BEHAVIOUR OF BUTACHLOR AND PENDIMETHALIN IN SOME SELECTED SOIL SERIES OF KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled **"Behaviour of butachlor and pendimethalin in some selected soil series of Karnataka"** submitted by **Mr. N.B. Prakash** for the degree of **Doctor of Philosophy in Soil Science** of The University of Agricultural Sciences, Bangalore is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

Weeds have been a problem for man ever since he took to domestication of plants and therefore, weed management seems to be as old as agriculture itself. The global loss of food production due to weeds was estimated to be 287 million metric tons per annum accounting for 11.5 per cent of total food production (Parker and Fryer, 1975). In India out of the total annual loss of agricultural produce, due to various pests; weeds account for 45 per cent, insects 30 per cent, diseases 20 per cent and other pests 5 per cent (Rao, 1983). During 1992, the yield loss in India due to weeds alone was 30 per cent valued at Rs. 1,980 crores (Mukhopadhyay, 1992; Dhanaraj, 1994). Timely control of weeds can substantially contribute to the increase in crop yields, which can be achieved effectively using herbicides.

India ranks sixth in terms of pesticide usage and seventh in terms of production, whereas the countries like Japan, Europe and United States of America occupy the first three places in terms of usage and production. The actual consumption in 1990-91 on all India basis was 47,074 MT (technical) of insecticides, 17,770 MT (technical) of fungicides and 4,862 MT (technical) of herbicides.

The progressive modernization of Indian agriculture involves intensive input like use of herbicides to control weeds. From a mere 2 per cent share of the total pesticide consumption in the seventies in India, herbicides now account for about 12 per cent of the pesticides market. Herbicide consumption, however in our country is still much less than that in the developed countries where herbicides constitutes 40-50 per cent of the total pesticide consumption (Mehta, 1992).

The two commonly used herbicides in Indian agriculture are butachlor [*N-(Butoxy methyl)-2-chloro-N-2',6'-diethyl acetanilide*] and pendimethalin [*N-1-(ethyl propyl) 3-4-dimethyl -2,6 dinitro benzeneamine*]. Butachlor is a pre emergence herbicide belonging to chloroacetanilide group used for the control of annual grasses and certain broad leaved weeds in rice, both seeded and transplanted. Pendimethalin is a selective dinitro aniline herbicide effective against most annual grasses and several small seeded annual broad leaved weeds. It can be applied pre emergence after seeding in the cereals maize and rice; or as shallow soil incorporation before seeding beans, cotton, groundnut and soybeans.

Among the herbicides, butachlor stands first in actual consumption and accounted for 1/3rd of the total consumption of herbicides during 1990-91. In Karnataka, 60 MT (technical) of butachlor and 2 MT (technical) pendimethalin were estimated to have been consumed during 1992-93. The projected consumption for 1994-95 is 65 MT (technical) of butachlor and 3 MT (technical) of pendimethalin (Department of Agriculture, Govt. of Karnataka).

The fate of any herbicide depends on its properties and that of soils to which it is applied. Hence, the effectiveness of herbicides depend on the sorption, transport and degradation processes. Herbicides applied to control the spectrum of weeds should not have any adverse or phytotoxic effects on the target crop. The desired duration of persistence of herbicides in the soil is often dictated foremost by the critical period of the crop growth. Thus, for example, for rice a herbicide that persist for 40 days from planting is desired. Herbicides which persist much longer than desired, pose several potential environmental problems. Further more, they may cause injury to succeeding crop particularly in multiple cropping system. Hence, the residue problems are also to be tackled from both environmental and agricultural point of view. In the last decade, public has become increasingly aware of the potential danger from pesticide residues in the environment. The accumulation of residues in water sources and its entry in to the food chain cause health problem. These demand accurate methods of predicting the persistence of a herbicide in the soil system.

However, the problem of herbicide residues in soils, plants and harvested products is not as serious as that of residues of other pesticides. Research done under Indian conditions indicated levels of residues below tolerance limit set by WHO/FAO for many herbicides (butachlor, fluchloralin, alachlor, MBT and isoproturon).

The knowledge regarding the interactions of butachlor and pendimethalin in soils of Karnataka are scarce. Therefore, an investigation was under taken to study the behaviour of these two herbicides in three bench mark soils of Karnataka with the following objectives.

1. The adsorption-desorption pattern of butachlor and pendimethalin in three different soils.

2. The persistence of butachlor and pendimethalin in soil under three moisture regimes.

3. The persistence of butachlor and pendimethalin in sterile and nonsterile soils.

4. The leaching/mobility of butachlor and pendimethalin in soil columns.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The soil can be thought of as both an environmental compartment and ecosystem. As an environmental compartment, its importance lies in the uptake of pesticides from soil by crop plants and in the transfer of pesticides to other compartments through processes such as leaching (ground water) and runoff (surface water). Soil can also be thought of as an ecosystem with multiple transformation (i.e. degradation) processes, nutrient cycles and metabolic pathways operating in a complex biological community of bacteria, fungi, algae and microinvertebrates. The literature on adsorption, persistence and leaching of butachlor and pendimethalin in soils are reviewed in this chapter.

2.1 ADSORPTION - DESORPTION IN SOILS

Pesticide adsorption refers to the bonding of the chemical to sites on soil mineral or organic surfaces and must be considered when calculating herbicide application rates. Intermolecular forces of adsorption involves high and low energy bonds. Ionic and ligand bonds are high energy whereas charge-dipole, dipole-dipole, hydrogen bonding, charge transfer, Van der Waal's, entropy generation and magnetic bonds are low energy bonds (Calvet, 1980; Jury, 1987). Adsorption is influenced by soil organic matter, clay and water contents, ion exchange capacity, bulk density, solution composition, pH, temperature, tillage practices and structural properties of the herbicide.

2.1.1 ADSORPTION - DESORPTION OF BUTACHLOR AND OTHER RELATED CHLOROACETANILIDES

Brightwell and Rueppel (1978) found that adsorption of butachlor to soil particles followed Freundlich isotherm and the Freundlich coefficient K values ranged from 3.5 to 20.0. They concluded that though butachlor adsorption was reversible, it would not be readily desorbed into water.

Soil adsorption of alachlor and metolachlor (chloro-acetanilide herbicides) is better described by Freundlich than by Langmuir isotherms (Obrigawitch *et al.*, 1981; Sato *et al.*, 1987; Sethi and Chopra, 1975; Wood *et al.*, 1987). The Freundlich equation is empirical and imposes no limits on adsorption, while the Langmuir equation is based on theoretical considerations and shows maximum adsorption when a monolayer covers all surfaces. The Freundlich equation relates adsorbed and solution phase concentration at equilibrium.

Weber and Peter (1982) characterized alachlor and metolachlor adsorption isotherms as L-shaped on organic matter and S-shaped on montmorillonite. L-shaped isotherms signify that the soil has a high affinity for the herbicides, adsorption occurs in a planar configuration and bonding is multifunctional. S-shaped isotherms signify that the soil has higher affinity for water than the herbicides and adsorption is in vertical configuration and bonding is monofunctional.

Obrigawitch *et al* (1981) confirmed the mono and multi layer adsorption of metolachlor on three Texas soils of low organic matter. Monolayer adsorption occurred at low concentrations in the soil solution and the multilayer adsorption at high concentrations. The inflection point between the two regions was at equilibrium concentrations of 9-12 ug mL^{-1}. Multilayer bonding energies are lower than monolayer bonding energies and desorption occurs most readily from multilayer sites and is enhanced by increasing application rates. Metolachlor is desorbed more readily from soils of low organic matter and clay contents. Jordan (1978) found that alachlor and metolachlor adsorbed by three Wisconsin soils were desorbed readily by water. Desorption of alachlor and metolachlor by four washings with water from a sandy loam (11 % clay and 12 % organic matter) was 9 and 17 %, from a silt loam (17 % clay and 4.8 % organic matter) 37 and 43 % and from a sand (5 % clay and 0.8 % organic matter) 52 and 57 % respectively. Strek and Weber (1982) showed that there was greater adsorption of alachlor than metolachlor and desorption of alachlor by water was less for some soils. The K_d values of soils from different studies did not show parallel increase with organic matter and clay contents, suggesting that the type of organic matter may affect the magnitude and mechanism of adsorption and desorption. Attention should be focussed on organic matter and clay minerals when addressing adsorption effect on herbicide transport models. Other considerations are concentration range of herbicide, soil : water ratio, temperature and pH.

There are only a very few studies on adsorption of chloroacetanilide herbicides on different soil organic matter fractions. One such study by Kozak *et al* (1983) is on adsorption of metolachlor by humic, fulvic, humin and non oxidizable organic matter from three soils. Humic acids were most important and humins had no significant adsorption even though hydrophobic bonds were expected to form between humin and metolachlor. Oxidation of organic matter freed some mineral adsorption sites and was responsible for increasing adsorption of alachlor by soils (Sethi and Chopra, 1975).

Sato *et al* (1987) studied adsorption of butachlor in paddy soils of Japan. They observed that rate of adsorption of butachlor was very rapid initially and then decreased with time. The time needed for achieving equilibrium mainly depended on soil texture. Adsorption of butachlor to most of the soils was better described by Freundlich isotherm than Langmuir isotherm was found to increase with butachlor, soil organic matter and temperature. The heat of adsorption of butachlor to soils calculated from the Clausius - Clapeyr equation was 5-7 K Cal mol^{-1} indicating that adsorption is physical and reversible and herbicide concentration in rice paddy water can be maintained in narrow desired range by the reversibility between adsorption and desorption.

2.1.2 ADSORPTION - DESORPTION OF PENDIMETHALIN AND OTHER RELATED DINITROANILINES

The dinitroanilines have low water solubility and are relatively non-polar and essentially nonionic. Their properties suggest that adsorption would be associated with hydrophobic and lipophilic organic surfaces in soils.

Lambert (1967) indicated that adsorption isotherm for dinitroaniline herbicides were linear, though the concentration range was narrow. Lambert (1968) obtained a high correlation between sorption of two dinitroanilines and the organic matter content of the soils. The distribution coefficients were calculated for each compound in each soil, considering organic matter in the soil as primary sorbing surface.

Mc Call *et al.* (1972) found that the extent of trifluralin adsorption was of the order of nonionic = anionic (hydroxyl) > anionic (chloride) > cationic resins. Furthermore, the herbicide was not desorbable from the hydroxyl saturated resin, but an unknown yellow product was removed with 1 M NaCl in 60 per cent aqueous ethanol. Weber (1972) reported high sorption of trifluralin, butralin and profluralin on soil organic matter and concluded that the hydrophobic bonding could be the nature of retention on the surface, because of the lipophilic character of the compounds. Grover (1974) noticed high sorption of trifluralin, triallate and diallate by activated charcoal and peat moss, moderate sorption by wheat straw and low sorption by anion and cation exchange resins, kaolinite, montmorillonite and silica gel. High and moderate sorption showed L-type ($1/n<1.0$) of sorption isotherms whereas, low sorption showed S-type ($1/n>1.0$) of sorption isotherms.

Van Bladel and Moreale (1977) reported that Freundlich isotherms were L-type for p-chloroanilines on soils and it was found that sorption increased with increasing organic matter content. Jacques and Harvey (1979) also described the sorption of six dinitroanilines on soils by Freundlich equation. Isotherms were L-type and sorption increased with increasing organic matter. Herbicide adsorption by the soils was related more closely to soil organic matter than to the other soil chemical and physical properties.

Wheeler *et al.* (1979) reported that trifluralin partitioned into the organic matter fraction of soils and the amount partitioned was high in soils with high organic matter content (3.9 %) and low in soils with low organic matter content (0.9%). Peter and Weber (1985) determined the Freundlich K values for butralin and trifluralin sorption on nine soils and found high correlations between herbicide sorption and organic matter content of soils.

Weber (1987) reported that the dinitro groups decreased the water solubility of dinitroaniline herbicides by formation of hydrogen bonds with alkyl groups of neighbouring molecules, creating lipophilic micelles, which resist solvation into water molecule. It was further stated that the dinitroanilines were bound to soil particles by hydrogen bonds between nitrogroups of the chemicals and proteinaceous sites in soil organic matter and/or by charge transfer bonds between high charge density aromatic rings in soil humic substances and low charge density aromatic rings of the dinitroanilines. According to him, these are some of the mechanisms by which dinitroanilines are retained by soil organic matter.

2.2 PERSISTENCE OF BUTACHLOR IN SOIL

Butachlor is used extensively as a pre emergence herbicide to control weeds in both transplanted rice grown under flooded conditions and in direct drill seeded rice (Kolhe & Mitra, 1981; and Moorthy and Manna, 1984).

Beestman and Deming (1974) found that butachlor had short half lives of 9.4 and 14.4 days under warm, moist field conditions in silt and silty clay soils respectively. Degradation was 50 times slower in sterilized system indicating that major pathways of degradation in soils were mediated by microorganisms. According to them chemical degradation accounted for less than two per cent of the observed field losses.

Chen and Chen (1977) reported that main degradation pathways of butachlor were debutoxy methylation and dechlorination followed by hydroxylation, o-dealkylation and polymerisation. The degradation of butachlor in soil under flooded conditions varied with incubation periods and type of soil. They identified 2-chloro 2'-6' diethylacetanilide as one of the degradation products in soil and noticed that soil fungus *Fusarium oxysporum* schleucht could effectively degrade butachlor.

Chen and Chen (1978) indicated that photodecomposition of butachlor was rapid under UV light when it was exposed as a thin film on glass. Half life was found to be about 1.5 hr under the experimental conditions. The decomposition reaction followed first order kinetics and they observed seven decomposition products by TLC and GLC analysis.

Chen and Wu (1978) observed effective degradation of butachlor by soil microbes, *viz. Mucor sufui* and two other M.spp., *Penicillium citrinum, P. glaucum, Aspergillus niger, Bacillus subtilis, Fusarium oxysporum* and *Trichoderma viride* in the 0.02 M KH_2PO_4 buffer solution at pH 5.2 for fungi or pH 7.0 for bacteria. Three other soil microbes, *A. oryzae, A. usamii and B. megatherium* were found to be less effective and *Streptomyces* sp. NTU-014 was unable to degrade butachlor. Degradation of butachlor by *M. sufui*, NTU-358 produced at least 8-12 metabolites. Among these products, 2-chloro-2',6'-diethyl acetanilide, 2-hydroxy-2',6'-diethylacetanilide, 2,6-diethylaniline, N-chloroacetyl-7-ethyl-2,3-dihydroindole, 2',6'-diethylacetanilide and N-methyl-2-chloro-2',6'-diethylacetanilide were identified and the partial pathways involved in the degradation of butachlor were proposed. Recovery of butachlor in the autoclaved and non-autoclaved soils were found to be 74.5 % and 26.3 % respectively for 24 days of incubation. It was presumed that the soil microbes may play an important role in the degradation of butachlor in soils.

