadily increased with time when mesosulfuron-methyl was applied at lower doses (10.0 and 11.5 g ha^{-1}) but increase was not identical in case of highest dose (12 g ha^{-1}). However, actinomycetes population at 5 days after application was statistically same under different doses of

Table 4 : Effect of day time application of mesosulfuron-methyl on *Azotobactor* population (X 10^4 cfu g^{-1})

Treatment	Exposure time (Days after application)							
	2014-15				2015-16			
	5	10	30	80	5	10	30	80
Main plot (Herbicide dose)								
Mesosulfuron-methyl 10 g ha^{-1}	10.33	11.00	12.00	10.33	10.67	13.00	18.33	13.00
Mesosulfuron-methyl 11.5 g ha^{-1}	10.17	10.67	12.33	8.83	10.33	13.00	18.17	12.50
Mesosulfuron-methyl 12 g ha^{-1}	10.00	10.50	12.33	7.50	9.67	10.67	17.33	9.00
Hand weeding (30 DAS)	10.33	12.33	14.00	12.83	12.00	14.33	25.00	23.83
Unweeded check	10.33	12.50	15.83	13.83	13.50	17.33	26.17	25.17
LSD (P=0.05)	NS	NS	NS	2.25	NS	NS	3.80	6.33
Sub-plot (day time of spray)								
Morning (8 a.m.)	10.20	11.10	13.30	10.70	10.90	13.30	20.90	16.10
Noon (12 p.m.)	10.30	11.40	13.20	11.00	11.40	13.80	21.50	18.80
Evening (6 p.m.)	10.20	11.70	13.40	10.30	11.40	13.90	20.60	17.00
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

mesosulfuron-methyl to that of non herbicidal treatments. While at 10, 30 and 80 days after application, actinomycetes population was identically decreased with corresponding increase in mesosulfuron-methyl doses and had 22.70, 11.86 and 12.97 %, respectively, lower population under highest dose in comparison to non herbicidal treatments *viz*., unweeded check, on account of stimulatory effect of rhizosphere on actinomycetes under non chemical environment. While, the effect of mesosulfuron-methyl on actinomycetes population was more pronounced during second year of experimentation and it differed significantly under different treatments at various time period. During 2015-16, the population of actinomycetes was minimum under12 g ha^{-1} mesosulfuron-methyl application as it had 26.60, 25.00, 15.95 and 35.24% lower population at 5, 10, 30 and 80 days after application, respectively, in comparison to weedy check which had maximum population followed by hand weeded plots at all time periods. However, the significant difference did not exist among herbicidal treatments. These effects attributed to better growth and development of actinomycetes under latter treatments on account of higher root biomass under non herbicidal environment, whereas reverse was true in case of herbicidal treatments. Sebiomo *et al*. (2011) reported maximum population of actinomycetes in control soil samples compared to herbicidal treated soil samples. While the effect of day time application of mesosulfuron-methyl on actinomycetes was noticeable at 10 and 30 days after application during 2014-15 and at 30 days after application during 2015-16. Among the day time applications, actinomycetes population was significantly higher at noon application over evening time, being statistically at par to morning time application. This may be due to less inhibitory effect of herbicide, on account of rapid degradation of mesosulfuron-methyl under relatively higher temperature when it was applied during noon hrs as well as there is less chances of runoff of herbicide due to absence of dew (Stewart *et al*., 2009), especially during winter season. However, day time application of mesosulfuron-methyl did not cause significant variation on the actinomycetes population 80 days after application during both the years because considerable amount of herbicide degraded as the time passes under the all day time applications upto 80 days.

