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Effect of Different Temperature Regimes on Persistence of Imazethapyr and Trifluralin

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ABSTRACT

Temperature is one of the main factors of crop production and it influences herbicide persistence by affecting different herbicide degradation reactions in the soil. To study the persistence of trifluralin and imazethapyr affected by different temperature regimes, an experiment was carried out under lab and screen house conditions at CCSHAU, Hisar. Bioassay technique was used to quantify the persistence by employing sensitive plants of oat and mustard for trifluralin and imazethapyr bioassay, respectively. Soil treated with these herbicides at different rates (trifluralin 0.0, 0.125, 0.25, 0.5, 1.0 and 2.0 kg/ha and imazethapyr 0, 10, 20, 40, 80 and 160 g/ha) after incubation at 15, 25, 35 and 45^{O}C temperature regimes in incubator. Persistence of herbicides affected by different temperature regimes at different herbicide rates was measured by comparing shoot and root growth, fresh and dry weight with control treatment, at different intervals. With increase in incubation temperature of different imazethapyr rates; all growth parameters of mustard except germination, increased, indicating that the increased temperature showed decreased persistence of imazethapyr, with minimum persistence between 35 and 45^{O}C. Whereas trifluralin showed minimum persistence at 25^{O}C and maximum at 15^{O}C as revealed by different growth parameters of oat. In both the herbicides, different growth parameters of test plant decreased with increase in herbicide rate at different temperature incubations pointing that there was increased persistence with increased herbicide rates.

Key words : Imazethapyr, trifluralin, temperature, persistence

INTRODUCTION

Imazethapyr an acetolactate synthase (ALS) inhibiting herbicide is used mainly in soybean and other edible legumes for broad spectrum weed control. This herbicide has a great potential of carry over effect to next crop. Though it has a typical half life of 60-90 days under field conditions, but persistence is governed by several factors. This carry over effect is reported to be controlled by soil, climatic and herbicidal properties, but when other factors remain constant, degradation is largely determined by soil temperature and soil moisture content.

Similarly, trifluralin is a soil applied, pre-plant or pre-emergence herbicide. Persistence of trifluralin is also dependent on several factors, including soil moisture, soil temperature, soil type, soil organic carbon content and length of time before incorporation takes place (Probst *et al*., 1967; Horowitz *et al*., 1974; Kennedy and Talbert, 1977; Savage, 1978).

Temperature affects the rate of herbicide degradation by controlling different physical, chemical and microbial reactions in soil which are responsible for degradation. Rate of degradation of trifluralin increased with temperature as it was raised from 10 to 40^{O}C (Horowitz *et al*., 1974). Flint and Witt (1997) found that persistence of imazaquin and imazethapyr herbicides at 15^{O}C was two time longer than persistence at 30^{O}C. Soil low temperature caused high level of imazethapyr residue in soil (Jourdan *et al.*, 1998). Similarly, degradation rate of alachlor increased with increase in temperature (Zimdahl and Clark, 1982). Also, direct correlation was observed between temperature and rate on persistence of pendimethalin and trifluralin at 1.0, 1.5 and 2.0 kg/ha (Pahwa and Bajaj, 1997). Persistence of metsulfuron was less at 35^{O}C as compared to 15 and 25^{O}C (Yadav *et al*., 1997).

Present experiment was designed to study the persistence of imazethapyr and trifluralin under different temperature regimes under pot culture by bioassay method employing mustard and oat plant, respectively.

MATERIALS AND METHODS

All bioassay studies were carried out in plastic pots (20 cm diameter). The soil used for experiment

was sandy loam (Sand=63.1%, silt=18% and clay=18.9%). Chemical analysis showed that soil used was low in carbon (0.41%), deficient in available N (102 kg/ha) and P (6 kg/ha) and sufficient in K (252 kg/ha). Soil reaction was recorded near neutral and towards alkaline.