Lee (1978) studied the degradation of butachlor by a soil fungus *Chaetomium globosum* and identified more than 10 metabolites some of which were characterized.

Chen and Chen (1979) revealed that different ranges of pH did not affect the degradation of butachlor but volatilization of butachlor from aqueous solution and adsorption on soil were significantly influenced by temperature. Degradation of butachlor was more rapid when the weather was hot and clear than when it was relatively cold and cloudy. Photodecomposition, volatilization and microbial degradation were the major avenue of degradation.

In a rice field experiment Chen (1981) observed that butachlor was readily degraded by photodecomposition, microbial degradation and volatilization, and concluded that at the recommended rate, butachlor did not affect soil properties or pose a serious problem of environmental pollution.

Chen *et al.* (1982) revealed that photodecomposition of butachlor in aqueous solution was very fast and more complicated than that as a thin film on a glass surface and the half lives were demonstrated to be about 0.8 hr under UV light and 5.4 hr under sunlight irradiation respectively. As many as 24 compounds were detected and partial pathways were proposed.

A laboratory study was conducted by Mabbayad *et al.* (1984) to determine the effect of different soil moisture conditions and temperatures on dissipation of butachlor. They noticed rapid dissipation of butachlor during the first 42 days of incubation and slower disappearance thereafter. As the temperature increased from 25 to 45 °C, the dissipation of butachlor in soils maintained at 90% of field capacity was also increased. In the field study at 21 days after treatment only one ppm of butachlor was detected and by 70 days after treatment essentially no herbicide was present and they concluded that dissipation of butachlor was faster under field conditions than laboratory conditions because the herbicide was exposed to fluctuating environmental conditions.

Kulshrestha (1987) reported that the mode of dissipation of different formulations of butachlor was not influenced by the rate of applications. Half lives were ranged from 6.8 to 8.9 days at 3 kg a.i ha^{-1} in soils of direct seeded rice field. The dissipation for different formulations of butachlor followed the first order rate kinetics with short half lives in both plant and soils. In a previous study Kulshrestha *et al* (1981) reported that butachlor did not persist for more than 38 days in soil, rice crop and water under field conditions.

Leela (1987) conducted a pot culture experiment to study the persistence of butachlor in soils. Persistence was measured by ragi bioassay. Butachlor at

2 Kg a.i.ha^{-1} persisted for 40 days in sandy clay loam (0.6 % organic matter) and for 60 days in sandy (no organic matter) and clayey (0.2 % organic matter) soils. In organic soils (3.6 % organic matter) butachlor lost its activity rapidly resulting in cent per cent germination of ragi within 4-5 days of sowing. This study indicated the behaviour of butachlor under different soil types and mainly the inactivation of butachlor in natural soil with high organic matter content.

Chakraborty *et al.* (1990) studied the dissipation of butachlor under lab conditions on four different soils of West Bengal under different moisture conditions. The order of dissipation of butachlor was water logged > moist > dry. The order of persistence in soil was Bankuran > Nadia > Burds Wan > Coochbehar, irrespective of soil moisture level, initial pH of soil and rate of application of herbicide and followed first order kinetics. When the application rate was 2 Kg ai ha^{-1}, the half lives of butachlor for dry, moist and water logged conditions were 8.29, 7.93 and 7.66 days in Coochbehar soil, 9.93, 9.23 and 8.75 days in Burd Wan soil, 12.19, 11.74 and 11.31 days in Bankura soil and 9.22, 8.87 and 8.31 days in Nadia soil respectively and the values indicated a negligible differences between the moisture conditions.

In a field study on persistence and degradation of herbicides in transplanted rice, Jayakumar and Sree Ramulu (1993) revealed that butachlor at the rate of 1.25 Kg a.i ha^{-1} degraded completely before harvest with a half life of 19 days.

Jitender Kumar and Jai Prakash (1993a; 1993b) studied the persistence of thiobencarb and butachlor by bioassay technique using *Echinochloa crusgalli* seeds as test material. The degree of inhibition of germination was considered as indicator of persistence. They reported that both the herbicides degraded with time irrespective of their concentration and incubation at higher temperature helped in faster degradation. Among the two herbicides, butachlor had greater effect on germination than thiobencarb.

2.3 PERSISTENCE OF PENDIMETHALIN IN SOIL

Pendimethalin can be applied as pre plant incorporation, pre emergence or post emergence with or without incorporation. Persistence of pendimethalin is influenced by cultivation practices, soil temperature and moisture conditions and soil type.

2.3.1 SOIL TEXTURE

Flom and Miller (1978) reported that pendimethalin applied under no tillage conditions in North Dakota was found to be more persistent in a silty clay soil and least persistent in a sandy soil. The persistence of pendimethalin was comparable to the persistence of profluralin, trifluralin, fluchloralin and dinitramine.

Berayan and Mercado (1983) used sorghum as a test crop for bioassay of persistence of pendimethalin in clay, clay loam and fine sandy loam soils. Herbicidal activity was lost more rapidly from the soil 20-25 days after application and slowly there after. Highest phytotoxicity was noticed in clay loam soil than in clay or fine sandy loam at 50-110 days indicated more persistence in clay loam soil.

2.3.2 SOIL MOISTURE

Walker and Bond (1977) showed that the rate loss of pendimethalin under controlled conditions obeyed the first order equation. They noticed that the half life of pendimethalin in a sandy loam soil at 75 per cent field capacity was inversely related to temperature and increased with decreasing soil moisture.

Savage (1978) described the dissipation of pendimethalin in soil by the first order kinetics. Half-life in flooded and field capacity conditions were 37 and 99 days respectively in clay soil. It was found that flooding the soil significantly increased the dissipation rate of pendimethalin. Flooding the soil for relatively short periods of time resulted in a significant increase in dissipation rate of pendimethalin as compared to constant field capacity. It was also noticed that when flooded and field capacity soil water treatments were dried for 20 day period, the pendimethalin dissipation rate was greater with flooded treatment.

Smith *et al* (1979) studied the degradation of ^{14}C- pendimethalin and its derivatives in aerobic and anaerobic soils. Pendimethalin appeared to be more stable than its derivatives. The degradation of derivatives was found to be more rapid in anaerobic than in aerobic conditions.

Barrett and Lavy (1983) conducted a laboratory experiment to evaluate the dissipation of pendimethalin in silt loam soil. It was found that dissipation rates of pendimethalin followed pseudo first order kinetics, except in air dried soil that had no significant loss of pendimethalin. Half lives for air dried, continuously flooded and alternately flooded treatments were 59, 63 and 30 days respectively. Application rates of 0.5, 1.0 and 2.0 ug g^{-1} of soil had no significant influence on the rate of dissipation of pendimethalin.

Zimdahl *et al* (1984) found that the pendimethalin degradation did not follow first order kinetics but could be described by a quadratic model. The degradation rate was same at 75 and 100 per cent field capacity, but was slower at 50 per cent field capacity. Based on chemical analysis of soil from field and laboratory studies the half-life was approximately 47 days. Based on biological analysis of soil, the half life of pendimethalin ranged from 78 to 111 days and concluded that bioassay was qualitatively satisfactory but was not quantitatively accurate.

Vouzounis and Americanos (1994) reported that soil temperature and moisture were the predominant factors influencing the degradation of pendimethalin. The results indicated that the degradation rate of pendimethalin increased as temperature increased from 10 to 30°C in soils with 15 per cent water content (close to field capacity). When soil moisture content was reduced to two per cent the rate of degradation was retarded even at 30°C.

2.3.3 ORGANIC MATTER AND MICROFLORA

The organic matter content of soil, its stage of decomposition and microbial activities are interrelated. Organic matter and microflora play an important role on persistence and degradation of pendimethalin in soil. Organic matter enhances the degradation of the chemical by activating microflora. It also adsorbs more herbicides on its sites, which may not be available for microbial degradation.

Laonio *et al* (1973) observed that microbial degradation of pendimethalin and some analogous components were involved in the transformation processes like N-dealkylation, nitro group reduction and cyclization to benzimidazoles.

Walker and Bond (1977) evaluated the influence of organic matter on pendimethalin degradation. As the soil organic matter content decreased, rate of loss of pendimethalin in soil also reduced and the half-life varied from 72 to 172 days.

Berayan (1982) found higher residual phytotoxicity of pendimethalin in a soil with lower organic matter content than other soils. The studies of Nelson *et al* (1983) indicated that soil sterilization had reduced pendimethalin degradation, which was attributed to the loss of microflora in soil which indicated that the degradation of pendimethalin was mainly biological. Eleftherohorinos (1985) reported that organic matter had greater influence on degradation of pendimethalin. The persistence of pendimethalin increased with decrease in organic matter content of soil.

Barua *et al* (1990) examined the degradation of pendimethalin by various soil fungi viz., *Aspergillus flavus*, *A. terreus*, *Fusarium solani*, *F. oxysporum*, *Penicillium citrinum* and *P. simplicissinum*. They found that these fungi can effectively degrade pendimethalin when it was supplied as sole carbon source in mineral solution. Degradation of pendimethalin by *Fusarium solani* resulted in the isolation and identification of *N-propyl-3-methyl 4-hydroxy, 2-6,-dinitroaniline, N(1-ethyl propyl) 2-amino 6-nitro 3,4-xylidine* and *2-6-dinitro 3-4, xylidine.* The main metabolic pathways involved partial N-dealkylation followed by ring hydroxylation, nitro group reduction and complete N-dealkylation.

Singh and Kulshrestha (1991) reported that *Fusarium oxysporum* and *Paecilomyces varioti* in culture media degraded pendimethalin to two metabolites namely *N(1-ethyl Propyl)-3,4-dimethyl-2-nitrobenzene-1,6,diamine* and *3,4-dimethyl 2,6-dinitroaniline*, whereas *Rhizoctonia bataticola*, another soil fungus decomposed pendimethalin yielding only the latter metabolite. It was also observed that these soil fungi could reduce less hindered nitro group and also split off the alkyl substituent of the amine moiety in the parent molecule.

2.3.4 FIELD CONDITIONS

Gibson and Hamilton (1977) found that pendimethalin was highly persistent in both irrigated and fallow conditions, compared to other related herbicides like fluchloralin and dinitramine.

In a field experiment, Barrett and Lavy (1983) observed a strong influence of soil water content on the dissipation of pendimethalin in the first two weeks after herbicide application. Half lives in the field were much shorter during the initial two weeks than after two weeks with more than 50 per cent of the applied herbicide disappearing within one week.

A field experiment was conducted at IARI, New Delhi in winter season to study the persistence of pendimethalin in soil following pre emergence application to wheat (Kulshrestha and Yaduraju, 1987). Pendimethalin was applied as pre-emergence to wheat one or two days after sowing. They reported that the half lives of pendimethalin ranged from 58 to 63 days and approximately 35 per cent pendimethalin dissipated in 35 days and about 20 per cent remained in soil at the time of wheat harvest.

Nalayini *et al* (1991) conducted a field experiment in a clay loam soil with sunflower to study the persistence of pendimethalin under different moisture regimes. Half life period was found to be 10.45 days in low moisture regime (0.50 IW/CPE ratio), 8.36 days in medium moisture level (0.75 IW/CPE ratio) and 7.0 days in high moisture regime (1.00 IW/CPE ratio) treatments.

Tripathi *et al* (1993) conducted a field experiment to study the effect of soil applied pendimethalin at different doses in pea crop on its persistence. Analysis of soil samples indicated that presence of pendimethalin upto 60 days after application on sandy loam soil and the half life of pendimethalin was between 66 and 71 days and the relationship between time and persistence of pendimethalin was not linear but followed quadratic pattern.

Yadav *et al* (1993) reported that rate of degradation of pendimethalin was very slow in initial stage (0-50 days) and increased steadily upto 100 days. After 200 days; 63.5, 75.2 and 88.0 per cent of initial doses of pendimethalin applied in wheat fields disappeared at the level of two, four and six irrigations respectively. The half life of pendimethalin was 76, 92 and 122 days at the level of six, four and two irrigations respectively.

Pandit and Choudhury (1994) revealed that about 50 per cent of the pendimethalin residue disappeared within seven days after application and on 45th day, 98 per cent of the residue had been eliminated. When applied at the rate of 1.0 and 2.0 kg a.i.ha^{-1}, the half lives were 5.99 and 6.33 days respectively. At the time of harvest of groundnut, residue was not in detectable limit both in nuts and soil.

In a field experiment Tewary *et al* (1994) observed that high dose (2.5 kg ha^{-1}) of pendimethalin application resulted in higher (40 days) persistence in soil. The residue persisted for 15 days when applied at the rate of 0.5 kg ha^{-1} and 21 days at 1.5 kg ha^{-1}.

2.4 LEACHING / MOBILITY OF HERBICIDES IN SOILS

Three problems associated with leaching/mobility of herbicides through soils are (a) leaching to the root zone of sensitive non-target crop resulting in crop injury; (b) although leaching to the roots of target weeds is essential to obtain weed control, leaching below the root zone reduces herbicidal efficacy; and (c) leaching beyond the root zone may result in herbicidal transport to the ground water (Jordan and Harvey, 1980; Obrigawitch *et al*, 1981).

Leaching depends on the chemical characteristics of the herbicides, soil profile characteristics, environmental conditions and the method, time, formulation and amount of herbicide application.

2.4.1 LEACHING OF BUTACHLOR AND OTHER RELATED CHLOROACETANILIDES

In a field experiment Beestman and Deming (1974) reported that leaching and chemical decomposition did not contribute significantly to the loss of butachlor from soil and microbial decomposition played a major role in herbicide degradation. They noticed that butachlor had not moved beyond 4 cm depth in soil.

In some field studies leachability of metolachlor and alachlor were compared. Samples taken at 0, 2, 4, 8 and 12 weeks after treatment with 3.36 kg ha^{-1} of the herbicides incorporated 7-10 cm in a sandy clay loam indicated that no herbicide was leached beyond 8 cm, as judged by a bioassay (Cornellius *et al.*, 1976).

Leaching of butachlor in soil columns were studied by Chen and Chen (1979). Leaching of butachlor in soil columns resulted in movement of the compound to various depths in the soil. Their data indicated that the movement was correlated with leaching rates and amounts of butachlor applied. In a soil column the applied rate was 4.19 kg ha^{-1} and with an amount of water equivalent to 110 mm (leaching rate of 2.32 mm/hr) of rainfall, the distribution of butachlor at 0-2 cm depth was 9.63 ppm and an insignificant amount (< 0.50 ppm) of butachlor was leached to layers below 2 cm.

