Persistence and management of dinitroaniline herbicides residues in sandy loam soil

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Abstract: The addition of organic manure affects the biological, chemical and physical properties of soil that control the fate of herbicides. Three dinitroaniline herbicides were studied to asses their persistence, dissipation and residue management in sandy loam soil with and without addition of farmyard manure (FYM) under middle western Indian agro-climatic conditions. The herbicides, pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine], trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl) benzenamine] and fluchloralin [*N*-(2-chloroethyl)-2,6-dinitro-*N*-propyl-4-(trifluoromethyl)benzenamine], were applied at a rate of 0.5 and 1.0 kg ha^{-1} as a pre-plant incorporation in the field, cropped with Indian mustard (*Brassica juncea* L.). FYM incorporation at a rate of 10 t ha^{-1} decreased herbicide persistence in all the sampling intervals. Relatively lower half-lives of 44.93, 41.81; 41.23, 39.09 and 39.61, 43.00 days, each at the rate of 0.5 and 1.0 kg ha^{-1}, respectively for pendimethalin, trifluralin and fluchloralin were recorded with FYM incorporation. On the other hand, the half-life values in absence of FYM were higher for all three dinitroaniline herbicides used. Dissipation rate of all three dinitroanilines increased progressively with time at both application rates.

Keywords: farmyard manure; FYM; herbicide residues; persistence; dissipation; dinitroaniline; pendimethalin; fluchloralin; trifluralin.

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1 Introduction

Pesticides have been used extensively in many countries. India's consumption of pesticides per hectare, for example, is low when compared with world's average, 0.5 kg ha^{-1}, Korea's 6.6 kg ha^{-1} and Japan's 12.0 kg ha^{-1} (Agnihotri, 2000). Despite the low use of pesticides in India, the contamination of food products is alarming. The reasons lie in non-judicious use of pesticides and inadequate information. Among the various groups of pesticides, the growth rate of consumption of herbicides was higher (24.80%) in the course of the last 20 years in this country. With the rise in cost of labour, herbicides are becoming more and more important in modern agriculture (Hegde et al., 1977). In India, the reduction in yield due to weeds has been roughly estimated as 32–35% in cereals, pulses and oilseeds and consequently various herbicides are becoming more popular day by day (Pandey and Prakash, 2003). The persistence of herbicides in soil is an important factor in their performance as weed killers and in their unintended side effects. The agriculturists need to know about the duration of their phytotoxicity in order to avoid the possibility of damaging succeeding crops (Rao, 1999).

Dinitroaniline herbicides have been extensively used for controlling broadleaf weeds and grasses in agronomic and horticultural crops worldwide (Helling, 1976). All dinitroaniline herbicides in use are 4-alkyl (or sulfonyl)-2,6 dinitro-N-N-(mono-or disubstitued) anilines (Helling, 1976) with orange-yellow coloured compounds, low solubility and basicity (Rao, 1999). The primary mode of action of dinitroanilies is by inhibition of cell mitosis (Rytwo et al., 2005) that inhibits polymerisation of tubulin, the major protein constituent of microtubules (Morejohn et al., 1987; Strachan and Hess, 1983), indeed dinitroanilinines are classified in Group 3 of the new classification scheme (Mallory-Smith and Retzinger, 2003). When applied to the soil, they undergo N-dealkylation, nitroreduction and cyclisation (Marquis et al., 1979). All dinitroaniline herbicides are highly volatile and undergo little leaching in soil (Anderson, 1996). So, they are more effective when applied as a pre-plant incorporation. Generally, dinitroanilines are moderately persistent (Kearney et al., 1976), have relatively short life in soil, even though some of the dinitroanilines such as pendimethalin have persisted up to 50 weeks (Pritchard and Stobbe, 1980) and cause toxic effects on the succeeding crops (Zimdalh et al., 1984; Smith et al., 1995).

Farmyard manure (FYM) consists of humic materials, plant and animal residues and soil microbes which increases soil organic matter and generally stimulate soil microbial activity. Soils with low organic matter have a higher capacity for pesticide mobility (Guo et al., 1991), especially humic substances are the primary adsorbent for pesticides (Piccolo and Celano, 1994). They reduce pesticide contamination of ground water (Zsolnay, 1992; Arienzo et al., 1994; Barriuso et al., 1995; Cox et al., 1997). It is generally accepted that persistence of herbicides is influenced by the colloidal fraction of soil; organic matter is of particular important (Bardsley et al., 1967). The behaviour of herbicides varies with the nature and reactivity of the organic amendments and with their effect on microbial activity (Cox et al., 2000). FYM application may affect the fate of herbicides that is controlled by many factors like volatilisation, degradation, sorption and desorption. In case of low solubility compounds, it has been demonstrated that interactions between dissolving organic matter and herbicides occur (Gauthier et al., 1987; Lee and Farmer, 1989). Although dinitroaniline herbicides are chemically related, they differ considerably in their persistence and volatility (Weber and Monaco, 1972; Parochetti and Hein, 1973; Harvey, 1974; Parochetti et al., 1975).

The aim of the current study was to assess the influence of FYM application on persistence and dissipation of three dinitroaniline herbicides under the crop, Indian mustard (*Brassica juncea* L.) in sandy loam soil using the Gujarat State of India as the case study area.