The influence of mesosulfuron-methyl on *Azotobactor* is shown in Table 4. Unweeded check recorded highest population of *Azotobactor* over the all doses of mesosulfuron-methyl application being at par to hand weeding at all stages. It is clear that with the herbicide application, there was numerically same population of *Azotobactor* under all the treatments at 5 and 10 days after application, but gradually increased upto 30 days after application. This may be attributed to more reproduction of *Azotobactor* due to increased root biomass regardless of mesosulfuron-methyl application. However, 80 days after application the population was significantly 25.31 and 48.31% reduced when mesosulfuron-methyl was applied at 10 g ha^{-1}, 36.15 and 50.34% with 11.5 g ha^{-1} and maximum reduction (45.77 and 64.24%) was occurred at 12 g ha^{-1} during both years 2014-15 and 2015-16, respectively, over weedy check which had more population of *Azotobactor*. This decline in Azotobactor population at later period was in line with the result of He *et al*. (2006) and Lone *et al*. (2014). Such a negative response of *Azotobacter* population could be attributed to competition between dominant population of fungi and actinomycetes at 80 days after application when large portion of mesosulfuron-methyl was degraded by bacteria and this lead to active growth of initial sensitive species of fungi and actinomycetes. However, day time application of mesosulfuron-methyl had no significant effect on *Azotobacter* population.

It is concluded that mesosulfuron-methyl application between 10.0 to 11.5 g ha^{-1} during noon hours is safe as it had a little inhibitory effect on bacteria, *Azotobacter* including fungal and actinomycetes population of wheat rhizosphere, which are responsible for nitrogen mineralization, nitrogen fixation and biotransformation of organic matter in soil.

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References

Ahtiainen, J.H., P. Vanhala and A. Myllymaki: Effects of different plant protection programs on soil microbes. *Ecotox. Environ. Safe*., **54**, 56-64 (2003).

Bollen, W.B.: Interaction between pesticides and soil microorganisms. *Annu. Rev. Microbiol*., **15**,69-92 (1961).

Brown, H.M. and J.C. Cotterman: Recent advances in sulfonylurea herbicides. *Chem. Plant Prot*., **10**, 47-81 (1994).

Crouzet, O., I. Batisson, P. Besse-Hoggan, F. Bonnemoy, C. Bardot, F. Poly, J. Bohatier and C. Mallet: Response of soil microbial communities to the herbicidemesotrione: A dose–effect microcosmapproach. *Soil Biol. Biochem*., **42**,193–202 (2010).

EFSA (European Food Safety Authority): Opinion on a request from EFSA related to the default Q10 value used to describe the temperature effect on transformation rates of pesticides in soil. *EFSA J*., **6**,1,622,32 (2008).

EFSA (European Food Safety Authority): Peer review of the pesticide risk assessment of the active substance mesosulfuron (variant evaluated mesosulfuron-methyl). *EFSA J*., **14**,10,4584 (2016).

He, Y.H., D.S. Shen, C.R. Fang, R. He and Y.M. Zhu: Effects of metsulfuron-methyl on the microbial population and enzyme activities in wheat rhizosphere soil. *J. Environ. Sci. Heth. B*., **41**,3,269-84 (2006).

Ismail, B.S. and H.J. Lee: Persistence of metsulfuron-methyl in two soils. *J. Environ. Sci. Hlth*., **30**,485–497 (1995).

James, N.: Soil extract in soil microbiology. Can. *J. Microbiol*., **4**,363-370 (1958).

Lone, A.H., K.P. Raverkar and N. Pareek : *In-vitro* effects of herbicides on soil microbial communities. *Bioscan*, **9**, 11-16 (2014).

Lovieno, P. and E. Baath: Effect of drying and rewetting on bacterial growth rates in soil. *FEMS Microbiol Ecol*., **65**, 3,400-7 (2008).

Parkinson, D., T.R.G. Gray and S.T. Williams: Methods for studying

ecology of soil microorganisms. IBP Hand Book 19, Blackwells Science Publication Limited, Oxford (1971).

Rao, S.: Soil Microorganisms and Plant Growth. Oxford and IHB Publishing Co., India (1977).

Ratcliff, A.W., M.D. Busse and C.J. Shestak: Changes in microbial community structure following herbicide (glyphosate) addition to forest soils. *Appl. Soil Ecol*., **34**,114–124 (2006).