Two characteristics of a herbicide affecting leaching are water solubility and adsorption. The higher the water solubility, the more weakly it is adsorbed, increasing leachability. Spillner *et al* (1983) in soil column studies using metolachlor, alachlor and butylate indicated that mobility was correlated with water solubility. Alachlor and metolachlor have water solubilities of 240 and 530 ug L^{-1} and were more mobile than butylate (solubility of 46 mg L^{-1}). Although twice as soluble as alachlor, metolachlor was only slightly more mobile in soils. In the sandy loam the herbicides were adsorbed to a similar extent but metolachlor leached 5-10 cm farther than alachlor. Gerber *et al* (1974) found equal leachability of alachlor and metolachlor and suggested that adsorption was more important than solubility in controlling leaching. Peter and Weber (1985) also emphasized adsorption. In a Norfolk sand, alachlor and metolachlor had similar adsorption coefficients but metolachlor was only slightly more mobile. Leachate from 30 cm soil columns collected over 24 days in 3.5 L of water (51 cm rainfall) contained 11% and 10% of applied metolachlor and alachlor.

Laboratory, greenhouse and field studies have shown a relationship between soil texture and herbicide leaching. Generally, the coarser the texture, the more herbicide is leached. Coarser soils have less clay, less surface area, larger pores and higher hydraulic conductivities under wet conditions. These relationships are overridden if there are large differences in organic matter among soils. Obrigawitch *et al* (1981) found metolachlor leached > 30 cm in a fine sandy loam but only 15 cm in a clay loam.

In a field study Kulshrestha (1987) revealed that low water solubility (23 ppm at 24 °C) restricted mobility of butachlor in soil especially beyond 10 cm depth.

Contamination of ground water by chloroacetanilides has not been the focus of most field studies. Data are inconclusive with regard to concentrations reaching the saturated zone under different conditions. Soil column studies indicate that with heavy precipitation on coarse textured soils low in organic matter the herbicides leach beyond the root zone in significant amounts.

2.4.2 LEACHING OF PENDIMETHALIN AND OTHER RELATED DINITROANILINES

The dinitroanilines are among the least mobile herbicides. In soil column study comparing 28 herbicides, Harris (1967) assigned these relative mobility factors (considering monuron as 1.0); dipropalin, 0.5; trifluralin, 0.6; nitralin, 0.5-0.6; and benefin, 0.4-0.7.

Gagnon and Hamilton (1973) reported no leaching for seven dinitroanilines (butralin, dinitramine, GS-38946, GS-39985, nitralin, profluralin and trifluralin) during a one year period in which 145 cm of rainfall and irrigation water entered the sandy loam plots.

Signori and Deuber (1979) revealed higher leaching of pendimethalin in loamy soils than in clay soils. Savage and Jordan (1980) reported that the amount of pendimethalin in the 15-30 cm soil layer could be detected only on 45th day after application. The content was higher at high moisture regime followed by medium and low moisture regimes.

Berayan and Mercado (1983) found that leaching was not observed to be a significant means of pendimethalin loss in soil. Herbicide residues as measured by sorghum bioassay were found to be present mostly in upper 5 cm layer in both daily watered and those watered at every four days at 20, 50, 80 and 110 days after treatment. Langemeier *et al* (1984) reported that rainfall did not influence the movement of pendimethalin in field.

Kulshrestha and Yaduraju (1987) studied the persistence of pendimethalin in soil following pre emergence treatment at 1.0 to 1.5 Kg a.i. ha^{-1} to wheat in 0-5, 5-10 and 10-15 cm soil depths and reported that more than 80 per cent of the total residues were present in the 0-5 cm layer. The results of bioassay studies also indicated that the pendimethalin residues were more concentrated in 0-5 cm layer and conformed the results of chemical analysis.

Ankegowda *et al* (1993) studied the mobility of pendimethalin in soil at field capacity and at 50 per cent field capacity moisture regimes by using battery containers (30 X 20 X 10 cm^3). Mobility of pendimethalin from 0-5 cm top layer to 5-10 cm was more and very little movement occurred to 10-15 cm depth. Ninety per cent of the applied herbicide remained in top 0-10 cm layer and only 10 per cent moved to deeper layers of 10-15 cm after one and 24 days after treatment.

Tewari *et al* (1994) reported that pendimethalin residues were confined to the upper layer (0-5 cm) of soil, while in lower soil depths *viz.* 5-10 and 10-15 cm either residues were present or absent.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation was undertaken to study adsorption-desorption, persistence-degradation and mobility of two herbicides namely butachlor and pendimethalin in soils from three identified soil series in Karnataka. The details of the procedures used in the experiments are described below.

3.1 EXPERIMENTAL SOILS

For soil-herbicide interaction studies, surface soil samples from 0 to 15 cm depth were collected from Hiriyur (*fine mixed isohyperthermic chromic haplusterts*-Hiriyur series), Mandya (*fine loamy mixed isohyperthermic typic ustropepts*-Mangala series) and Mudigere (*loamy skeletal kaolinitic isothermic ustic Kanhaplo humult*-Mudigere series). The samples were air dried, hand pounded and passed through 2 mm sieve and stored in plastic containers. The initial physical and chemical properties of these soils were estimated as per the standard procedures given in Table. 1.

3.2 HERBICIDES

The chemical configuration, molecular weight, water solubility, vapour pressure and technical purity of butachlor *[N-(Butoxymethyl)-2-chloro-N-2',6'-diethyl acetanilide]* and pendimethalin *[N-(1-ethyl propyl)-3-4-dimethyl-2,6-dinitro benzeneamine]* are presented in Table 2. The herbicides pendimethalin and butachlor were obtained from M/S Rallis India Pvt. Ltd., Bangalore and Searle India Pvt. Ltd., Bombay respectively. Radio labelled ^{14}C-pendimethalin (methyl labelled, Sp. act. 25.67 uCimg^{-1}) was obtained from BARC, Bombay.

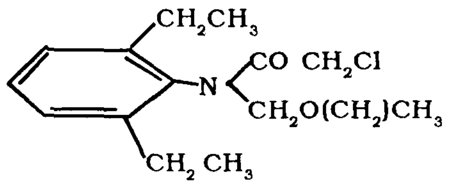
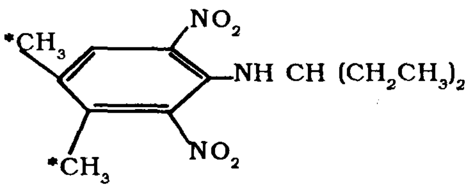
3.3 ADSORPTION-DESORPTION OF BUTACHLOR

The adsorption-desorption of butachlor was studied in soils by following batch equilibration method (Raman *et al.*, 1988). The adsorption of butachlor on to three soils with various shaking period upto 48 hrs indicated that shaking

Table - 1 Analytical procedures used for soil analysis

Sl.No	PARAMETER	METHODOLOGY	REFERENCE
1.	Mechanical analysis	International pipette method	Piper, 1966
2.	Soil reaction (Soil Water ratio 1:2.5)	Combined glass electrode	Jackson, 1973
3.	Electrical Conducitivity (EC)	Conductometry	Jackson, 1973
4.	Cation Exchange Capacity (CEC)	Ammonium saturation with ammonium acetate and sodium saturation with Sodium acetate	Black, 1965
5.	Exchangeable Calcium	Versenate titration	Hesse, 1971
6.	Exchangeable Mangesium	Versenate titration	Hesse, 1971
7.	Organic Carbon	Walkley & Black wet oxidation	Piper, 1966
8.	Availabe Nitrogen	Alkaline Permanganate	Subbaiah and Asija, 1956
9.	Available Phosphorus	Bray's extractant and Olsen's extractant	Jackson, 1973
10.	Available Potassium	Neutral ammonium acetate	Jackson, 1973
11.	Iron and Aluminium Oxide	0.2M ammonium oxalate (pH3.0) extractant	Mckeagne & Day, 1966
12.	Moisture content at Field capacity	Ceramic plate pressure plate apparatus	Black, (1965)
13.	Hydraulic Conductivity	Soil column	Black, (1965)

Table 2. Properties of Butachlor and Pendimethalin

HERBICIDE	CHEMICAL CONFIGURATION	MOLECULAR WEIGHT	WATER SOLUBILITY (mgL^{-1} Water)	VAPOUR PRESSURE (at 25°C)	TECHNICAL PURITY (%)
1. BUTACHLOR		311.9	23.0 (at 24°C)	600uPa	94.43
2.PENDIMETHALIN		281.3	0.3 (at 20°C)	4.0mPa	97.00

* ^{14}C labelled

of soil with butachlor for a period of 12 hrs was found to be sufficient to attain equilibrium.

Adsorption was studied by using 2 g of 2 mm sieved soils with 10 mL of aqueous solutions containing 0, 2.5, 5.0, 10.0, 15.0 and 20.0 ug ml^{-1} butachlor in 0.01 M $CaCl_2$ in teflon lined screw capped glass centrifuge tubes. These concentrations were equivalent to 0, 12.5, 25.0, 50.0, 75.0 and 100.0 ug of butachlor per gram of soil respectively. The contents were equilibrated for 12 hrs on a wrist action shaker. At the end of equilibration, the contents were centrifuged at 5,000 rpm for 15 minutes. Two mL of supernatant was removed from the centrifuge tube for the estimation of butachlor. The quantity of butachlor adsorbed was calculated by determining the difference between the initial concentration and concentration present in the equilibrium solution.

For studying desorption, batch equilibration was followed by replacing the supernatant with 0.01 M $CaCl_2$. After removing two mL for adsorption study, two mL of 0.01 M $CaCl_2$ was added to the same centrifuge tubes to make the volume to 10 mL. The soil suspension was equilibrated again for 12 hrs as described above and centrifuged. The process of withdrawal of 2 mL of supernatant for measuring the herbicide concentration and replacing it by 2 mL of 0.01 M $CaCl_2$ solution for reequilibration was repeated four times. The butachlor in supernatant was extracted with hexane and analysed by Gas Liquid Chromatography as described in 3.6.1.

For each measurement, a fortified blank was included to measure the effect of adsorption of herbicide on to the wall of centrifuge tubes. The amount of herbicide adsorbed on soil was calculated by equation $\mathbf{A = (C_0 - C) V / m}$, where 'A'is the amount adsorbed (ug g^{-1} of soil), 'C' and 'C_0' are equilibrium concentration (ppm) of herbicides after shaking with no soil and with soil,'V' is the volume of solution (2 mL) and 'm' is the weight of soil (2 g). Each measurement was carried out in duplicates. The adsorption-desorption was also studied in soils with two and four per cent FYM (organic carbon 9.2 %).

3.4 ADSORPTION-DESORPTION OF ^{14} C PENDIMETHALIN

Adsorption-desorption of pendimethalin was also studied in these three soils by batch equilibration method using methyl labelled ^{14}C pendimethalin.

Solution containing approximately 15,000 counts per minute per milliliter (cpm ml^{-1}) ^{14}C- pendimethalin was mixed with additional non labelled pendimethalin so that concentrations of 0, 0.1778, 0.3559, 0.5338 and 0.7117 uM pendimethalin in 0.01 M $CaCl_2$ were obtained, which corresponded to 0, 89 X 10^{-2}, 178 X 10^{-2}, 267 X 10^{-2} and 356 X 10^{-2} uM kg^{-1} soil respectively. These concentrations were equivalent to 0, 0.25, 0.50, 0.75 and 1.00 ppmw of soil.

Two g of soil and 10 mL of herbicide solution were placed in 15 mL teflon lined screw cap centrifuge tubes. The samples were equilibrated by shaking on a wrist action shaker for 6 hrs at 25+5°C. Preliminary studies indicated no significant change in pendimethalin adsorption between 6 and 24 hrs of shaking. The tubes were centrifuged at 5,000 rpm for 15 minutes. Two mL aliquot of supernatant was removed from each tube and placed in 15 mL of scintillation cocktail [7 g PPO *(2,5-Diphenyl oxazole)*, 300 mg POPOP *{1,4 bis (2-4-methyl 5-phenyl oxazolyl) benzene}* and 100 g Naphthalein dissolved in one liter of 1,4 Dioxan] and ^{14}C-activity was determined by liquid scintillation system. The quantity of pendimethalin adsorbed was calculated by determining the difference between initial herbicide concentration (cpm ml^{-1}) and concentration present in equilibrium solution.

Desorption was determined on the same samples used for adsorption. Desorption was achieved by removing 2 mL of the supernatant from the centrifuged samples and then replacing it with 2 mL of 0.01 M $CaCl_2$ solution. This process of removing 2 mL supernatant and addition of 2 mL of fresh 0.01 M $CaCl_2$ was repeated four times. Prior to each desorption, the samples were shaken for 6 hrs at 25±5°C.

A fortified blank was included in the adsorption studies to measure the effect of adsorption of herbicide to the walls of centrifuge tubes. The adsorption-desorption study was also studied in the soils amended with two and four per cent FYM (organic carbon 9.2 %).

3.5 ADSORPTION ISOTHERMS

Adsorption isotherms were constructed using the best fit regression equations. Freundlich constants K and 1/n were calculated from the equation

$$\log x/m = \log K + 1/n \log C$$

where x/m = quantity of herbicide adsorbed per unit weight of soil (mg kg^{-1} or uM kg^{-1})

C = Equilibrium concentration (mg L^{-1} or uM L^{-1})

K = Freundlich constant

$1/n$ = Slope

K is an indicator of relative adsorption affinity among herbicides at unit concentration and 1/n indicates relative linearity between adsorption and concentration of herbicides.

The adsorption varies with a number of soil properties, with the soil organic carbon content being apparently the single best predictor of the sorption coefficient. The sorption coefficient for a particular pesticide, when normalised with respect to soil organic carbon (OC) content is essentially independent of soil type and hence the normalized sorption coefficient (K_{oc}) is calculated as

$$K_{oc} = \frac{K}{\% OC} \times 100$$

where K is the Freundlich's constant and % OC is the per cent organic carbon content of soil.

3.6 PERSISTENCE OF BUTACHLOR IN SOILS

The persistence of butachlor was studied in Hiriyur, Mandya and Mudigere soils at air dry (100 MPa), at field capacity (0.033 MPa) and at submergence (0 MPa). The levels of butachlor used were 2.5 mg kg^{-1} and 5.0 mg kg^{-1}.