2 Materials and methods

2.1 Experimental site

The study was carried out during the winter (November–February) season of 2001–2002 at College Agronomy Farm, B.A. College of Agriculture in Anand, India. The venue records for 22° 35’ north latitude, 72° 55’ east longitude and 45.11 m elevation from the mean sea level, geographically. The region represents semi-arid and sub-tropical with hot summers and cool winters. Winter is chilly and dry (minimum temperature 10°C) which starts in mid October and lingers till the end of February. The soil at the experimental site was sandy loam in nature with pH 7.5, 0.34% organic carbon, low in total nitrogen (0.041%), medium in phosphorus (50.88 kg ha^{-1}) and high in potassium (315.90 kg ha^{-1}). It is alluvial in origin, deep, well drained and has fairly good moisture holding capacity.

2.2 Treatment details

Treatment comprised two levels of FYM, (0 and 10 t ha^{-1}) applied before sowing the crop and three herbicides (pendimethalin, trifluralin and fluchloralin), applied as pre-plant incorporation, each at 0.5 and 1.0 kg a.i. ha^{-1}. The experiment was laid out in a factorial complete randomised block design (FRBD) with four replications. The crop was drilled in November, 2001 at spacing of 45 cm × 15 cm and at a seed rate of 3.5 kg ha^{-1}. The size of each gross plot area was 4.5 m × 2.7 m and net plot area was 3.6 m × 1.8 m, from where soil samples were collected to avoid any border effect. The fertilizer was applied at a recommended dose of 25 kg N and 50 kg P_2O_5 ha^{-1} at the time of sowing and 25 kg N ha^{-1} was applied as a top dressing before the first irrigation. No rain fall was received during the field experiment and a total five irrigations were given by surface channel. The harvesting of the crop was done in March, 2002. The seeds of Indian mustard (cultivar: Gujarat Mustard-2) and FYM were purchased from a local dealer in Anand City. The FYM used was of exceptionally good quality with 1.8% N, 0.48% P_2O_5, 0.26% K2O and 35.65% organic matter. Technical grade pendimethalin, trifluralin and fluchloralin were procured from American Cyanamid, De-Nocil Crop Protection and BASF, respectively.

2.3 Soil sampling and residue analysis

The physico-chemical properties of all three dinitroaniline herbicides used in this experiment are listed in Table 1. Soil samples were collected from each net plot area at zero, one, five, ten, 30, 60 and 120 days after herbicide application from surface soil (0–7.5 cm), taking five, 3.5 cm diameter cores (using a pipe auger) randomly from each net plot area. Sampling at zero days after sowing (DAS) was after application of herbicides but before seeding of crop. All soil samples were preserved at –10°C until the residue analysis was done.

Prior to extraction of herbicide residues, a few drops of liquid ammonia were added to the soil samples, thoroughly mixed and excess ammonia was allowed to evaporate at room temperature. A 20 g soil sample was extracted with 200 ml hexane: acetone (9:1) by shaking for 20 minutes and filtered under vacuum. The filtrate was concentrated. Residue analysis was done by injecting 1 µl aliquots of filtrate into gas liquid chromatograph (Chemito model 8510 and 3865) equipped with Ni^{63} electron capture detector with following operating parameters

Column	GLT, 20 cm long, 3 mm i.d., packed with 5 % OV-17 on chromosorb W (HP) 80–100 mesh
Temperature	column: 220°C; injector: 220°C; detector: 350°C
Carrier gas	nitrogen, flow rate 40 ml min^{-1}

The following formula was used for calculation of herbicide half-life,

$$C_t = C_0 e^{-Kt}$$

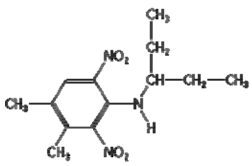
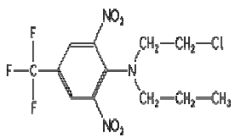
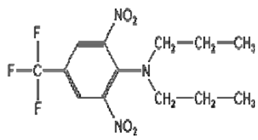
where

C_t residue (ppm) at 't' time

C_o residues (ppm) at initial time

K rate constant results

Table 1 Physico-chemical properties of the three dinitroaniline herbicides used in this experiment

Properties	*Pendimethalin*	*Fluchloralin*	*Trifluralin*
IUPAC name	*N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine	*N*-(2-chloroethyl)-2,6-dinitro-*N*-propyl-4-(trifluoromethyl) aniline or *N*-(2-chloroethyl)-α,α,α-trifluoro-2,6-dinitro-*N*-propyl-*p*-toluidine	α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine
Product name/trade name	Stomp, Tata Penida 30 EC	Basalin 45 EC	Treflan, Daw Elanco 48 EC
Manufacturer	American Cynamide, Tata Rallis	BASF	De-Nocil Crop Protection
Molecular formula	$C_{13}H_{19}N_3O_4$	$C_{12}H_{13}ClF_3N_3O_4$	$C_{13}H_{16}F_3N_3O_4$
Structure			
Vapour pressure mm Hg at 25°C	3.0×10^{-5}	0.28×10^{-4} at 20°C	1.1×10^{-4}
Molecular weight	281.3	355.7	335
Solubility in water at 25°C (g/100 ml)	0.275	< 0.0001	0.00003
K_{ow}	152,000	-	118,000
pKa	2.8	-	None
Boiling point	330°C	-	139–149°C at 4.2 mm Hg