Ryan, M.R., R.G. Smith and D.A. Mortensen: Weed crop competition relationships differ between organic and conventional cropping systems. *Weed Res*., **49**,572-580 (2009).

Sebiomo, A., V.W. Ogundero and S.A. Bankole: Effect of four herbicides on microbial population, soil organic matter and dehydrogenase activity. *Afr. J. Biotechnol*., **10**, 770-778 (2011).

Singh, G., V.P. Singh and M. Singh: Studies on the effect of mesosulfuron and iodosulfuron on weeds in wheat, their compatibility with other chemicals and residual effects on succeeding crops. *Indian J. Agron*., **35**,173- 178 (2003).

Smith, R.G., D.A. Mortensen and M.R. Ryan: A new hypothesis for the functional role of diversity in mediating resource pools and weed-crop competition in agro-ecosystems. *Weed Res*., **50**,37-48 (2010).

Snedecor, G.W. and W.G. Cochram: Statistical Methods. Oxford and IBH Publication, 6th Edn., pp.325-330 (1967).

Sondhia, S., S. Rajpoot and R.K. Varma: Biodegradation of the herbicide penoxsulam (triazolopyrimidine sulphonamide) by fungal strains of *Aspergillus* in soil. *Appl. Soil Ecol*., **105**,196-206 (2016).

Sondhia, S., U. Waseem and R.K. Varma: Fungal degradation of an acetolactate synthase (ALS) inhibitor pyrazosulfuron-ethyl in soil. *Chemosphere*, **93**,2140-2147 (2013).

Sondhia, S.: Persistence of metsulfuron-methyl in wheat crop and soil. *Environ. Monit. Assess*., **147**,463–469 (2008).

Stewart, C.L., R.E. Nurse and P.H. Sikkema: Time of day impacts post emergence weed control in corn. *Weed Tech*., **23**,3,346-355 (2009).

Tamilarasi, S., K. Nanthakumar, K. Karthikeyan and P. Lakshmanaperumalsamy : Diversity of root associated microorganisms of selected medicinal plants and influence of rhizomicroorganisms on the antimicrobial property of *Coriandrum sativum. J. Env. Biol*., **29**,1,127-134 (2008).

Walker, A. and P.A. Brown: Crop response to low doses of pendimethalin, napropamide, metazachlor and chlorsulfuron in soil. In: Proceedings of British Crop Protection Conference on Weeds, pp.141-147 (1982).

Wellingtonn, E.M.H. and I.K. Toth : Microbiology and biochemical properties. University of Warwick (1963).

Whitcomb, C.E.: An introduction to ALS-inhibiting herbicides. *Toxicol. Ind. Hlth*., **15**,1-2 (1999).

Ye, Q., J. Sun and J. Wu: Causes of phytotoxicity of metsulfuron-methyl bound residues in soil. *Environ Pollut*., **126**,417–423 (2003).

Yuan, X., P. Guo, X. Qi, N. Ning, H. Wang, H. Wang, X. Wang and Y. Yang: Safety of herbicide Sigma Broad on *Radix isatidis* (*Isatis indigotica* Fort.) seedlings and their photosynthetic physiological responses. *Pestic. Biochem. Physiol*., **106**,45-50 (2013).

Zabaloy, M.C., J.L. Garland and M.A. Gomey: Assessment of the impact of 2,4-dichlorophenoxyacetic acid (2,4-D) on indigenous herbicide degrading bacteria and microbial community function in an agricultural soil. *Appl. Soil Ecol*., **46**,240–246 (2010).

Zain, N.M.M., R.B. Mohamad, K. Sijam, M.M. Morshed and Y. Awang: Effects of selected herbicides on soil microbial populations in oil palm plantation of Malaysia: A microcosm experiment. *Afr. J. Microbiol. Res*., **7**, 367-374 (2013).