Five g of soil was introduced into the glass test tubes and butachlor was added to achieve the concentration levels of 2.5 mg kg^{-1} and 5.0 mg kg^{-1} of soil. The samples were then homogenized by shaking the test tubes manually. Then the samples were brought to required soil moisture tensions by adding distilled water. Submergence (0 MPa) was achieved by adding 8 mL of water to all the soils so that 1.5 cm water column was maintained over the soil surface. The test tubes were then incubated in B.O.D at 30°C. Initial weight of each test tube was recorded and moisture contents were maintained by periodic additions of water. At periodic intervals (0, 1, 8, 15, 22, 36, 57 and 85 days after treatment) tubes were removed for residue analysis in duplicate.

3.6.1 PERSISTENCE OF BUTACHLOR IN ORGANIC AMENDED SOILS

The persistence of butachlor (5 mg kg^{-1}) was also monitored in Hiriyur, Mandya and Mudigere soils fortified with one and two per cent of FYM (organic carbon 9.2 %) and paddy straw (organic carbon 28.5 %) on w/w basis under two moisture regimes namely field capacity (0.033 MPa) and submergence (0 MPa). The experimental procedure was similar as in 3.6 and 3.6.3. The soils were analysed for butachlor residue at 0, 1, 4, 8, 15, 22, 36 and 57 days after application.

3.6.2 RELATIVE PERSISTENCE OF BUTACHLOR IN AUTOCLAVED (STERILE) AND NONAUTOCLAVED (NON STERILE) SOILS UNDER FIELD CAPACITY AND SUBMERGENCE

In order to get more insight into the degradation of butachlor in soil the relative persistence in autoclaved and nonautoclaved soils were compared. Test tubes containing 5 g of soil moistened with two to three drops of water were autoclaved for 1 hr at 15 psi. Autoclaving was repeated three times on alternate days. Butachlor stock solution was then added to sterile and non sterile soils to achieve concentrations of 5 mg kg^{-1} of soil. Additional sterile water was added to achieve field capacity and flooded conditions. The tubes were plugged with cotton and kept for incubation in BOD at 30°C. At periodic intervals two tubes were removed for residue analysis by gas chromatographic method as given in 3.6.3.

3.6.3 EXTRACTION OF BUTACHLOR AND RESIDUE ANALYSIS

The extraction of butachlor from soil was carried out by using methanol, acetone and acetonitrile and latter partitioned with hexane. Since established methods with acetone (Mabbayad *et al.* 1984), acetonitrile (Kulshrestha, 1987) gave only 60% recovery, extraction by methanol and subsequent partitioning with hexane gave a recovery of 85%, a method was standardised with methanol as extractant and subsequent partitioning with hexane.

The soil samples were transferred to 100 mL stoppered conical flask along with 50 mL methanol. The flasks were shaken for one hr in a reciprocating shaker and filtered under suction. The extract was then transferred to separating funnel. Fifty mL of hexane was added, shaken for 30 seconds and layers were allowed to separate. Upper hexane layer was collected and lower layer was further extracted twice with 25 mL of hexane. The hexane fractions were pooled and passed through anhydrous sodium sulphate and was concentrated by using rotary flash evaporator under vacuum at 40°C. The concentrated hexane was transferred to graduated test tube and made up to 5 mL by adding repeated washings. Two uL aliquot of the extract was injected into a Chemito 2865 Gas Chromatograph for analysis. The gas chromatographic parameters were as follows

Detector	-	Electron Capture Detector (ECD) at 250 °C.
Column Specifications		
Liquid Phase	-	5 % SE 30
Solid Phase	-	CH (WHP)
Mesh Size	-	80/100
Length	-	1 m
Diameter	-	1.8 mm
Injector Port Temperature	-	240 °C
Oven Temperature	-	225 °C
Carrier Gas	-	Nitrogen
Carrier Flow rate	-	40 mL min^{-1}
Retention time	-	3.16 minutes

Recovery per cent of butachlor was determined for three soils at two rates of application under three moisture regimes. Recovery per cent was also determined in soils with organic amendments and the data are furnished in Table. 3.

3.7 PERSISTENCE OF PENDIMETHALIN IN SOILS

The persistence of pendimethalin was studied in Hiriyur, Mandya and Mudigere soils under three moisture regimes namely air dry (100 MPa), field capacity (0.033 MPa) and submergence (0 MPa).

Two levels of ^{14}C- pendimethalin @ 0.5 mg kg^{-1} and 5.0 mg kg^{-1} were introduced into 50 mL test tubes containing 5 g each of the soil. Respective levels were achieved by adding 50 uL and 500 uL of 50 ppm stock solutions. The soil was homogenised after addition of pendimethalin by manual shaking. Additional water was added to bring the soils to moisture regimes equivalent to either 0.033 MPa or 0 MPa soil water tension. Submergence (0 MPa) was achieved by adding 8 mL of water to all the soils, so that 1.5 cm of water column was maintained over the soil surface. The weight of each test tube was recorded for periodic adjustments of water content. A set of test tubes were removed immediately to determine the initial counts of ^{14}C - pendimethalin. Test tubes were incubated at 30°C in B.O.D incubator. Duplicate tubes were removed for estimation of pendimethalin residues at 1, 8, 15, 22, 36, 57 and 85 days after treatment.

3.7.1 PERSISTENCE OF PENDIMETHALIN IN ORGANIC AMENDED SOILS

The persistence of pendimethalin (5mg kg^{-1}) was also carried out in Hiriyur, Mandya and Mudigere soils fortified with one and two per cent FYM and paddy straw under field capacity (0.033 MPa) and submergence (0 MPa). The experimental procedure was similar as in 3.7. The soil samples were analysed for residue at 0, 1, 4, 8, 15, 22 and 36 days after application of pendimethalin as in 3.7.3.

3.7.2 RELATIVE PERSISTENCE OF PENDIMETHALIN IN AUTOCLAVED (STERILE) AND NONAUTOCLAVED (NONSTERILE) SOILS UNDER FIELD CAPACITY AND SUBMERGENCE

In order to study the role of microorganisms in the degradation of pendimethalin in soils, the relative persistence of pendimethalin in autoclaved and nonautoclaved soils were compared. To sterilize, 5 g of each soils moistened with two to three drops of water were placed in 50 mL test tubes with thin shallow moist layers and then autoclaved for 1 hr at 15 psi. Autoclaving was repeated three times on alternate days. ^{14}C-labelled pendimethalin was added to autoclaved and nonautoclaved soils to achieve 5 mg kg^{-1} level of herbicide. Additional water was added to achieve required moisture levels namely field capacity and submergence. The samples were incubated in B.O.D. incubator at 30°C. Test tubes were removed in duplicate each time for residue analysis at periodic intervals.

3.7.3 EXTRACTION OF ^{14} C PENDIMETHALIN AND RESIDUE ANALYSIS

The extraction and analysis of pendimethalin were carried out as per the method of Zimdahl *et al.* (1984). The contents of the test tubes were quantitatively transferred to 100 mL conical flask using 50 mL acidified methanol (methyl alcohol, water and concentrated HCl in the ratio of 75:24:1). The flasks were shaken for one hour on a reciprocating shaker and filtered under suction. The extract was transferred to 250 mL separating funnel. Fifty mL of hexane was added to the funnel, shaken for 30 seconds and layers were allowed to separate. The aqueous layer was further extracted twice with hexane, each time with 25 mL. The pooled hexane was passed through anhydrous sodium sulphate and evaporated to dryness by using rotary flash evaporator. The residue was dissolved in hexane and transferred to graduated storage vials and the volume was made up to 2 mL. Fifty uL of aliquot was transferred to scintillation vials containing five mL of scintillation cocktail (7g PPO, 300 mg POPOP and 100 g naphthalein dissolved in one liter of 1,4 dioxan) and ^{14}C activity was determined by using liquid scintillation system. The data on recovery per cent of pendimethalin in soils and also with organic amendments under different moisture regimes are presented in Table.4.

Table - 3 Percent recovery of Butachlor & ^{14}C-Pendimethalin from soils under different moisture regimes

SOIL	Rate of application (mg kg-1)	Moisture Regimes		
		Air dry	Field Capacity	Submergence
		Butachlor		
Hiriyur	2.5	89.16	86.86	88.66
	5.0	90.12	87.79	89.27
Mandya	2.5	88.15	86.15	86.41
	5.0	90.89	86.86	87.03
Mudigere	2.5	92.44	88.34	90.52
	5.0	93.17	90.18	91.14
		^{14}C - Pendimethalin		
Hiriyur	0.5	94.65	94.25	92.08
	5.0	94.04	86.54	88.92
Mandya	0.5	95.81	92.08	92.89
	5.0	92.78	84.01	86.78
Mudigere	0.5	93.09	91.07	89.84
	5.0	89.27	88.57	88.22

Table - 4 Per cent recovery of Butachlor & ^{14}C-Pendimethalin from soils with organic amendements under different moisture regimes

Soil	Field Capacity	Submergence
	Butachlor	
HF1	82.86	86.47
HF2	81.49	85.33
HPS1	83.44	86.12
HPS2	83.00	86.00
MaF1	80.16	84.86
MaF2	78.44	84.15
MaPS1	82.59	86.45
MaPS2	80.47	85.39
MuF1	86.34	90.15
MuF2	85.55	89.06
MuPS1	88.11	89.53
MuPS2	87.00	88.13
	^{14}C-Pendimethalin	
HF1	92.86	89.38
HF2	92.10	88.93
HPS1	93.44	87.74
HPS2	92.10	86.17
MaF1	85.17	86.29
MaF2	85.76	84.54
MaPS1	87.41	88.19
MaPS2	86.10	85.50
MuF1	90.49	88.56
MuF2	89.24	87.74
MuPS1	89.55	88.96
MuPS2	89.10	86.87

H - Hiriyur Ma - Mandya Mu - Mudigere

F- Farm Yard Manure PS - Paddy Straw 1 - One percent 2 - Two percent

3.8 DEGRADATION KINETICS

The results of the persistence and degradation of butachlor and pendimethalin were fitted to first order exponential equation in order to interpret the rate of degradation. The equation is

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

where C is the concentration after time t, C_0 is the initial concentration and K the rate constant. Thus a plot of the logarithm of concentration against time gives a straight line with slope proportional to the rate constant. Writing $t_{1/2}$ as the time taken for 50 per cent degradation or "half life", the above equation becomes

$$t_{1/2} = 0.6932 / K$$

3.9 LEACHING/MOBILITY OF HERBICIDES IN SOILS

3.9.1 PREPARATION OF SOIL COLUMNS

Polyvinyl chloride (PVC) pipes of 2.5 mm thickness were used in the present study. Each column was of 35 cm length with 6 cm inner diameter. The columns were split open longitudinally into two equal halves. The two halves of each column were joined together and held in place with the help of adhesive tapes. The bottom of soil column was closed with aluminium sheet with perforations and tied with the help of metal clamps. A layer of one cm thick glasswool was placed at the bottom, over which soil was packed to 30 cm length. The experimental set up is shown in Plate. 1.

3.9.2 APPLICATION OF HERBICIDE

Butachlor stock solution of 2000 ppm was prepared and required quantity was added to the soil columns in order to achieve the concentration of 5 mg kg^{-1} of soil.

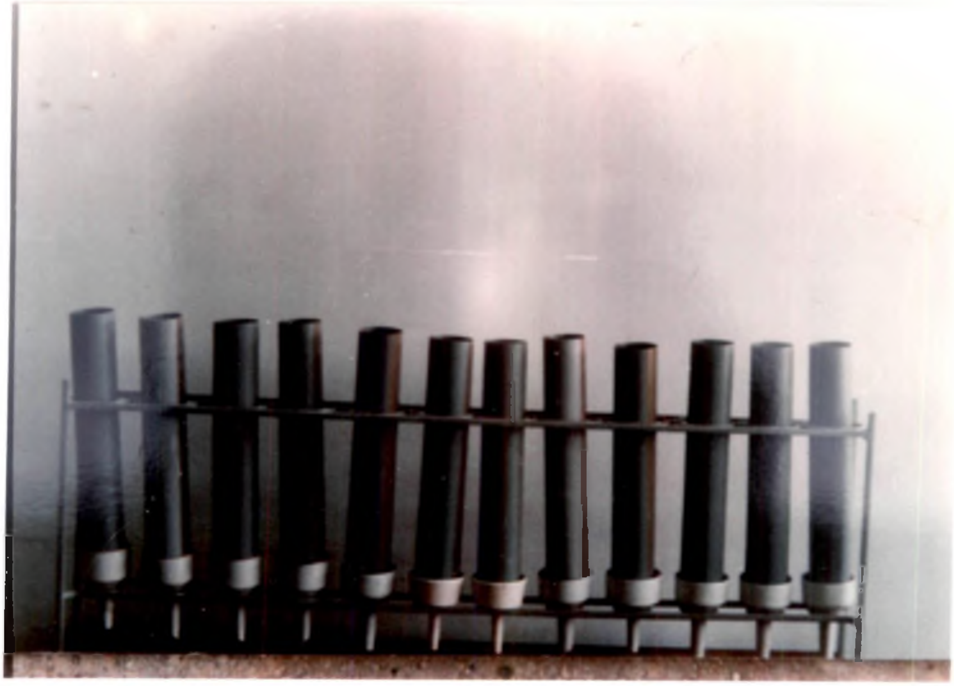


Plate-1. Experimental set up for mobility study

Pendimethalin (^{14}C-labelled) was mixed with 2000 ppm stock solution of nonlabelled pendimethalin to obtain approximately 40,000 counts per minute (cpm). From the stock solution required quantity was added to soil columns to achieve a concentration of 5 mg kg^{-1} of soil. The required chemical was mixed with top 1 cm soil and stirred thoroughly without disturbing the soils below to ensure distribution of the chemical on the surface of the column.

3.9.3 MOBILITY STUDY - I

After the addition of herbicide, one cm layer of glasswool was placed. Calculated amount of water was added to soil columns to achieve field capacity (0.033 MPa). Duplicate columns were used for each interval of 6, 24 and 72 hrs of leaching study. After 6 hours a volume of 100 mL of water was added to all the columns set to remove after 24 and 72 hrs. There was no leachate in all the soil columns in the first 6 hrs interval. After 24 hrs another increment of 100 mL of water was added to the soil columns to be removed at the end of 72 hrs. To avoid any degradation of chemical, the collected leachate was removed at every 6 hrs interval and stored at -5°C. The leachate were then pooled and analysed for butachlor and pendimethalin.