Notes: IUPAC International Union for Pure and Applied Chemist

EC emulsify concentration

Source: Herbicide Handbook of Weed Science Society of America (1989)

3 Results and discussions

3.1 Soil persistence

The amount of herbicide residues extracted from sandy loam soil at different sampling intervals is shown in Table 2. Slightly higher initial deposits of fluchloralin (0.179–0.315 ppm) were recorded followed by pendimethalin (0.145–0.294 ppm) and trifluralin (0.116–0.216 ppm) at both the doses (0.5 and 1.0 kg a.i. ha^{-1}). At the harvest of the crop (120 DAS), pendimethalin (0.032 ppm) and fluchloralin (0.056 ppm), at 0.5 and 1.0 kg a.i. ha^{-1}, respectively showed maximum persistence.

Table 2 Residues (ppm) and dissipation (%) of three dinitroaniline herbicides in sandy loam soil

Herbicide (kg a.i. ha^{-1})	*FYM (t ha^{-1})*	*Herbicide residues (ppm)*							*$t_{½}$ (days)*
		Sampling intervals (DAS)							
		0	*1*	*5*	*10*	*30*	*60*	*120*	
Pendimethalin at 0.5	0	0.152	0.144	0.127	0.087	0.074	0.043	0.032	53.8
		-	(5.2)	(14.4)	(42.6)	(51.2)	(71.4)	(79.0)	
	10	0.145	0.139	0.115	0.080	0.058	0.034	0.022	44.9
		-	(4.2)	(21.0)	(44.4)	(60.0)	(76.5)	(84.7)	
Pendimethalin at 1.0	0	0.294	0.281	0.242	0.190	0.127	0.078	0.052	47.8
		-	(4.6)	(17.6)	(35.5)	(56.8)	(73.1)	(82.2)	
	10	0.282	0.267	0.218	0.165	0.113	0.059	0.039	41.8
		-	(5.1)	(22.7)	(41.5)	(59.9)	(78.9)	(86.2)	
Trilfluralin at 0.5	0	0.123	0.116	0.102	0.081	0.057	0.032	0.018	43.0
		-	(5.5)	(17.0)	(34.3)	(45.9)	(73.9)	(85.4)	
	10	0.116	0.107	0.096	0.067	0.048	0.022	0.016	41.2
		-	(7.1)	(17.2)	(42.0)	(58.7)	(81.3)	(85.9)	
Trilfluralin at 1.0	0	0.216	0.205	0.191	0.151	0.110	0.052	0.032	42.4
		-	(4.7)	(11.5)	(30.1)	(49.1)	(75.9)	(85.2)	
	10	0.199	0.189	0.165	0.138	0.097	0.047	0.024	39.1
		-	(5.4)	(17.5)	(31.0)	(51.3)	(76.6)	(88.1)	
Fluchloralin at 0.5	0	0.188	0.180	0.169	0.133	0.091	0.050	0.029	43.6
		-	(4.6)	(10.0)	(29.2)	(51.8)	(73.2)	(84.5)	
	10	0.179	0.167	0.154	0.117	0.080	0.043	0.022	39.6
		-	(7.1)	(14.4)	(35.0)	(55.5)	(76.3)	(87.9)	
Fluchloralin at 1.0	0	0.315	0.304	0.273	0.221	0.165	0.098	0.056	47.8
		-	(3.4)	(13.4)	(29.6)	(47.5)	(68.9)	(82.3)	
	10	0.303	0.291	0.258	0.197	0.139	0.080	0.043	43.0
		-	(4.0)	(14.8)	(34.9)	(54.0)	(73.5)	(85.7)	

Notes: Figure in parenthesis indicates % dissipation over the initial deposition.

DAS days after sowing of the crop

FYM farmyard manure, a.i. – active ingredient

Figure 1 Semi-logarithmic plot of persistence data of three dinitroaniline herbicides in sandy loam soil (see online version for colours)