Imazethapyr (Pursuit 10% SL**)** at 0, 10, 20, 40, 80 and 160 g/ha, and trifluralin (Treflan 48 EC**)** at 0, 0.125, 0.25, 0.5, 1.0 and 2.0 kg/ha rates were tested. In both the herbicides, rate taken was four times of the higher rate of the experiment i.e. for imazethapyr 160 x 4=640 g/ha, and for trifluralin 2.00 x 4= 8.00 kg/ha for serial dilutions so that appropriate amount of soil could be incubated to temperature conditions. Based on the capacity of pot and the requirement of soil for experiment, amount of soil taken for each temperature treatment worked out to be 8.0 kg.

The two lots (each for imazethapyr and trifluralin) of soil weighing 8 kg each were mixed with 1.6 litre (quantity of water equal to field capacity) containing calculated amount of each herbicide as given above. Treated soil with both the herbicides was incubated at temperatures 15, 25, 35 and 45^{O}C separately for 30 days. After 30 days the soils were taken out from the incubator and shifted in the deep freezer maintained at -5^{O}C to -10^{O}C to arrest all the reactions responsible for herbicide degradation.

At the start of **rabi** season, treated soil samples kept in the deep freezer were taken out and were serially diluted with soil having soil : sand : vermicompost : 3 : 1 : 1 to get the desired concentration of the herbicides. Twenty seeds of mustard and oat, test plant for imazethapyr and trifluralin, were planted in each pot, replicated four times. Irrigation was given according to evapotranspiration demand to avoid leaching of herbicides. Observations were recorded for each test plant for shoot/root growth and fresh/dry weight at seven weeks after sowing (WAS). For measurement of root length, each pot was saturated with water and then plant was rooted out gently under running tap with mild water pressure by ensuring no damage to root system. Fresh weight per pot of rooted plant was taken immediately and the plants of each pot were put in paper bags for recording of dry weight. The paper bags were first sun dried and then dried in oven at 70^{O}C for about 72 h till constant weight was achieved.

This experiment was asymmetrical factorial which was designed in CRD. Significance of various treatments was tested by using F test. The significant difference among treatments was tested by calculating CD against 5% level of significance. All experimental data were analyzed using software SPSS version 7.5. Arcsine transformation for data per cent and square root transformation for data with zero value were used. Histograms were prepared from analyzed data and curve fitting was done on the basis of "best fit" approach.

RESULTS AND DISCUSSION

Effect of Different Temperature Regimes on Imazethapyr Persistence

Shoot length recorded with imazethapyr incubated at 35, 45 and 25^{O}C was found significant to each other (Fig. 1). At all observation stages, mean shoot growth was minimum in pots with 15^{O}C temperature incubation of imazethapyr. Reduction in shoot growth at 15^{O}C incubation of imazethapyr was 33% compared to 45^{O}C and expressed in the power model [($y = 34.69x^{-1.74}$, $R^2 = 0.962$ for 15^{O}C), ($y = 43.30x^{-1.42}$, $R^2 = 0.988$ for 25^{O}C), ($y = 48.17x^{-1.39}$, $R^2 = 0.971$ for 35^{O}C) and ($y = 52.76x^{-1.45}$, $R^2 = 0.962$ for 45^{O}C)] (Fig. 1). Mustard shoot length was drastically reduced by 61, 78, 85, 91 and 93% over control with increasing imazethapyr rate from 10 to 160 g/ha, respectively, when data averaged over temperature incubation (Fig. 1).

Data regressed in polynomial model [15^{O}C ($y = 2.460x^2 - 22.18x + 46.95$, $R^2 = 0.882$), 25^{O}C ($y = 1.902x^2 - 18.45x + 44.43$, $R^2 = 0.904$), 35^{O}C ($y = 1.936x^2 - 18.49x + 44.91$, $R^2 = 0.925$) and 45^{O}C ($y = 1.912x^2 - 18.28x + 44.93$, $R^2 = 0.934$)] depict increased root length with increased temperature (15 to 45^{O}C) imazethapyr incubations. Significantly different root length was recorded at all the temperature regimes, when data averaged over imazethapyr rates (Fig. 1). Increasing imazethapyr rate caused reduction in root length by 70, 84, 87, 94 and 97% at 10, 20, 40, 80 and 160 kg/ha compared to untreated pots, when data averaged over different temperature incubations (Fig. 1).