3.9.4 MOBILITY STUDY - II

In order to simulate mobility of herbicides in soils at varying moisture regimes in the field, another study was conducted using saturated soil columns for the application of herbicides. In this experiment, PVC columns filled with soils upto 30 cm height as described in 3.9.1 were kept in 600 mL beakers containing about 200 mL of water to allow upward movement of water. After one and two hrs additional 100 mL of water was added to beakers and the columns were kept for 24 hrs to attain saturation by upward movement of water. Herbicide was added at the rate of 5 mg kg^{-1} soil. Two hundred mL of water was added to each column in aliquots of 50 mL and leachate was collected after 6 hrs. Similarly 200 mL of water was added in aliquots after every 6 hrs upto 24 hrs and leachates were collected at respective intervals. Leachates were analysed for the herbicides as mentioned in 3.6.3 and 3.7.3.

3.9.5 CHEMICAL ASSAY

At the end of each interval, soil columns were split open longitudinally, removing the adhesive tape by passing an aluminium knife through the longitudinal opening.

One half of each column was separated into four equal depths at 0-7.5, 7.5-15.0, 15-22.5 and 22.5-30.0 cm. Soil from each depth was thoroughly mixed and 100 g was taken for herbicide extraction and analysed. Butachlor extraction was done by adding 200 mL of methanol to 100 g of soil in 500 mL conical flask. The detailed procedure of extraction and analysis is mentioned in the section 3.6.3. Pendimethalin extraction was done by adding 200 mL of acidified methanol to 100 g of soil in 500 mL conical flask and extracted and analysed as described in the section 3.7.3. Butachlor extraction in leachate was done with hexane and analysed by gas liquid chromatography and pendimethalin extraction in leachate was also done with hexane and analysed by liquid scintillation system.

3.9.6 BIOASSAY

The other half of the soil column was used for bioassay by growing ragi *(Eleucine coracana)* var. PR 202 as indicator plant(Leela, 1988). The whole length of the soil column was bifurcated into four depths by aluminium foils. Ragi seeds were sown at the rate of 0.5 g in each depth which accounted for about 150 seeds. After sowing, the columns were kept in germination chamber and optimum moisture was maintained by using mist sprayer to ensure growth of seedlings. Minimum water was used to avoid any further leaching of chemical. Seedlings were removed 10 days after sowing and fresh weights of shoots were recorded.

In another experiment ragi was grown in soils with graded levels of herbicides to test its sensitivity to herbicide residues. One hundred g of soil was mixed with either butachlor or pendimethalin to achieve the standard concentrations of 0, 0.5, 1.0, 2.0, 4.0 and 8.0 mg kg^{-1} soil and transferred to petridishes. Calculated amount of water was added to maintain field capacity. One hundred ragi seeds were sown uniformly. The weight of petridishes were recorded for the addition of water twice daily. Seedlings were removed 10 days after sowing and fresh weights of shoots were recorded.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Studies were conducted to monitor adsorption, desorption, persistence-degradation and movement of butachlor and pendimethalin herbicides in three soils representing different series of Karnataka. The soils were collected from Hiriyur *(Fine mixed isohyperthermic chromic haplusterts - Hiriyur Series)*, Mandya *(Fine loamy mixed isohyperthermic typic ustropepts - Mangala Series)* and Mudigere *(Loamy skeletal kaolinitic isothermic ustic Kanhaplohumult - Mudigere Series)*. The results of the studies are presented in this chapter.

4.1 PHYSICO-CHEMICAL PROPERTIES OF SOILS

The data on physico-chemical properties of soils are presented in Table. 5. The Hiriyur soil was clayey in texture with a clay content of 45.85 per cent while Mandya and Mudigere soils were sandy clay loam in texture with 25.78 and 20.13 per cent clay respectively.

The moisture content at field capacity (0.033 MPa) was lowest in Mudigere soil (18.9 %) as compared to Hiriyur (38.6%) and Mandya (31.4%) soils. The soil organic carbon content was highest in Mandya (1.1 %) and lowest in Mudigere (0.30 %) and Hiriyur recorded an intermediate value (0.57%). The hydraulic conductivity at saturation, in Hiriyur, Mandya and Mudigere soils were 0.56, 1.89 and 2.95 cm hr^{-1} respectively.

Soil reaction (pH) of these soils varied widely. Hiriyur soil was alkaline (9.12) with a cation exchange capacity of 35.93 cmol kg^{-1}, whereas Mandya and Mudigere soils were neutral (6.98) and acidic (4.95) with cation exchange capacity of 21.72 and 10.79 cmol kg^{-1} respectively.

The available N, P and K contents were 292.49, 28.97 and 145.85 kg ha^{-1} in Hiriyur, 487.43, 18.74 and 176.29 kg ha^{-1} in Mandya and 260.79, 3.62 and 139.91 kg ha^{-1} in Mudigere soil respectively. The exchangeable Ca, Mg and Na were highest in Hiriyur soil when compared to Mandya and Mudigere soils.

Table - 5 Physico - Chemical properties of soils

Sl. No.	PARAMETERS	HIRIYUR	MANDYA	MUDIGERE
1.	Particle size distribution			
	Sand (%)	41.19	65.82	51.44
	Silt (%)	11.00	8.15	27.88
	Clay (%)	45.85	25.78	20.13
	Textural Class	Clay	Sandy clay loam	Sandy clay loam
2.	Taxonomical Classification	Fine mixed isohyper thermic chromic haplusterts	Fine loamy mixed isohyperthermic typic ustropepts	Loamy Skeleted Kaolinitic isothermic ustic Kanhaplohumult
3.	Colour	10YR 5/4	7.5YR 5/6	5 YR 5/6
4.	Moisture content (%) at			
	Field capacity	38.6	31.4	18.9
5.	Organic carbon (%)	0.57	1.10	0.30
6.	Hydraulic conductivity (cm h^{-1})	0.56	1.89	2.95
7.	pH (1:2.5 Soil : Water)	9.12	6.98	4.95
8.	Electrical conductivity (dSm^{-1})	0.45	0.22	0.04
9.	Cation exchange capacity (cmol kg^{-1})	35.93	21.72	10.79
10.	Available N (kg ha^{-1})	292.49	487.43	260.79
11.	Available P (kg ha^{-1})	28.97	18.74	3.62
12.	Available K (kg ha^{-1})	145.85	176.29	139.91
13.	Exchangeable Ca (cmol kg^{-1})	15.54	10.86	3.07
14.	Exchangeable Mg (cmol kg^{-1})	11.21	5.02	2.30
15.	Exchangeable Na (cmol kg^{-1})	6.41	0.75	0.47
16.	Exchangeable K (cmol kg^{-1})	0.95	0.36	1.18
17.	Fe_2O_3 (mg kg^{-1})	1.89	6.28	3.95
18.	Al_2O_3 (mg kg^{-1})	1.03	3.11	1.28

Exchangeable Ca and Mg were 15.54 and 11.21 cmol kg^{-1} in Hiriyur, 10.86 and 5.02 cmol kg^{-1} in Mandya and 3.07 and 2.30 cmol kg^{-1} in Mudigere soil respectively.

The free iron and aluminium oxides (Fe_2O_3 and Al_2O_3) were lower in Hiriyur (1.89 and 1.03 mg kg^{-1}) than Mandya (6.28 and 3.11 $mgKg^{-1}$) and Mudigere (3.95 and 1.28 mg kg^{-1}) soil.

4.2 ADSORPTION - DESORPTION OF BUTACHLOR

The results of adsorption - desorption of butachlor on Hiriyur, Mandya and Mudigere soils are presented in Tables. 6, 7 and 8 respectively.

The data in Table. 6. depict the adsorption desorption of butachlor in Hiriyur soil and also the soil incorporated with two and four per cent (w/w) farm yard manure (FYM) as organic amendment.

As illustrated in Fig. 1. adsorption of butachlor was lower at low equilibrating concentration and increased with increase in butachlor concentration. The adsorption of butachlor ranged from 8.27 to 53.37 mg kg^{-1} of soil for the initial concentration ranging from 12.5 to 100.0 mg kg^{-1}. Though there was an increase in adsorption with increase in equilibrating concentration, the per cent adsorption showed a reverse trend (69.38 % at 12.5 mg kg^{-1} and 53.37 at 100.00 mg kg^{-1}). The cumulative desorption of butachlor ranged from 2.00 to 16.36 mg kg^{-1} and the corresponding percentage desorptions were 24.22 to 30.66 (Table. 6).

Adsorption of butachlor increased with the incorporation of two per cent FYM, and ranged from 8.98 to 59.94 mg kg^{-1} for the initial concentration range of 12.5 mg kg^{-1} to 100 mg kg^{-1} respectively. The per cent adsorption of butachlor for Hiriyur soil with two per cent FYM decreased from 71.87 to 59.93 whereas cumulative desorption and per cent desorption increased from 2.09 to 17.47 mg kg^{-1} and 23.24 to 29.14 for an initial concentration range of 12.5 to 100.00 mg kg^{-1} respectively. Further increasing the level of FYM to four per cent

Table - 6 Adsorption - Desorption of Butachlor in Hiriyur soil

	INITIAL CONCENTRATION (mg kg^{-1})				
	12.5	25.0	50.0	75.0	100.0
SOIL ALONE					
Equilibrium Concentration (mg L^{-1})	0.85	1.79	3.67	6.18	9.33
Adsorption (mg kg^{-1})	8.27	16.06	31.67	44.12	53.37
% Adsorption	69.38	64.23	63.34	58.82	53.37
Cumulative Desorption (mg kg^{-1})	2.00	4.17	8.44	12.33	16.36
% Desorption	24.22	25.99	26.64	27.94	30.66
SOIL WITH 2% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	0.70	1.55	3.45	5.74	8.01
Adsorption (mg kg^{-1})	8.98	17.24	32.73	46.31	59.93
% Adsorption	71.87	68.94	65.47	61.77	59.93
Cumulative Desorption (mg kg^{-1})	2.09	4.25	8.61	13.06	17.47
% Desorption	23.24	24.64	26.30	28.19	29.14
SOIL WITH 4% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	0.59	1.29	3.03	5.10	7.13
Adsorption (mg kg^{-1})	9.53	18.56	34.84	49.48	64.37
% Adsorption	77.81	74.26	69.68	65.97	64.37
Cumulative Desorption (mg kg^{-1})	2.14	4.31	8.75	13.19	18.07
% Desorption	22.46	23.20	25.12	26.66	28.07

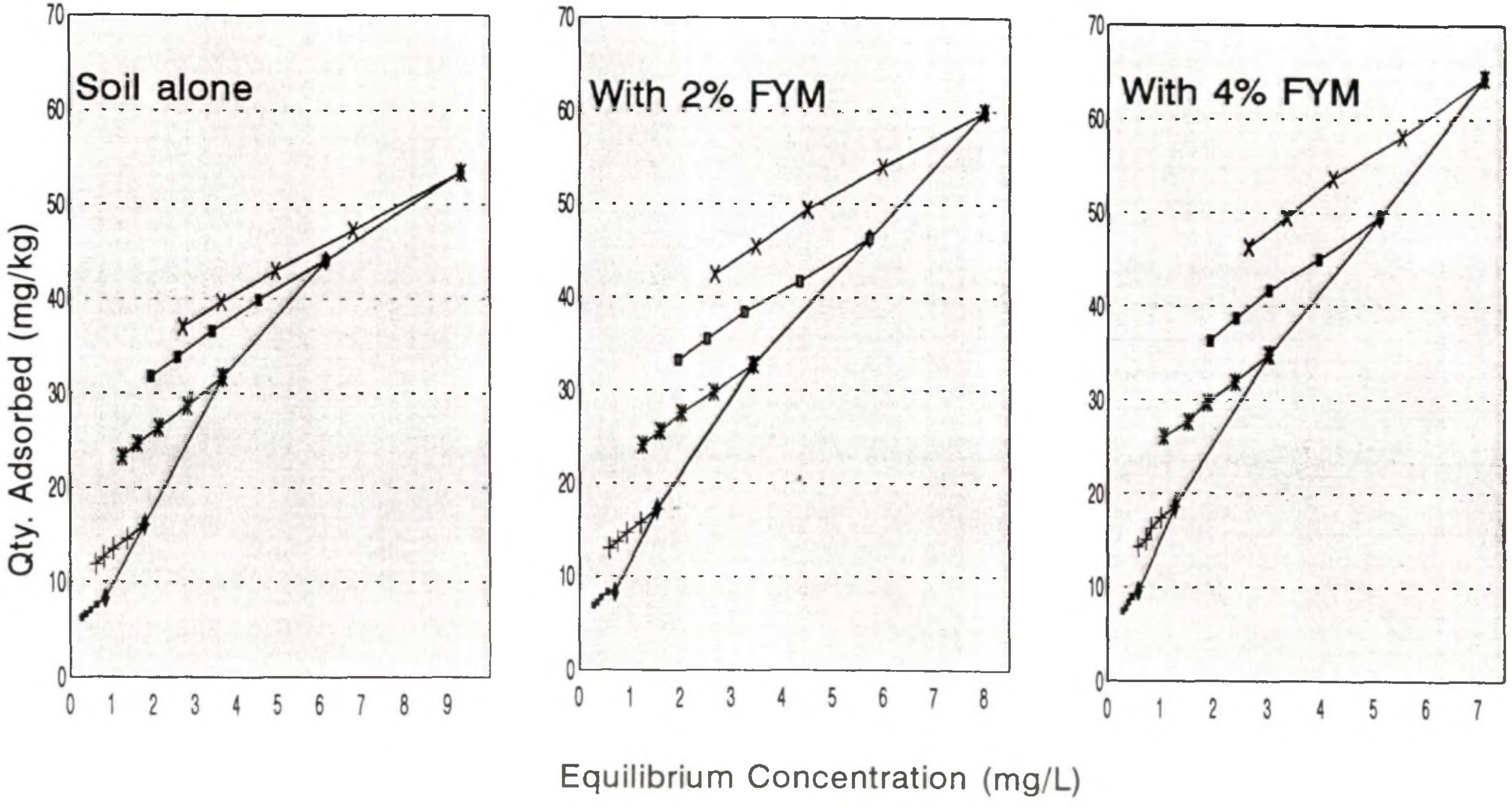


Fig.1 ***Adsorption-Desorption of Butachlor in Hiriyur Soil***

increased the adsorption of butachlor. The adsorption ranged from 9.53 to 64.37 mg kg^{-1} for the initial concentration range of 12.5 to 100.00 mg kg^{-1}. The per cent adsorption increased with the incorporation of FYM at four per cent level whereas, the per cent desorption showed a decreasing trend. The cumulative desorption and per cent desorption for Hiriyur soil ranged from 2.14 to 18.07 mg kg^{-1} and 22.46 to 28.07 respectively for the initial concentration range of 12.5 to 100.00 mg kg^{-1}.