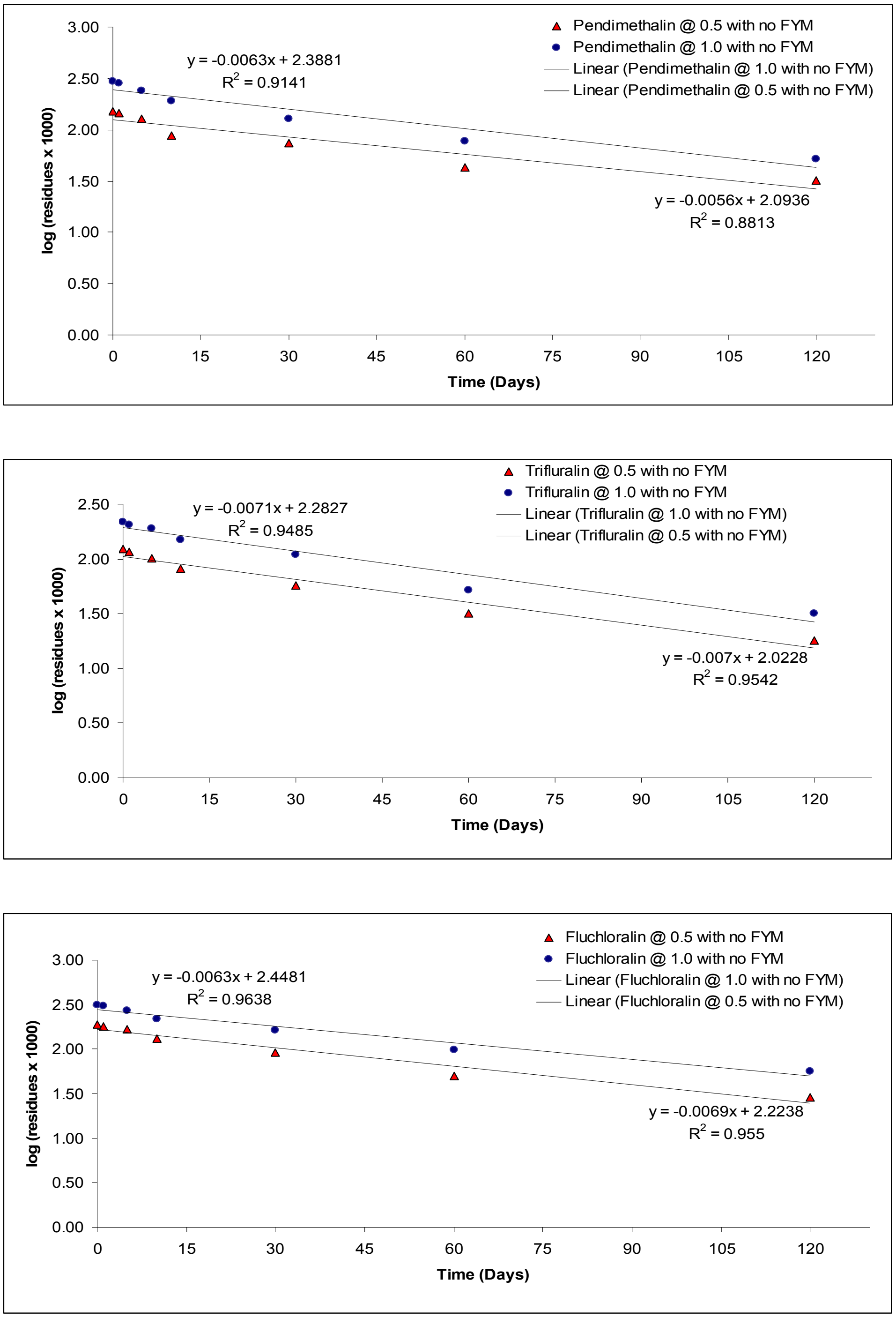
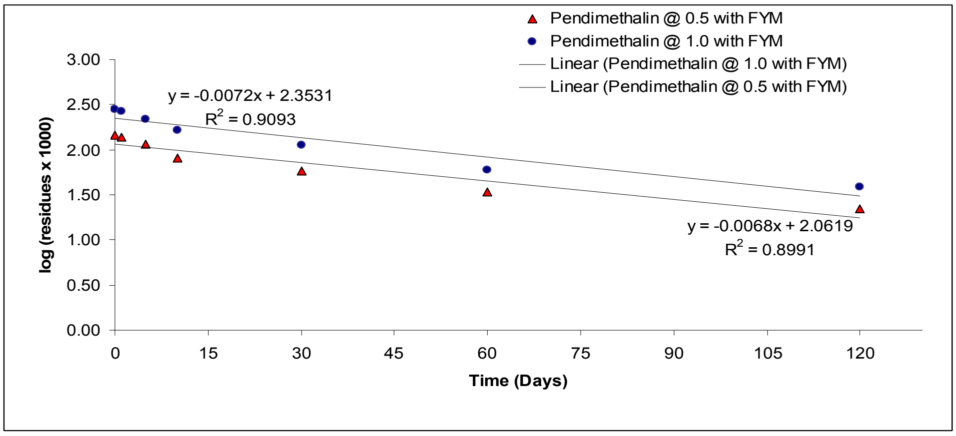
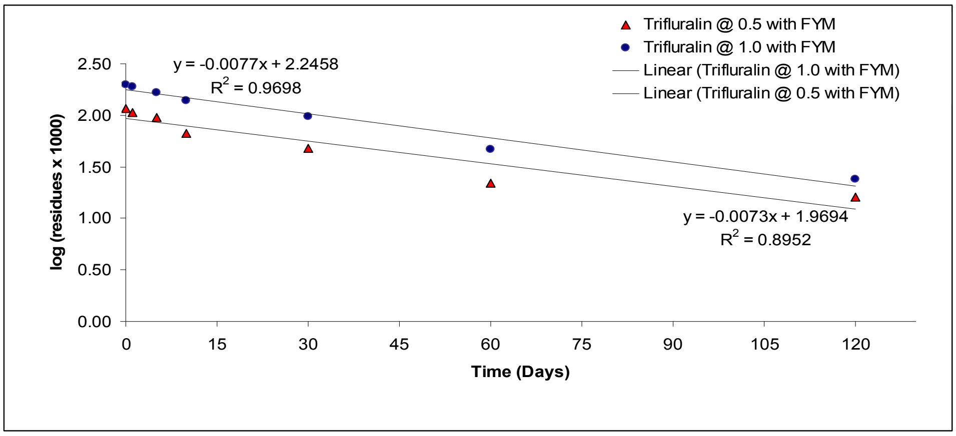