Maximum fresh weight was recorded at 45^{O}C imazethapyr incubation which was similar to 35^{O}C but significantly higher than 15 and 25^{O}C incubations of imazethapyr, when data averaged over different imazethapyr rates (Fig. 2). With increase in temperature incubation of imazethapyr, there was increase in fresh weight as regressed by polynomial model [($y = 3.703x^2 - 33.60x + 72.22$, $R^2 = 0.856$ for 15^{O}C), ($y = 2.722x^2 - 27.50x + 69.25$, $R^2 = 0.925$ for 25^{O}C), ($y = 2.714x^2$ -

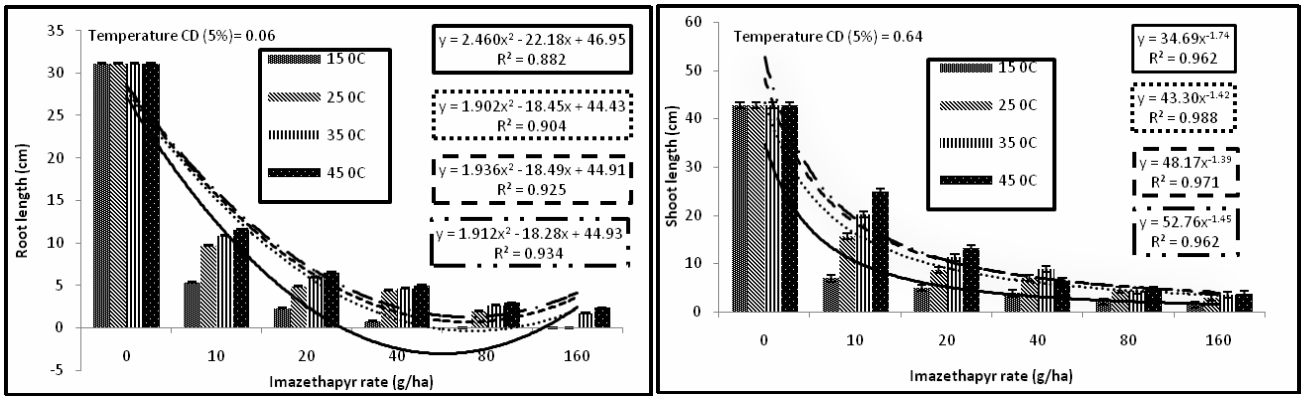

Fig. 1. Effect of imazethapyr incubated at different temperature regimes on shoot and root length (cm) of mustard, 7 WAS.

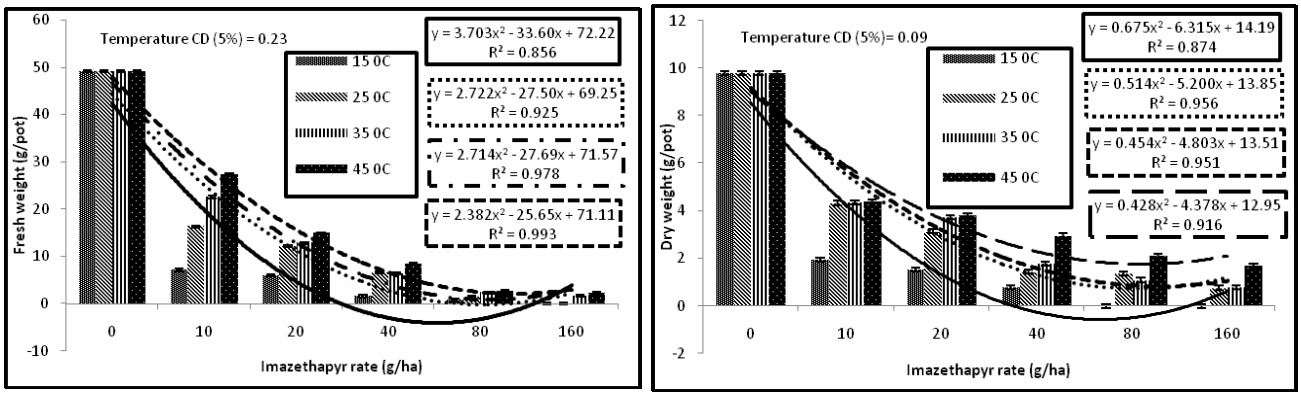

Fig. 2. Effect of imazethapyr incubated at different temperature regimes on fresh and dry weight (g/pot) of mustard, 7 WAS.