The data on adsorption and desorption of butachlor in Mandya soil are presented in Table. 7. The Fig. 2. illustrates the adsorption - desorption isotherm of butachlor in Mandya soil.

The adsorption of Butachlor increased with increase in the initial concentration as in Hiriyur soil. It increased from 9.25 to 70.32 mg kg^{-1} as the initial concentration increased from 12.5 mg kg^{-1} to 100 mg kg^{-1} soil. The per cent adsorption decreased from 75.49 at 12.5 mg kg^{-1} initial concentration to 70.37 at 100 mg kg^{-1}. The cumulative desorption and per cent desorption also showed an increasing trend with increasing initial concentration and ranged from 1.9 to 17.08 mg kg^{-1} and 20.52 to 24.29 per cent at 12.5 mg kg^{-1} and 100.0 mg kg^{-1} respectively.

Soil with two per cent FYM showed increase in adsorption from 9.94 to 72.32 mg kg^{-1} at 12.5 and 100.0 mg kg^{-1} of initial concentration respectively. It was found that the per cent adsorption increased with the addition of FYM and ranged from 81.09 to 72.32 for an initial concentration range of 12.5 to 100 mg kg^{-1}. The cumulative desorption and per cent desorption ranged from 1.99 to 17.50 mg kg^{-1} and 20.00 to 24.20 as the initial concentration increased from 12.5 to 100 mg kg^{-1}.

The incorporation of four per cent FYM further increased the adsorption but decreased the desorption at each initial concentration. The adsorption and per cent adsorption ranged from 10.38 to 74.93 mg kg^{-1} and 84.71 to 74.93 for a concentration range of 12.5 to 100.0 mg kg^{-1} respectively. The cumulative

Table - 7 Adsorption - Desorption of Butachlor in Mandya soil

	INITIAL CONCENTRATION (mg kg^{-1})				
	12.5	25.0	50.0	75.0	100.0
SOIL ALONE					
Equilibrium Concentration (mg L^{-1})	0.66	1.29	2.69	4.08	5.94
Adsorption (mg kg^{-1})	9.25	18.58	36.57	54.58	70.32
% Adsorption	75.49	74.30	73.14	72.77	70.37
Cumulative Desorption (mg kg^{-1})	1.90	3.98	8.19	12.81	17.08
% Desorption	20.52	21.43	22.41	23.48	24.29
SOIL WITH 2% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	0.51	1.10	2.29	3.78	5.54
Adsorption (mg kg^{-1})	9.93	19.50	38.55	56.09	72.32
% Adsorption	81.09	78.01	77.10	74.78	72.32
Cumulative Desorption (mg kg^{-1})	1.99	4.10	8.44	12.53	17.50
% Desorption	20.00	21.04	21.88	22.34	24.20
SOIL WITH 4% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	0.42	0.92	1.95	3.20	5.01
Adsorption (mg kg^{-1})	10.38	20.39	40.23	58.98	74.93
% Adsorption	84.71	81.55	80.47	78.65	74.93
Cumulative Desorption (mg kg^{-1})	1.67	3.31	6.85	10.94	16.67
% Desorption	16.06	16.25	17.03	18.55	22.25

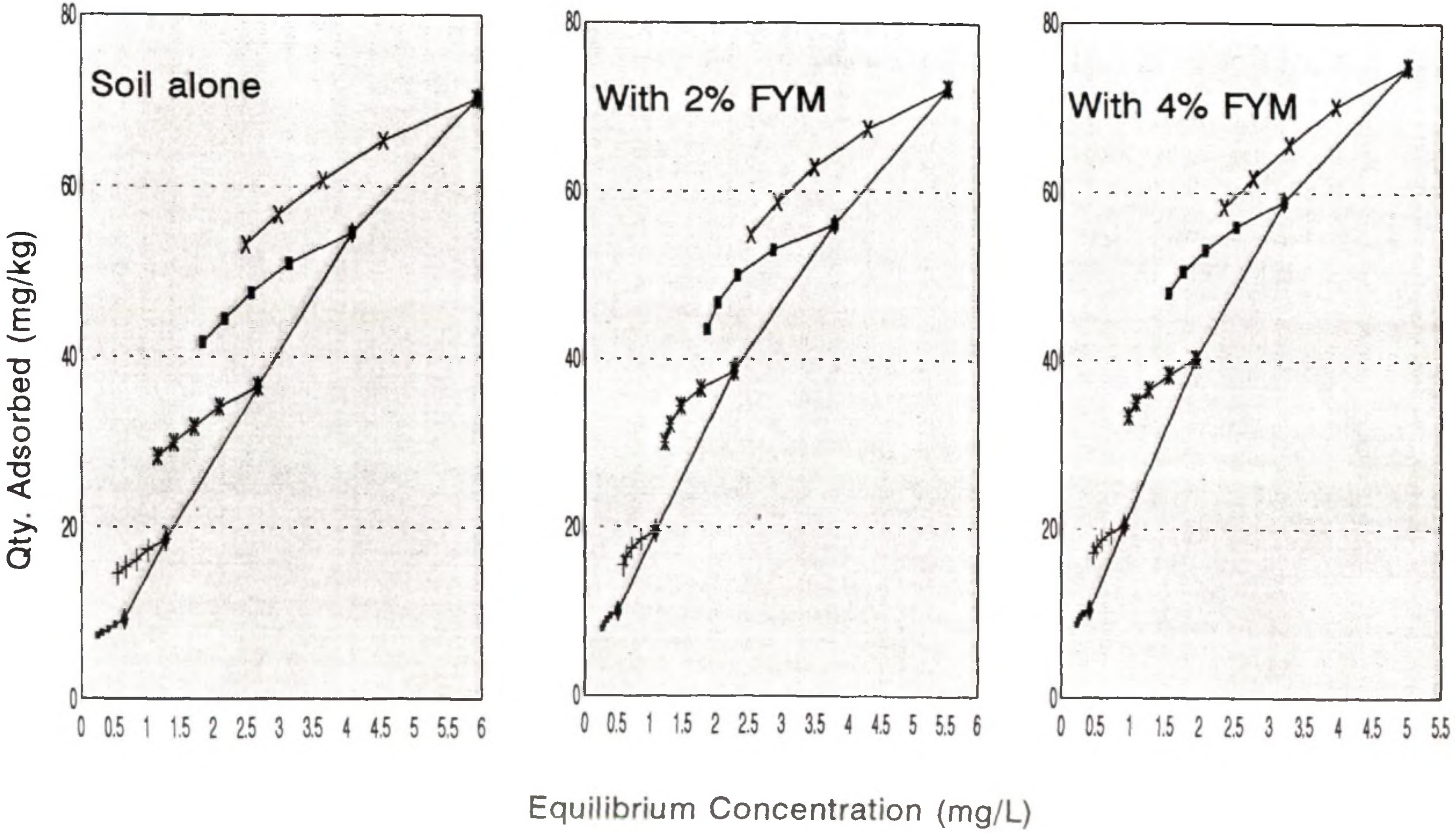


Fig.2 ***Adsorption-Desorption of Butachlor in Mandya Soil***

desorption and per cent desorption ranged from 1.67 to 16.67 mg kg^{-1} and 16.06 to 22.25 per cent as the initial concentration increased from 12.5 to 100 mg kg^{-1}. It was observed that the addition of FYM decreased the cumulative desorption and per cent desorption.

The data in Table. 8. pertain to the adsorption and desorption of butachlor in Mudigere soil. The Fig. 3. illustrates the adsorption - desorption isotherm of butachlor in Mudigere soil.

The adsorption and desorption of butachlor in Mudigere soil showed a similar trend as observed in Hiriyur and Mandya soils. As the initial concentration increased from 12.5 to 100 mg kg^{-1}, the adsorption and per cent adsorption increased from 5.83 to 43.9 mg kg-1 and 47.56 to 43.90, whereas, cumulative desorption and per cent desorption decreased from 1.90 to 16.72 mg kg^{-1} and 32.62 to 38.09 respectively. In case of soil with two per cent FYM the adsorption of butachlor and per cent adsorption increased from 6.66 to 48.66 mg kg^{-1} and 53.25 to 48.66 as the initial concentration increased from 12.5 to 100.0 mg kg^{-1} respectively. Addition of FYM decreased the cumulative desorption and per cent desorption. With 12.5 mg kg^{-1} initial concentration 30.99 per cent desorption was observed whereas, with 100.0 mg kg^{-1} 35.10 per cent was the cumulative desorption.

The incorporation of four per cent FYM further increased the adsorption and per cent adsorption from 7.53 to 55.23 mg kg^{-1} and 60.24 to 55.23 at an initial concentration range of 12.5 to 100 mg kg^{-1} respectively. The cumulative desorption and per cent desorption of adsorbed butachlor also registered decreasing trend with the addition of FYM and ranged from 2.19 to 18.82 mg kg^{-1} and 29.03 to 34.08 respectively for a concentration range of 12.5 to 100.0 mg kg^{-1}.

The Freundlich constant **K**, slope **1/n**, determination coefficient $\mathbf{r^2}$ and K_{oc} values for Hiriyur, Mandya and Mudigere soils and also with two and four per cent FYM are given in the Table. 9. The Freundlich constant (K) was highest

Table - 8 Adsorption - Desorption of Butachlor in Mudigere soil

	INITIAL CONCENTRATION (mg kg^{-1})				
	12.5	25.0	50.0	75.0	100.0
SOIL ALONE					
Equilibrium Concentration (mg L^{-1})	1.33	2.63	5.35	8.38	11.22
Adsorption (mg kg^{-1})	5.83	11.84	23.24	33.12	43.90
% Adsorption	47.56	47.34	46.47	44.17	43.90
Cumulative Desorption (mg kg^{-1})	1.90	3.81	8.29	12.19	16.72
% Desorption	32.62	34.51	35.68	36.82	38.09
SOIL WITH 2% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	1.17	2.36	4.82	7.43	10.27
Adsorption (mg kg^{-1})	6.66	13.21	25.88	37.84	48.66
% Adsorption	53.25	52.87	51.76	50.45	48.66
Cumulative Desorption (mg kg^{-1})	2.06	4.21	8.45	12.94	17.08
% Desorption	30.99	31.83	32.66	34.19	35.10
SOIL WITH 4% (W/W) FYM					
Equilibrium Concentration (mg L^{-1})	0.99	2.03	4.20	6.53	8.95
Adsorption (mg kg^{-1})	7.53	14.84	28.98	42.34	55.23
% Adsorption	60.24	59.37	57.96	56.45	55.23
Cumulative Desorption (mg kg^{-1})	2.19	4.56	9.24	14.09	18.82
% Desorption	29.03	30.73	31.90	33.27	34.08

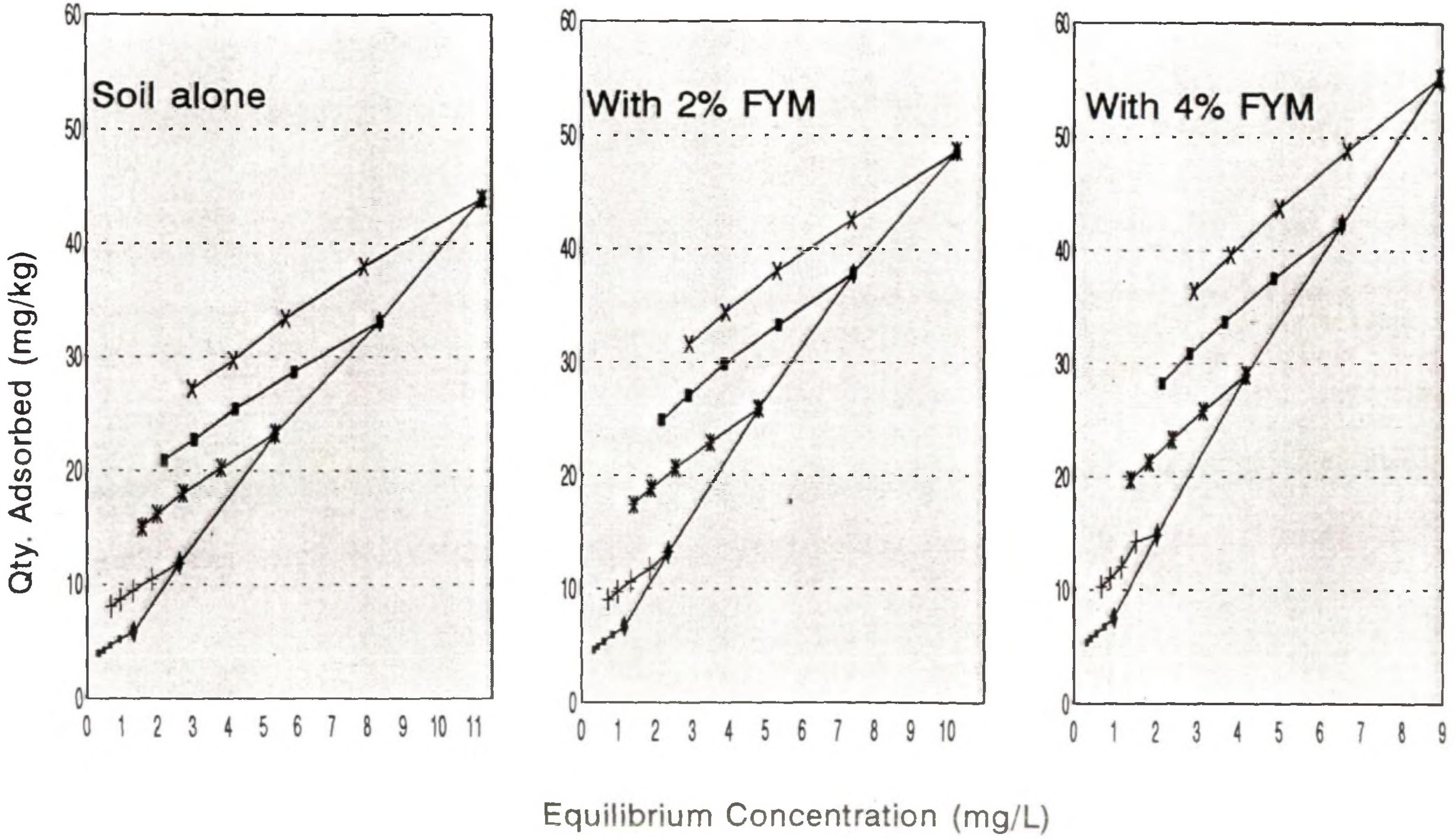


Fig.3 Adsorption-Desorption of Butachlor in Mudigere Soil

Table - 9 Freundlich constant (K & 1/n), Determination coefficients (r^2) and sorption coefficients for organic carbon (K_{oc}) for Butachlor adsorption by soils and with FYM.