Figure 2 Semi-logarithmic plot of persistence data of three dinitroaniline herbicides in sandy loam soil with addition of FYM at the rate of 10 t ha^{-1} (see online version for colours)





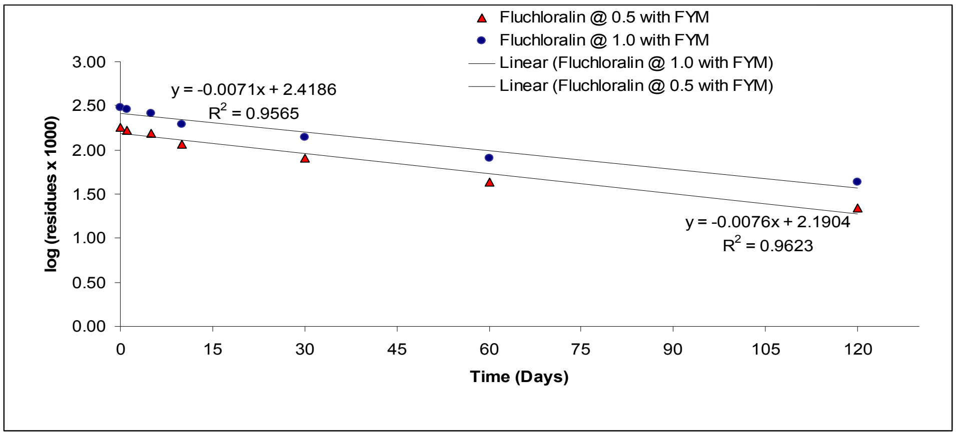
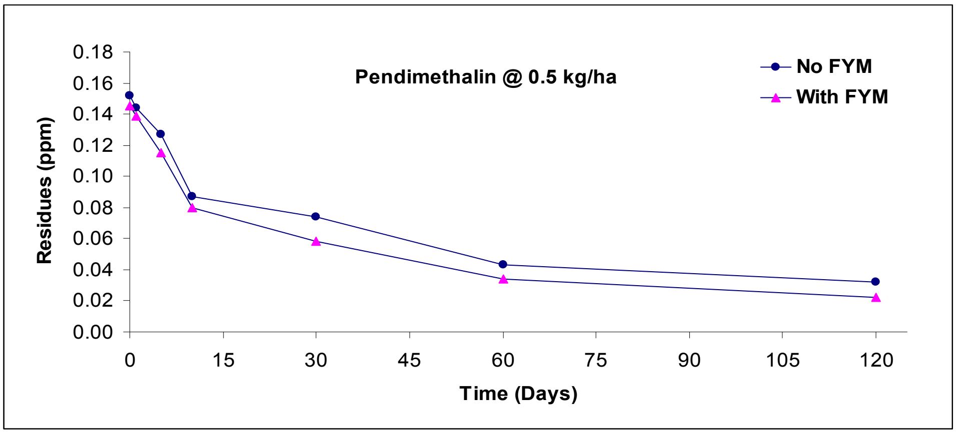
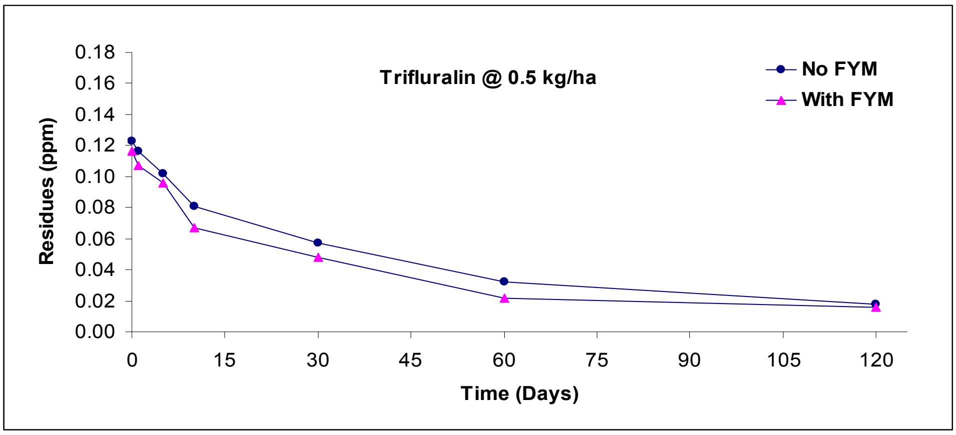


Figure 3 Dissipation pattern of three dinitroaniline herbicides applied at the rate of 0.5 kg ha^{-1} with and without FYM (see online version for colours)