27.69x + 71.57, R^2 = 0.978 for 35°C) and (y = 2.382x^2 - 25.65x + 71.11, R^2 = 0.993 for 45°C)]. There was no significant difference in fresh weight at 80 and 160 g/ha imazethapyr but both differed significantly from other treatments, when data were averaged over different temperature incubations (Fig. 2).

Maximum dry weight of mustard was recorded at 45°C incubation of imazethapyr, which was significantly higher than 15, 35 and 25°C, whereas all were non-significant to each other, when data over different imazethapyr rates were averaged (Fig. 2). There was 41, 16 and 13% reduction in dry weight at 15, 25 and 35°C temperature incubations, respectively, compared to 45°C incubation as evident from regression polynomial model [(y = 0.675x^2 - 6.315x + 14.19, R^2 = 0.874 for 15°C), (y = 0.514x^2 - 5.200x + 13.85, R^2 = 0.956 for 25°C), (y = 0.454x^2 - 4.803x + 13.51, R^2 = 0.951 for 35°C) and (y = 0.428x^2 - 4.378x + 12.95, R^2 = 0.916 for 45°C)]. Negative correlation was recorded between increasing imazethapyr rate and dry weight when averaged data over different temperature incubations were taken. Minimum dry matter was recorded with imazethapyr 160 g/ha and showing 92% reduction compared with control (Fig. 2).

Flint and Witt (1997) studied the importance of soil temperature and moisture on degradation of imazethapyr. Half life of imazethapyr in distilled water was 46 h when exposed to light from a xenon arc lamp filtered through borosilicate glass indicating the role of light in the degradation of imazethapyr (Anonymous, 2007). Increased adsorption has been reported in higher organic content and clay soils. Adsorption of imazethapyr increases with soil dryness over the time; however, sorption is reversible. In the present experiment the treated soil was packed in polythene bags and placed in incubator and shade for temperature and moisture incubations, respectively, so role of photo-degradation for imazethapyr bioavailability could be negligible before its evaluation under pot studies. Microbial degradation is the major pathway for imazethapyr, but no degradation occurs under anaerobic conditions (Anonymous, 2007). Similar to this Basham *et al.* (1987) and Cantwell *et al.*

(1989) studied the role of microorganisms in imazaquin and imazethapyr degradation.

All growth parameters of mustard recorded with imazethapyr incubated at different temperatures indicated that increasing temperature incubation of imazethapyr resulted in its enhanced degradation and maximum being at 45^{O}C. This could be attributed to increased activity of microorganism responsible for imazethapyr degradation. Also, there could be increased rate of adsorption of imazethapyr molecule on soil colloids with increase in temperature. Degradation rate of alachlor was increased with increase in temperature (Zimdahl and Clark, 1982). Flint and Witt (1997) also found that persistence of imazaquin and imazethapyr at 15^{O}C was two times longer than persistence at 30^{O}C. Also, pendimethalin showed same pattern of persistence with respective to temperature. Direct correlation was observed between temperature and rate on persistence of pendimethalin and trifluralin (Pahwa and Bajaj, 1997).

Vischetti *et al*. (2002) reported that the half life of imazamox (same group as of imazethapyr) increased as the temperature decreased from 25 to 10^{O}C. Degradation of metsulfuron-methyl by microbial activities increased with increased soil temperature (James *et al*., 1995). Similarly, Yadav *et al*. (1997) concluded that metsulfuron persistence was less at 35^{O}C compared to 15 and 25^{O}C. With increase in temperature from 10 to 40^{O}C, rate of degradation of trifluralin increased (Horowitz *et al*., 1974). Walker (2006) reported that in linuron, half-lives increased with a reduction in temperature from 30° to 5°C.