	K	1/n	r^2	K_{oc}
Hiriyur Soil	10.018	0.7955	0.9876	1757
Soil with 2% (w/w)FYM	12.056	0.7782	0.9990	1623
Soil with 4%(w/w) FYM	14.669	0.7587	0.9982	1602
Mandya Soil	14.181	0.9318	0.9969	1289
Soil with 2%(w/w) FYM	17.951	0.8453	0.9970	1422
Soil with 4%(w/w) FYM	21.707	0.8190	0.9980	1524
Mudigere Soil	4.599	0.9404	0.9980	1533
Soil with 2%(w/w) FYM	5.903	0.9205	0.9985	1235
Soil with 4% (w/w)FYM	7.698	0.9078	0.9998	1173

in Mandya (14.181) and lowest in Mudigere soil (4.599). Addition of two and four per cent FYM increased the K values from 10.018 to 12.056 and 14.669 in Hiriyur soil, 14.181 to 17.951 and 21.707 in Mandya soil and 4.599 to 5.903 and 7.698 in Mudigere soil respectively.

The linearity of slopes (1/n) were 0.7955, 0.9318 and 0.9404 in Hiriyur, Mandya and Mudigere soils respectively. Addition of two and four per cent FYM decreased the slopes in all the soils. The determination coefficients (r^2) were very high (> 0.9876) in all the soils.

The sorption coefficients for organic carbon (K_{oc}) values were 1757, 1289 and 1533 in Hiriyur, Mandya and Mudigere soils respectively. The addition of two and four per cent FYM decreased the K_{oc} values to 1623 and 1602 in Hiriyur soil and 1235 and 1173 in Mudigere soil, while the addition of FYM increased the K_{oc} values in Mandya soil to 1422 and 1524 respectively.

4.3 ADSORPTION - DESORPTION OF PENDIMETHALIN

The data on adsorption desorption of pendimethalin in Hiriyur,Mandya, and Mudigere soils are given in Tables. 10, 11 and 12 respectively. The adsorption - desorption of pendimethalin in Hiriyur, Mandya and Mudigere soils are illustrated in Figs. 4, 5 and 6 respectively.

The data presented in the Table. 10. pertain to the adsorption and desorption of pendimethalin in Hiriyur soil alone and with two and four per cent FYM as organic amendment.

The adsorption of pendimethalin increased with increase in initial concentration and ranged from 75.70 X 10^{-2} to 292.40 X 10^{-2} uM kg^{-1} at 89 X 10^{-2} and 356 X 10^{-2} uM kg^{-1} levels respectively. The per cent adsorption showed a declining trend as the initial concentration increased and the values ranged from 85.21 to 81.47. The cumulative desorption and per cent desorption showed an increasing trend with increase in initial concentration of

Table - 10 Adsorption - Desorption of Pendimethalin in Hiriyur soil

	INITIAL CONCENTRATION (10^{-2}uM kg^{-1})			
	89	178	267	356
SOIL ALONE				
Equilibrium Concentration (10^{-2}uML^{-1})	2.64	5.49	8.66	12.69
Adsorption (10^{-2}uM kg^{-1})	75.70	150.40	223.60	292.40
% Adsorption	85.21	84.59	83.78	81.47
Cumulative Desorption (10^{-2}uM kg^{-1})	8.50	17.60	27.10	39.07
% Desorption	11.23	11.70	12.12	13.36
SOIL WITH 2% (w/w) FYM				
Equilibrium Concentration (10^{-2}uML^{-1})	2.14	4.55	7.99	11.32
Adsorption (10^{-2}uM kg^{-1})	78.20	155.20	228.00	299.30
% Adsorption	87.96	87.21	85.41	84.09
Cumulative Desorption (10^{-2}uM kg^{-1})	8.10	17.03	27.07	38.55
% Desorption	10.36	10.97	11.87	12.88
SOIL WITH 4% (W/W) FYM				
Equilibrium Concentration (10^{-2}uM L^{-1})	1.72	3.66	6.35	9.68
Adsorption (10^{-2}uM kg^{-1})	80.30	159.60	235.20	307.50
% Adsorption	90.33	89.71	88.10	86.40
Cumulative Desorption (10^{-2}uM kg^{-1})	6.66	13.98	24.25	37.88
% Desorption	8.29	8.76	10.31	12.32

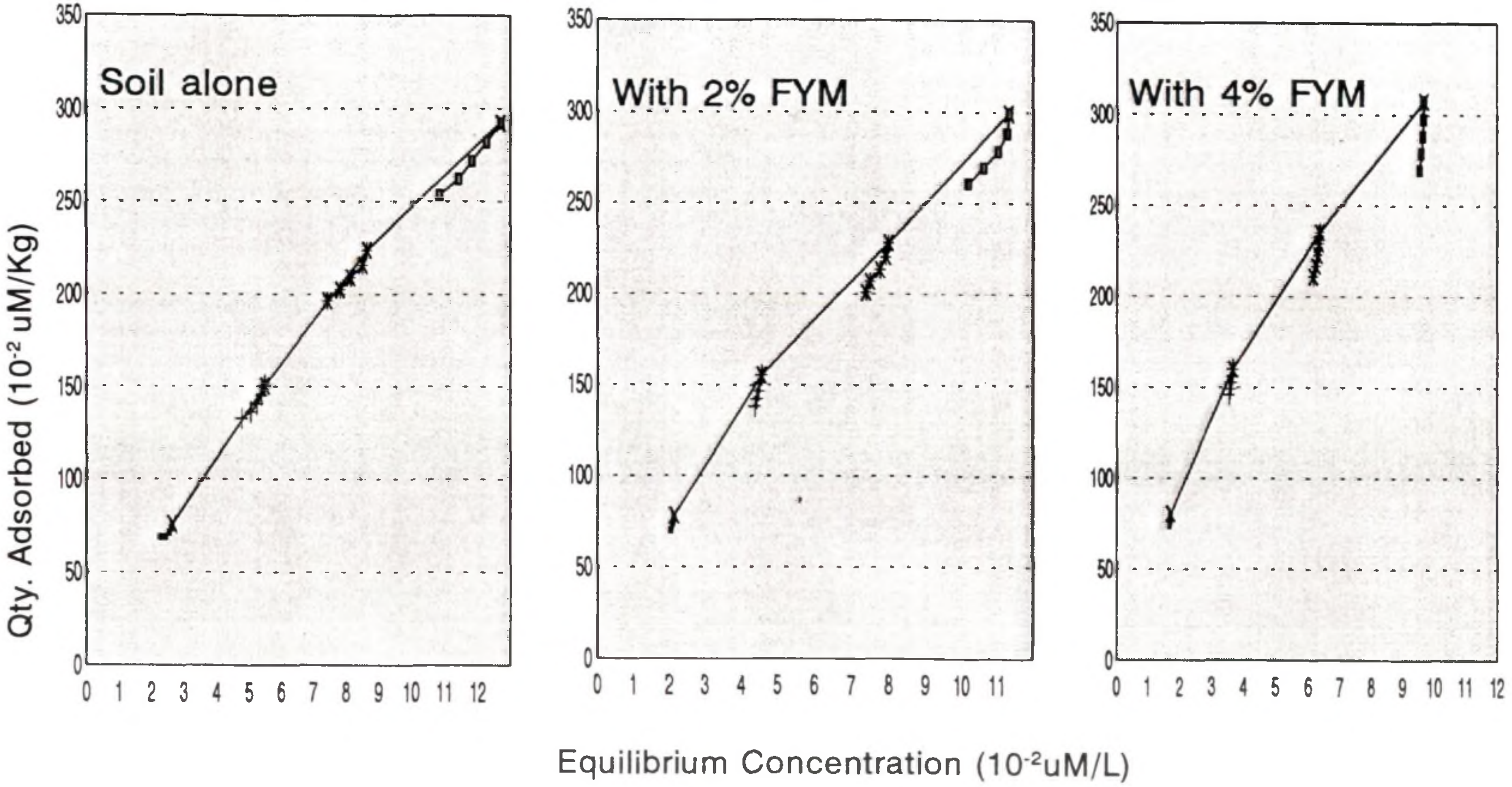


Fig.4 ***Adsorption-Desorption of Pendimethalin in Hiriyur Soil***

pendimethalin. The values for cumulative desorption ranged from 8.50 X 10^{-2} to 39.07 X 10^{-2} uM kg^{-1} whereas the per cent desorption ranged from 11.23 to 13.36 for the initial concentration range of 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil respectively.

The Hiriyur soil with two per cent FYM considerably increased the adsorption and decreased the desorption. The cumulative desorption and the per cent desorption decreased with the addition of FYM. The adsorption of pendimethalin increased from 78.20 X 10^{-2} to 299.30 X 10^{-2} uM kg^{-1} and the per cent adsorption decreased from 87.96 to 84.09 as the initial concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil respectively. The cumulative desorption and per cent desorption ranged from 8.10 X 10^{-2} to 38.55 X 10^{-2} uM kg^{-1} and 10.36 to 12.88 at 89 X 10^{-2} and 356 X 10^{-2} uM kg^{-1} soil initial concentration respectively.

Addition of four per cent FYM for Hiriyur soil further increased the adsorption and ranged from 80.30 X 10^{-2} to 307.50 X 10^{-2} uM kg^{-1}, whereas the per cent adsorption showed declining trend from 90.33 to 86.40 at initial concentration range of 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil respectively. The cumulative desorption decreased with the addition of four per cent FYM and ranged from 6.66 X 10^{-2} to 37.88 X 10^{-2} uM kg^{-1} soil. Corresponding per cent desorption ranged from 8.29 to 12.32 as the initial added concentration ranged from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil.

The data on adsorption desorption of pendimethalin in Mandya soil are given in Table. 11.

Adsorption of pendimethalin increased from 82.15 X 10^{-2} to 316.30 X 10^{-2} uM kg^{-1} as the initial concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} whereas the desorption showed the declining trend as in the case of Hiriyur soil and ranged from 92.41 to 88.89 for the corresponding initial concentration. The cumulative desorption and the per cent desorption ranged from 4.36 X 10^{-2} to 26.82 X 10^{-2} uM kg^{-1} and 5.31 to 8.48.

Table - 11 Adsorption - Desorption of Pendimethalin in Mandya soil

	INITIAL CONCENTRATION (10^{-2}uM kg^{-1})			
	89	178	267	356
SOIL ALONE				
Equilibrium Concentration (10^{-2}uM L^{-1})	1.35	2.84	5.30	7.91
Adsorption (10^{-2}uM kg^{-1})	82.15	163.75	240.4	316.30
% Adsorption	92.41	92.09	90.07	88.89
Cumulative Desorption (10^{-2}uM kg^{-1})	4.36	9.47	18.6	26.82
% Desorption	5.31	5.78	7.73	8.48
SOIL WITH 2% (W/W) FYM				
Equilibrium Concentration (10^{-2}uM L^{-1})	1.10	2.61	4.91	7.12
Adsorption (10^{-2}uM kg^{-1})	83.40	164.90	242.35	320.25
% Adsorption	93.76	92.67	90.80	89.99
Cumulative Desorption (10^{-2}uM kg^{-1})	3.51	8.43	15.95	24.97
% Desorption	4.21	5.11	6.58	7.80
SOIL WITH 4% (W/W) FYM				
Equilibrium Concentration (10^{-2}uM L^{-1})	1.03	2.39	4.49	6.48
Adsorption (10^{-2}uM kg^{-1})	83.75	166.00	244.45	323.45
% Adsorption	94.21	93.28	91.59	90.90
Cumulative Desorption (10^{-2}uM kg^{-1})	3.43	8.27	15.97	22.68
% Desorption	4.09	4.98	6.53	7.01

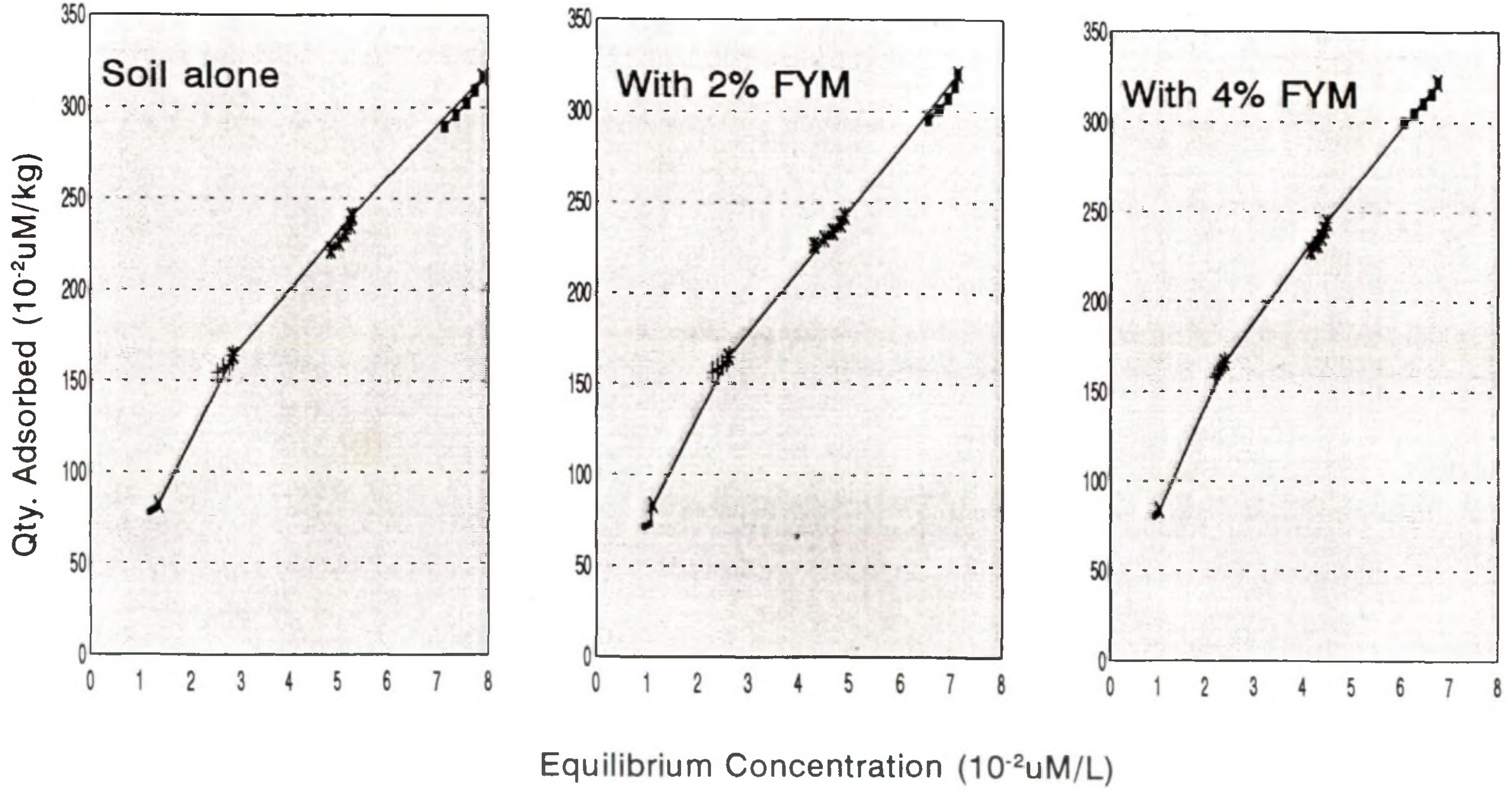


Fig.5 ***Adsorption-Desorption of Pendimethalin in Mandya Soil***

Incorporation of FYM at the rate of two per cent further increased the adsorption from 83.40 X 10^{-2} to 320.25 X 10^{-2} uM kg^{-1} soil as the initial pendimethalin concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1}, whereas the per cent adsorption decreased from 93.76 to 89.99. The cumulative desorption increased from 3.51 X 10^{-2} to 24.97 X 10^{-2} uM kg^{-1} soil and per cent desorption ranged from 4.21 to 7.80 respectively at initial concentration of 89 X 10^{-2} and 356 X 10^{-2} uM kg^{-1} soil.