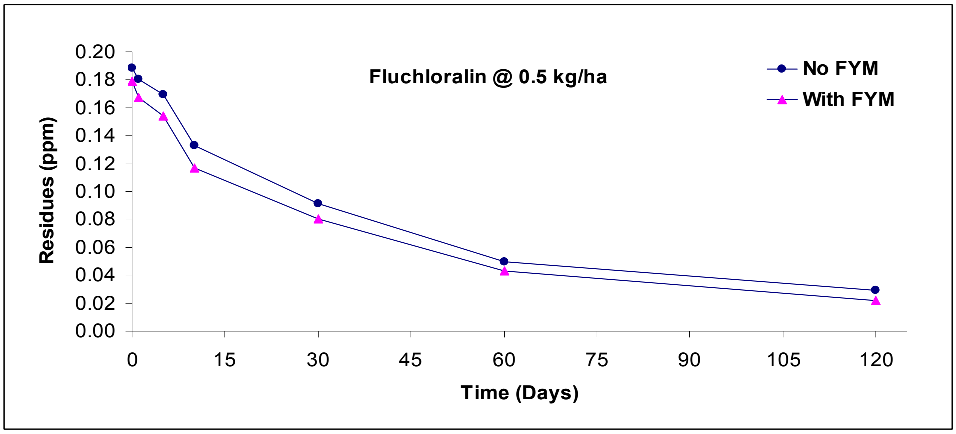
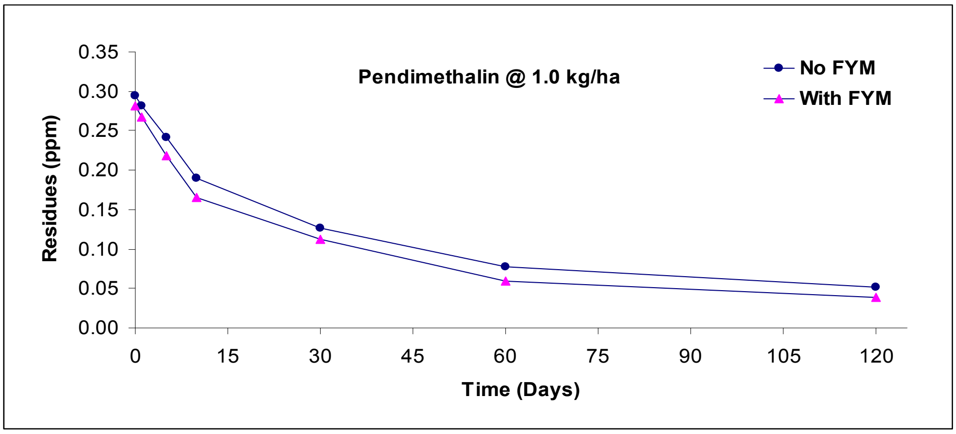
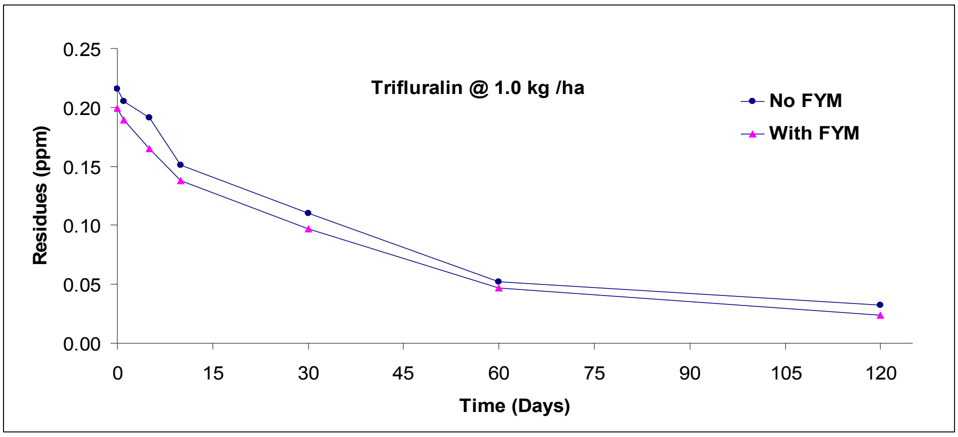
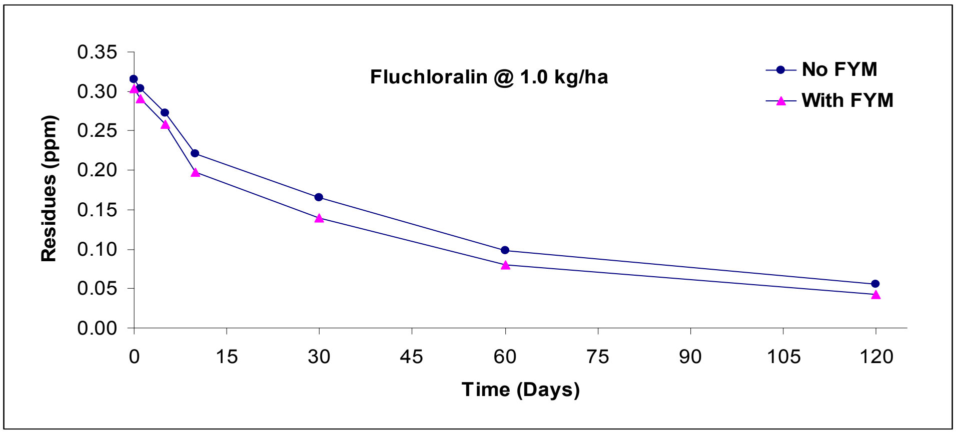


Figure 4 Dissipation pattern of three dinitroaniline herbicides applied at the rate of 1.0 kg ha^{-1} with and without FYM (see online version for colours)







The regression line, drawn by plotting log of residue against the sampling interval, showed that the rate of persistence of all three dinitroaniline herbicides followed a first order kinetic reaction which appeared to be monophasic (Figures 1 and 2). Moreover, semi-logarithmic plot of residues indicated that loss of all three herbicides were described adequately, R^2= 0.89 to 0.96, by first-order kinetics. These values are well in accordance with those reported by Savage and Jordan (1980), ranging from 0.92 to 0.98 for pendimethalin and fluchloralin. But in case of trifluralin, they reported that trifluralin dissipated drastically during 13–18 days period and thus, first-order kinetics failed to describe its behaviour statistically, i.e., R^2 = 0.34.