Effect of Different Temperature Regimes on Trifluralin Persistence

Temperature incubation of different trifluralin rates influenced the shoot length of oat significantly. Maximum shoot length was recorded at 25^{O}C that was significantly different from other temperature incubations, whereas minimum was recorded at 15^{O}C, when data were regressed in logistic model for different temperature incubations [(y = -22.5ln(x) + 55.30, R^2 = 0.922 for 15^{O}C), (y = -18.3ln(x) + 55.36, R^2 = 0.889 for 25^{O}C), (y = -20.5ln(x) + 55.54, R^2 = 0.921for 35^{O}C) and (y = -21.2ln(x) + 55.57, R^2 = 0.927 for 45^{O}C)] (Fig. 3).

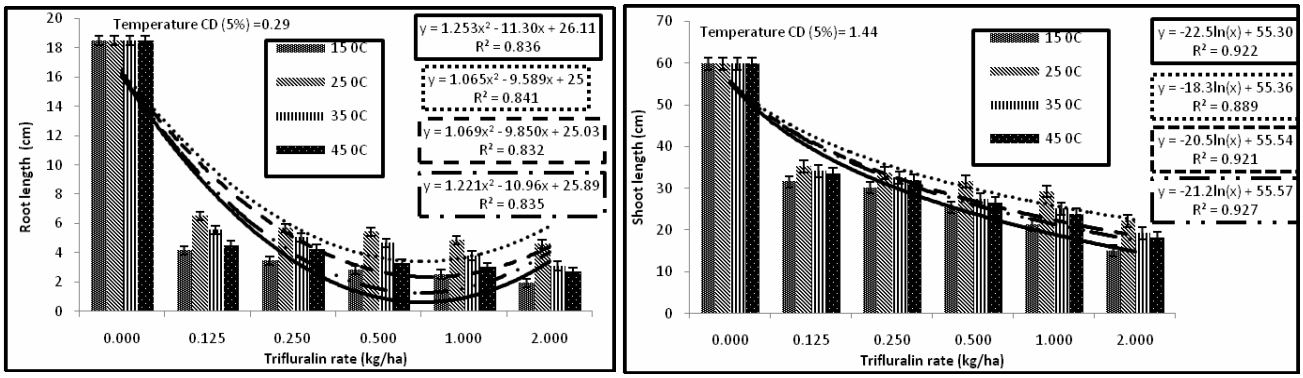

Fig. 3. Effect of trifluralin incubated at different temperature regimes on shoot and root length (cm) of oat, 7 WAS.

Maximum root length was recorded at 25^{O}C which varied significantly with all other temperature incubations when averaged over different trifluralin rates (Fig. 3). There was 27, 21 and 11% reduction in root length at 15, 45 and 35^{O}C, respectively, compared to 25^{O}C. The data on root length were best described by a polynomial regression line showing the effect of trifluralin incubations at different temperatures as [15^{O}C (y = 1.253x^2 - 11.30x + 26.11, R^2 = 0.836), 25^{O}C (y = 1.065x^2 - 9.589x + 25, R^2 = 0.841), 35^{O}C (y = 1.069x^2 - 9.850x + 25.03, R^2 = 0.832) and 45^{O}C (y = 1.221x^2 - 10.96x + 25.89, R^2 = 0.835)].

Fresh weight of oat recorded at 7 WAS exhibited significant reduction by trifluralin incubated at different temperature regimes with maximum fresh weight at 25^{O}C that varied significantly to all other temperature incubations, when data were averaged over rates (Fig. 4). Minimum fresh weight was recorded at 15^{O}C which showed 42% reduction compared to 25^{O}C. Fresh weight recorded at 45^{O}C incubation was non-significant with 35^{O}C but was significantly lower than at 15^{O}C (Fig. 4). Data pertaining to effect of trifluralin incubated at different temperature regimes on fresh weight of oat were regressed by power model [(y = 41.44$x^{-0.63}$, R^2 = 0.939

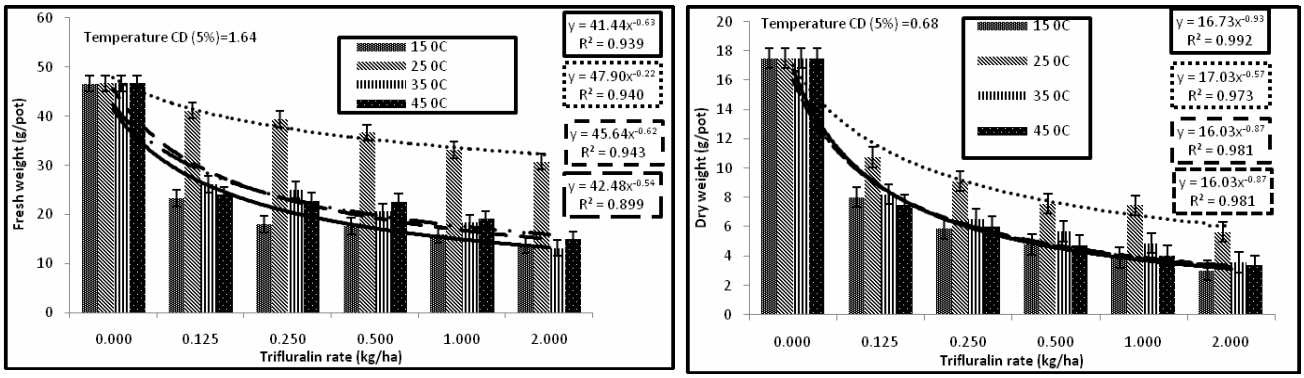

Fig. 4. Effect of trifluralin incubated at different temperature regimes on fresh and dry weight (g/pot) of oat, 7 WAS.

for 15^{O}C), ($y = 47.90x^{-0.22}$, $R^2 = 0.940$ for 25^{O}C), ($y = 45.64x^{-0.62}$, $R^2 = 0.943$ for 35^{O}C) and ($y = 42.48x^{-0.54}$, $R^2 = 0.899$ for 45^{O}C)]. Averaged data over different temperature incubations showed that with increase in trifluralin rate there was significant reduction in the fresh weight except at 0.250 and 0.5 kg/ha which were non-significant to each other.

At different temperature incubations, maximum dry weight was recorded at 25^{O}C, which was significantly higher than 15, 35 and 45^{O}C, whereas the latter was non-significant to each other, contrary to shoot and root length, when data over different trifluralin rates were averaged (Fig. 4). Reduction of 20% in dry weight at 15^{O}C (minimum) compared to 25^{O}C (maximum) was recorded and the trend expressed by regression model (Fig. 4) [($y = 16.73x^{-0.93}$, $R^2 = 0.992$ for 15^{O}C), ($y = 17.03x^{-0.57}$, $R^2 = 0.973$for 25^{O}C), ($y = 16.03x^{-0.87}$, $R^2 = 0.981$ for 35^{O}C) and ($y = 16.03x^{-0.87}$, $R^2 = 0.981$ for 45^{O}C)].

Trifluralin (á, á, á- trifluoro-2,6-dinitro-N, N-dipropyl-*p*-toluidine) a dinitroaniline herbicide, strongly adsorbed to clay and organic colloids (Anonymous, 2007), so leaching losses are negligible. Photodecomposition is major pathway for trifluralin degradation (Grover *et al.*, 1997), but in the present pot experiment, it can be overruled because the herbicide was well mixed with soil under lab conditions, kept away from direct sunlight and was incubated under dark conditions in a deep freezer for moisture and temperature treatments.

Chemical and biological pathways can be responsible for degradation but chemical degradation is not reported, hence microorganisms play the role in degradation (Anonymous, 2007). Soil sterilization of the herbicide treated soil increased persistence compared to unsterilized indicating the role of microorganisms in trifluralin degradation (Pahwa and Bajaj, 1997; Yadav *et al*., 1997). Microbial degradation is rapid under flooded anaerobic than moist aerobic soils (Anonymous, 2007). Under aerobic conditions primarily N-dealkylation, hydroxylation and oxidation is major pathway, whereas under anaerobic conditions, nitro reduction and N-dealkylation.

Wheeler *et al.* (1979) reported that "bound" trifluralin on soil colloids increased with time. Herbicide availability for degradation is determined by relative rate of adsorption and desorption from colloids (Halmaker and Goring, 1976; Anderson, 1981; Morrill *et al*., 1982). Adsorption reactions are reversible and equilibrium reactions, sometimes an adsorption process results in chemical change of adsorbed material. The changes are of such nature that desorption is inhibited and the process is called pseudo-adsorption (Tam, 1998).