3.2 Influence of FYM

FYM had considerable influence on the persistence of all three dinitroaniline herbicides. Results revealed that herbicide application (at both the levels) in absence of FYM showed the higher residues, which were markedly decreased with the addition of FYM (Table 2). The initial deposits of pendimethalin, trifluralin and fluchloralin residues in absence of FYM were 0.152 and 0.294; 0.123 and 0.216 and 0.188 and 0.315 ppm, when herbicides were applied at the rate of 0.5 and 1.0 kg a.i ha^{-1}, respectively (Table 2), which respectively dissipated to 0.032 and 0.052; 0.018 and 0.032 and 0.029 and 0.056 ppm at harvest. Whereas, with the incorporation of FYM at the rate of 10 t ha^{-1}, the initial deposits of pendimethalin, trifluralin and fluchloralin residues were 0.145 and 0.282; 0.116 and 0.199 and 0.179 and 0.303 ppm, each at the rate of 0.5 and 1.0 kg a.i ha^{-1}, respectively, which respectively reached to 0.022 and 0.039; 0.016 and 0.024 and 0.022 and 0.043 ppm at harvest (Table 2).

3.3 Half-lives and herbicide dissipation

The half-lives of pendimethalin, trifluralin and fluchloralin, worked out using a complex first order equation, were in the range 47.8–53.8, 42.4–43.0 and 43.6–47.8 days, respectively under absence of FYM treatment, whereas, they varied from 41.8–44.9, 39.1–41.2 and 39.6–43.0 days, respectively under FYM application (Table 2).

The initial concentrations of herbicides declined sharply irrespective of FYM incorporation, representing a mean loss of pendimethalin, trifluralin and fluchloralin to the extent of 39.05, 32.2 and 36.5% and 42.95, 36.5, 54.75% respectively with and without FYM, within the span of 30 days as evident from the dissipation curve (Figures 3 and 4). From the 30th day onwards, the progressive dissipation of herbicides was slower and gradual. On the 120th day (at harvest), the mean loss with FYM treatment was 80.6, 85.3 and 83.4% and with no FYM treatment, it was 85.45, 87.00 and 86.8%, respectively for pendimethalin, trifluralin and fluchloralin.

3.4 Assessment of soil persistence

Persistence in soil is an important feature of an herbicide as it determines its suitability in a particular soil, environment and cropping situation. Generally, dinitroaniline herbicides degrade to non-phytotoxic levels within the growing season in warm, moist soils (Kearney et al., 1976; Rahman, 1973). Since, no effort was made to measure $^{14}CO_2$ or volatile losses in our study, the exact contribution of metabolic versus vapour could not be determined. Compared to pendimethalin and trifluralin, a slightly higher initial deposit of fluchloralin was observed but in the long turn, pendimethalin at a lower rate and fluchloralin at a higher rate showed more persistence.

Trifluralin disappeared more rapidly compared to the other two herbicides under identical edaphic conditions. Pritchard and Stobbe (1980) also reported the same results for least persistence of trifluralin among four dinitroanilines in clay soil. The effectiveness of trifluralin was found to be greatly increased by incorporation into the soil (Savage and Barrentine, 1969; Fink, 1972). Many authors point out that volatilisation was one of the mechanisms by which trifluralin could be lost from the soil. It was more rapid when surface applied than when soil incorporated; maximum loss of up to 4 kg ha^{-1} day^{-1} was obtained by application of 1–10 kg ha^{-1} to wet soil surfaces (Spencer and Cliath, 1974). Trifluralin was most effective in dry soil but tended to desorb in wet soil (Standifer and Thomas, 1965). In contrast to our results, Harvey (1974) concluded that trifluralin was the most persistence among the twelve dinitroaniline herbicides used in Wisconsin. In clay loam soil, Pritchard and Stobbe (1980) also obtained maximum persistence for trifluralin.

Pendimethalin at a lower rate (0.5 kg ha^{-1}) gave the maximum persistence in soil compared to trifluralin and fluchloralin (Figure 1 and Table 2). This might be because pendimethalin is relatively less volatile (vapour pressure: 3×10^{-5} at 25°C; Table 1) than trifluralin and fluchloralin (Savage and Jordan, 1980). Persistence of pendimethalin can be influenced by many factors including soil temperature, soil moisture, type of soil, cultivation practices (Zimdahl et al., 1984) and soil organic matter (Garcia-Valcarcel and Tadeo, 2003). Walker and Bond (1977) observed that pendimethalin was more persistent when incorporated in the soil than applied to the soil surface. Zimdalh et al., (1984) revealed that pendimethalin was not affected by a few days delay in incorporation, however, losses increased if incorporation in the soil was delayed for more than three days (Kennedy and Talbert, 1977). When pendimethalin was applied under no-till conditions, it was found to be most persistence in silty clay and least persistence in sandy loam (Flom and Miller, 1978).