So, adsorption from soil solution to soil colloids and biological reactions could be the main pathways for degradation of trifluralin. Non-biological degradation of trifluralin is negligible. Temperature is the main factor influencing adsorption reactions in soils thus, affects the bioavailability of trifluralin. Also these factors control the activity of microorganisms, hence can control the degradation of trifluralin.

Shoot growth of oat recorded at different intervals indicated the effect of temperature on trifluralin persistence. Maximum and minimum shoot growth was recorded at 25 and 15^{O}C, respectively, when data averaged over trifluralin rates indicating minimum trifluralin persistence at 25^{O}C and maximum at 15^{O}C (Fig. 1). Reduction in shoot length at 15, 35 and 45^{O}C compared to 25^{O}C temperature incubations of trifluralin was 14, 6 and 8%, respectively, over 25^{O}C indicating significant role of different temperature incubations on

trifluralin persistence.

At 25°C temperature incubation of trifluralin 2.0 kg/ha, greater shoot length was recorded which was similar to 0.125 and 0.25 kg/ha incubated at 15°C; 0.25, 0.5, 1.0, 2.0 kg/ha incubated at 35°C and 0.125, 0.25, 0.5 and 1.0 kg/ha incubated at 45°C indicating 8-16, 2-16 and 1-8 times greater persistence of trifluralin at 15, 45 and 35°C, respectively, compared to 25°C. At 7 WAS, similar effect of temperature on trifluralin bioavailability was recorded (Fig. 1).

Like shoot growth, root growth was also recorded maximum at 25°C among all temperature incubations of trifluralin suggesting maximum degradation at this temperature, when data were averaged over trifluralin rates, but the effect of temperature incubation on trifluralin degradation was more clearer from root growth of oat (Fig. 2). There was 27, 21 and 11% reduction in root length at 15, 45 and 35°C, respectively, compared to 25°C indicating the effect of temperature incubation on trifluralin persistence. Trifluralin 0.5, 1.0 and 2.0 kg/ha incubated at 15°C recorded maximum inhibition in root growth due to greater persistence of trifluralin followed by 45°C over 25°C and 35°C temperature incubation. This injury was 16, 8-16 and 4-8 times at 15, 45 and 35°C compared to 25°C because statistically similar effect on root length was recorded with trifluralin 2.0 kg/ha incubated at 25°C compared with 0.125 kg/ha incubated at 15°C; 0.125 and 0.25 kg/ha incubated at 45°C and 0.25 and 0.5 kg/ha incubated at 35°C (Fig. 2).

Fresh and dry weight of oat recorded at 7 WAS also supports the results obtained with root and shoot length. Maximum reduction in fresh weight was recorded at 15°C compared to 35 and 45°C at higher trifluralin rates i. e. 0.5, 1.0 and 2.0 kg/ha indicating lower persistence of trifluralin at 35 and 45°C compared to 15°C (Fig. 3). Dry weight recorded with trifluralin 2.0 kg/ha incubated at 25°C showed statistically similar effect with 0.25 and 0.5 kg/ha incubated at 15°C; 0.25, 0.5 and 1.0 kg/ha incubated at 35°C and 0.25, 0.5 and 1.0 kg/ha incubated at 45°C indicating 4-8, 2-8 and 2-8 times more degradation of trifluralin at 15, 45 and 35°C, respectively, compared to 25°C temperature incubations (Fig. 4).

Parameters related to growth of oat in the present study indicted maximum degradation of trifluralin at 25°C and minimum at 15°C. This could be due to optimum temperature (25°C) for microorganisms responsible for trifluralin degradation. Contrarily, Pahwa and Bajaj (1997) using sorghum bioassay reported decreased persistence of trifluralin when incubation temperature was increased from 25 to 35°C, but with an increase in temperature beyond 45°C it decreased. Similarly, rate of degradation of trifluralin increased with increase in temperature from 10 to 40°C (Horowitz *et al*., 1974).

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