The maximum persistence was observed for fluchloralin when it was applied at the rate of 1.0 kg ha^{-1}. In semi-arid conditions, Yadav et al. (1991) reported residual activity of fluchloralin even after 234 days of its application in mustard-sorghum cropping system. In all three soil types: sandy loam, clay loam and clay, Pritchard and Stobbe, (1980) revealed that fluchloralin persistence was intermediate when compared to the other three dinitroaniline herbicides, dinitramine, trifluralin and profluralin.

3.5 Half-lives and herbicide dissipation

Half-lives of all three herbicides were calculated from the slope of the regression equation. Results indicated that half-lives decreased with addition of FYM, probably due to increased organic matter that adsorbed the herbicide molecules in their colloidal fraction (Kalpana et al., 1999). FYM also enhances microbial activity which in turn degrades herbicides at a faster rate (Rai and Chhonkar, 2000). In our study, the maximum value of half-life, 53.8 days, was recorded for pendimethalin. The values of half-lives of dinitroanilines obtained in this work were similar to the results obtained by Zimdahl et al., (1984); Tsiropolos and Miliadis (1998); Kalpana et al. (1999) and Rai and Chhonkar (2000). In contrast to this, Walker and Bond (1977) recorded half-lives of 98 ± 3.2 days at 30°C for pendimethalin in a soil with pH 6.2.

Relatively a small proportion of the soil applied herbicide is taken up and retained by plants and the remainder is subjected to dissipation in the soil. In this trial, first order kinetics adequately described dinitroaniline herbicides dissipation in sandy loam soil at both dosages. A rapid disappearance of herbicides was not observed in the initial 10 days. This was possibly due to the pre-plant incorporation of all three herbicides which might have greatly minimised the volatilisation loss of chemical and hence rapid loss of herbicides. By harvest time, about 80–87% of all three dinitroaniline herbicides were dissipated. Savage and Jordan (1980) observed rapid disappearance of dinitroaniline herbicides in the first three to five days of application.

3.6 Influence of FYM

The addition of FYM increased the activity of herbicides and organic matter but had a variable effect on herbicide persistence. In the current study, the persistence of all three dinitroaniline herbicides was decreased with addition of FYM. These results were in agreement with the findings of Jacques and Harvey (1979); An and Chen (1993) and Patel et al. (1996). All these authors also observed that dinitroaniline herbicides residues decreased with an incorporation of FYM and faster degradation of herbicides in soil with organic matter. FYM decomposed in soil may have a greater adsorption capacity than soil itself (Parochetti and Hein, 1973). The adsorption of herbicides by organic materials involves H-bonding, London-Van der Walls forces and cation exchange (Sensei and Testini, 1984). Warren (1973) reported that in a soil with low organic matter, propachlor dissipates so rapidly that it failed to control large crabgrass (*Digitaria sanguinalis*). However, it performed well in a soil with 3.0% organic matter, indicating the influence of organic matter on behaviour of herbicide.

The toxicity and persistence of trifluralin were related to the organic matter content of soil due to greater retention of the vapour phase of the herbicide (Bardsley et al., 1967). Weber et al. (1974) also revealed that trifluralin persistence was dependent on organic matter rather than clay content. However, the clay fraction contributed more to the reduction of phytotoxicity than the organic matter fraction (Webster et al., 1978). In contrast to this, the incorporation of colloidal fraction of leonardite or activated charcoal in mineral soils of low organic matter resulted in increased toxicity of surface applied trifluralin. When trifluralin was incorporated 2.5 cm in soil, no influence was observed from increased organic matter (Bardsley et al., 1967). Pritchard and Stobbe (1980) revealed that phytotoxicities of dinitroanilies decreased with increased organic matter but persistence of fluchloralin and trifluralin was increased with increased organic matter, which may cause crop injury a year latter.

The application of organic matter to soil before pendimethalin treatment may influence the fate of herbicides as reported by Garcia-Valcarcel and Tadeo (2003). They also revealed that organic fertilizers might influence pendimethalin behaviour in soil according to the nature of the organic matter used. The reduced persistence of pendimethalin by application of FYM might be because of an interaction of pendimethalin with organic matter.

At the end of the persistence assay (120 DAS), the herbicides residues in soil fertilized with FYM and without FYM were almost similar. These values were the same as reported by Smith et al. (1995). This may be due to dinitroanilines being degraded by chemical reactions, biological processes (Savage and Jordan, 1980) and volatility (Parochetti et al., 1975).

4 Conclusions

In this study the effectiveness of FYM was evaluated in reducing persistence of three dinitroaniline herbicides: pendimethalin, trifluralin and fluchloralin from a field, cropped with Indian mustard (*Brassica juncea* L.) in sandy loam soil of middle-west Indian agro-climatic conditions. Among the three dinitroaniline herbicides, fluchloralin persistent was slightly higher than pendimethalin and trifluralin. FYM incorporation helped in reducing the half-life of all three herbicides. Indeed, overall results suggested that application of pendimethalin, trifluralin and fluchloralin herbicides do not post any problem with respect to long term herbicide residual contamination in soil.

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