Incorporation of four per cent FYM showed considerable increase in sorption when compared to the soil without FYM addition. At the initial concentration of 89 X 10^{-2} uM kg^{-1} adsorption and per cent adsorption were 83.75 X 10^{-2} uM kg^{-1} and 94.21 and at 356 X 10^{-2} uM kg^{-1} soil the corresponding values were 323.45 X 10^{-2} uM kg^{-1} and 90.90. The cumulative desorption and per cent desorption ranged from 3.43 X 10^{-2} to 22.68 X 10^{-2} uM kg^{-1} and 4.09 to 7.01 as the added concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1}.

The results of adsorption, desorption of pendimethalin in Mudigere soil and also with two and four per cent FYM are presented in Table. 12.

Adsorption of pendimethalin in Mudigere soil was comparatively less and desorption was more when compared with Hiriyur and Mandya soils. The adsorption of pendimethalin ranged from 68.45 X 10^{-2} to 260.50 X 10^{-2} uM kg^{-1} at 89 X 10^{-2} and 356 X 10^{-2} uM kg^{-1} initial pendimethalin concentration. The per cent adsorption decreased from 76.99 to 73.21 for the corresponding initial concentration. The cumulative desorption and the per cent desorption increased from 14.32 X 10^{-2} to 58.84 X 10^{-2} uM kg^{-1} soil and 20.92 to 22.59 as the initial concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil.

With the incorporation of two per cent FYM, the adsorption increased from 70.00 X 10^{-2} to 264.70 X 10^{-2} uM kg^{-1} as the added concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} soil. The per cent adsorption increased to 78.74 and 74.39 for the corresponding initial concentrations. The cumulative

Table - 12 Adsorption - Desorption of Pendimethalin in Mudigere soil

	INITIAL CONCENTRATION (10^{-2}uM kg^{-1})			
	89	178	267	356
SOIL ALONE				
Equilibrium Concentration (10^{-2}uM L^{-1})	4.09	8.65	13.46	19.07
Adsorption (10^{-2}uM kg^{-1})	68.45	134.70	199.60	260.50
% Adsorption	76.99	75.70	74.78	73.21
Cumulative Desorption (10^{-2}uM kg^{-1})	14.32	29.13	43.86	58.84
% Desorption	20.92	21.63	21.97	22.59
SOIL WITH 2% (W/W) FYM				
Equilibrium Concentration (10^{-2}uM L^{-1})	3.78	8.02	12.76	18.23
Adsorption (10^{-2} uM kg^{-1})	70.00	137.85	203.10	264.70
% Adsorption	78.74	77.47	76.10	74.39
Cumulative Desorption (10^{-2}uM kg^{-1})	11.86	25.18	39.07	54.40
% Desorption	16.94	18.27	19.24	20.55
SOIL WITH 4% (W/W) FYM				
Equilibrium Concentration (10^{-2}uM L^{-1})	3.12	7.68	12.15	17.26
Adsorption (10^{-2}uM kg^{-1})	73.30	139.55	206.15	269.55
% Adsorption	82.45	78.42	77.24	75.78
Cumulative Desorption (10^{-2}uM kg^{-1})	10.29	23.28	35.62	50.14
% Desorption	14.04	16.68	17.28	18.60

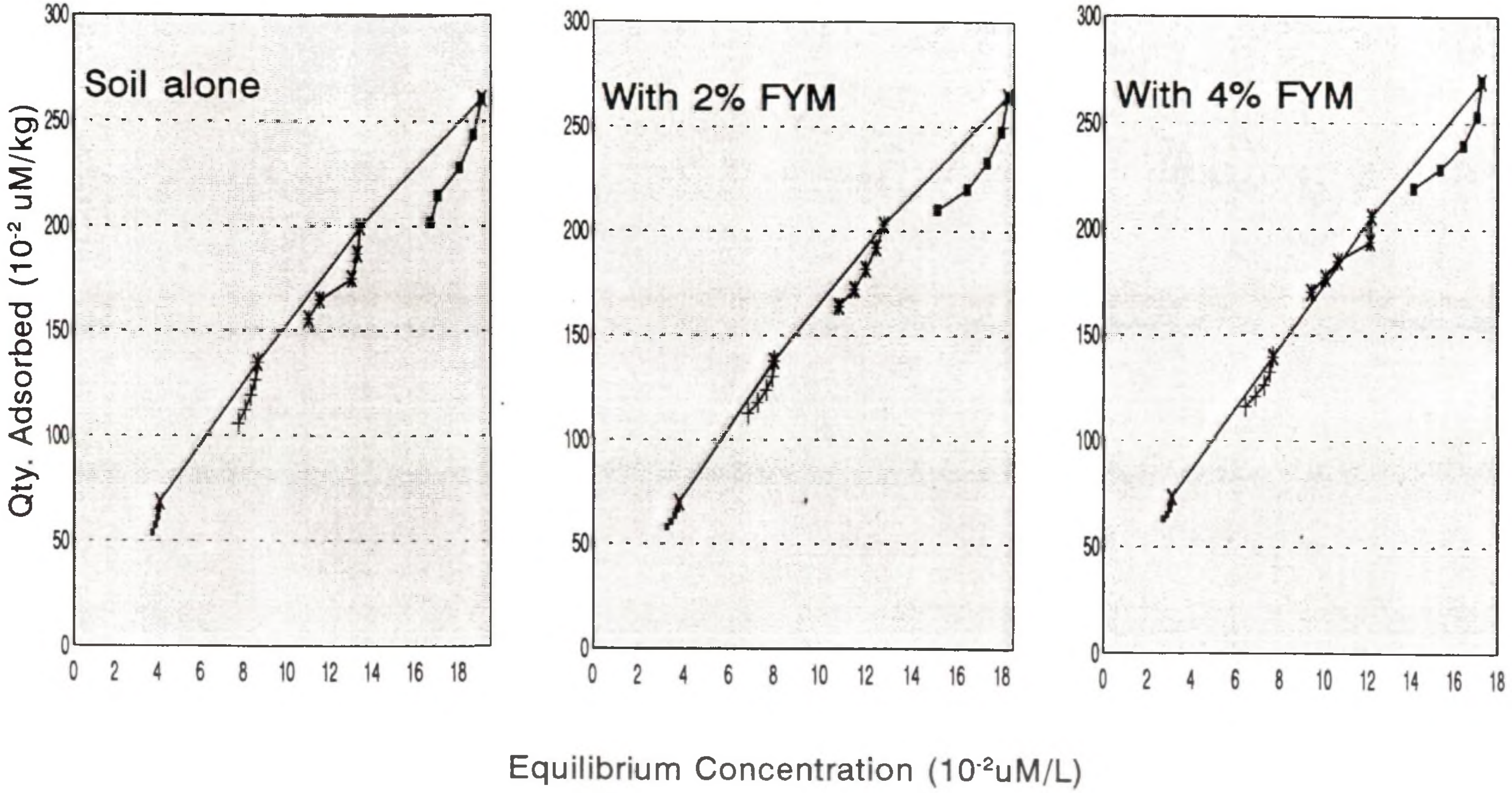


Fig.6 Adsorption-Desorption of Pendimethalin in Mudigere Soil

desorption and per cent desorption decreased with the addition of FYM and ranged from 11.86 X 10^{-2} to 54.40 X 10^{-2} uM kg^{-1} soil and 16.94 to 20.55.

Addition of FYM to the extent of four per cent further increased the adsorption and decreased the desorption at each initial concentration level of pendimethalin. The adsorption and per cent adsorption at 89 X 10^{-2} uM kg^{-1} soil level were 73.30 X 10^{-2} uM kg^{-1} and 82.45 respectively. The cumulative desorption and the per cent desorption in Mudigere soil with four per cent FYM was found to be higher than in Hiriyur and Mandya soils with the same level of FYM. As the initial pendimethalin concentration increased from 89 X 10^{-2} to 356 X 10^{-2} uM kg^{-1} the cumulative desorption and per cent desorption increased from 10.29 X 10^{-2} to 50.14 X 10^{-2} uM kg^{-1} and 14.04 to 18.60 respectively.

The Freundlich constant (K), slope (1/n), coefficient of determination (r^2) and K_{oc} values for pendimethalin in Hiriyur, Mandya and Mudigere soils and also with two and four per cent FYM are presented in Table. 13.

The Freundlich constant values were higher for Mandya (68.659) than for Hiriyur (33.297) and Mudigere (20.179) soils. It was found that Freundlich constant values increased with the addition of two and four per cent FYM in all three soils and the values were 43.782 and 54.726 for Hiriyur soil, 79.542 and 83.891 for Mandya soil and 22.951 and 30.359 for Mudigere soil respectively.

The 1/n values were 0.8689, 0.7539 and 0.8744 for Hiriyur, Mandya and Mudigere soils respectively and decreased with the addition of FYM in all the soils. The coefficient of determination (r^2) values were greater than 0.9902 indicating the best fit of Freundlich equation.

The sorption coefficients for organic carbon (K_{oc}) values were lower for Hiriyur (5840) than for Mandya (6241) and Mudigere (6726) soils. It was found that the addition of two and four per cent FYM increased the K_{oc} values to 5896 and 5980 in Hiriyur soil respectively. In Mandya soil addition of two per cent FYM increased the K_{oc} value to 6303, while four per cent FYM decreased the

Table - 13 Freundlich constants (K & 1/n). determination coefficients (r^2) and sorption coefficients for organic carbon (K_{oc}) for Pendimethalin adsorption by soils and with FYM

	K	1/n	r^2	K_{oc}
Hiriyur Soil	33.297	0.8689	0.9968	5840
Soil with 2% (w/w)FYM	43.782	0.7990	0.9958	5896
Soil with 4% (w/w)FYM	54.726	0.7784	0.9930	5980
Mandya Soil	68.659	0.7539	0.9902	6241
Soil with 2%(w/w) FYM	79.542	0.7123	0.9972	6303
Soil with 4%(w/w) FYM	83.891	0.7257	0.9983	5891
Mudigere Soil	20.179	0.8744	0.9990	6726
Soil with 2%(w/w) FYM	22.951	0.8502	0.9984	4801
Soil with 4%(w/w) FYM	30.359	0.7634	0.9986	4628

K_{oc} value to 5891. In Mudigere soil a conspicuous reduction of K_{oc} values were noticed with the addition of FYM and the values were 4801 and 4628 with two and four per cent respectively.

4.4 PERSISTENCE OF BUTACHLOR IN SOILS

The persistence of butachlor in soils was studied by incubating soils with 2.5 mg kg^{-1} and 5.0 mg kg^{-1} levels under three moisture regimes namely airdry (100 MPa), field capacity (0.033 MPa) and submergence (O Mpa). Butachlor residues were monitored at 1, 4, 8, 15, 22, 36, 57 and 85 days of incubation at 30 °C.

The data on persistence of butachlor in Hiriyur, Mandya and Mudigere soils are presented in Tables. 14, 15 and 16 respectively. The Fig. 7. illustrates the persistence of butachlor (per cent remaining) in soils under different moisture regimes when applied at the rate of 5 mg kg^{-1}.

The data on persistence of butachlor in Hiriyur soil are given in Table. 14. Application of 2.5 mg kg^{-1} of butachlor under airdry condition resulted in a residue level of 2.38 mg kg^{-1} on 1st day, 1.599 mg kg^{-1} on 22nd day and 0.559 mg kg^{-1} on 85th day. When the application rate was 5.0 mg kg^{-1} the residues were 4.610, 3.001 and 1.714 mg kg^{-1} on 1st, 22nd and 85th day respectively.

Under field capacity condition, the degradation of butachlor was faster than observed under airdry and submergence at both the levels of application. At 2.5 mg kg^{-1} level the butachlor residues were 2.107 and 0.419 on 1st and 22nd day respectively whereas the residues were not on detectable limits on 85th day. When the application rate was 5.0 mg kg^{-1} the persistence of butachlor in soils decreased from 4.476 mg kg^{-1} on 1st day to 1.046 mg kg^{-1} on 22nd day and 0.097 mg kg^{-1} on 85th day. When the moisture level was increased to submergence the persistence of butachlor in soil at 2.5 mg kg^{-1} level decreased from 2.23 mg kg^{-1} on 1st day to 1.235 mg kg^{-1} on 22nd day and

Table - 14 Persistence of Butachlor (mg kg^{-1}) in Hiriyur soil at different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation							
		1	4	8	15	22	36	57	85
100	2.5	2.380	2.153	2.012	1.830	1.599	1.329	1.095	0.559
	5.0	4.610	4.139	3.911	3.591	3.001	2.618	2.136	1.714
0.033	2.5	2.107	1.706	1.287	0.854	0.419	0.192	0.057	ND
	5.0	4.476	3.388	2.961	2.082	1.046	0.568	0.307	0.097
0	2.5	2.230	1.906	1.621	1.403	1.235	0.936	0.585	0.411
	5.0	4.629	3.886	3.510	3.074	2.648	2.185	1.374	0.883

100 MPa = Air dry 0.033MPa = Field Capacity 0 MPa = Submergence

ND - Not Detected

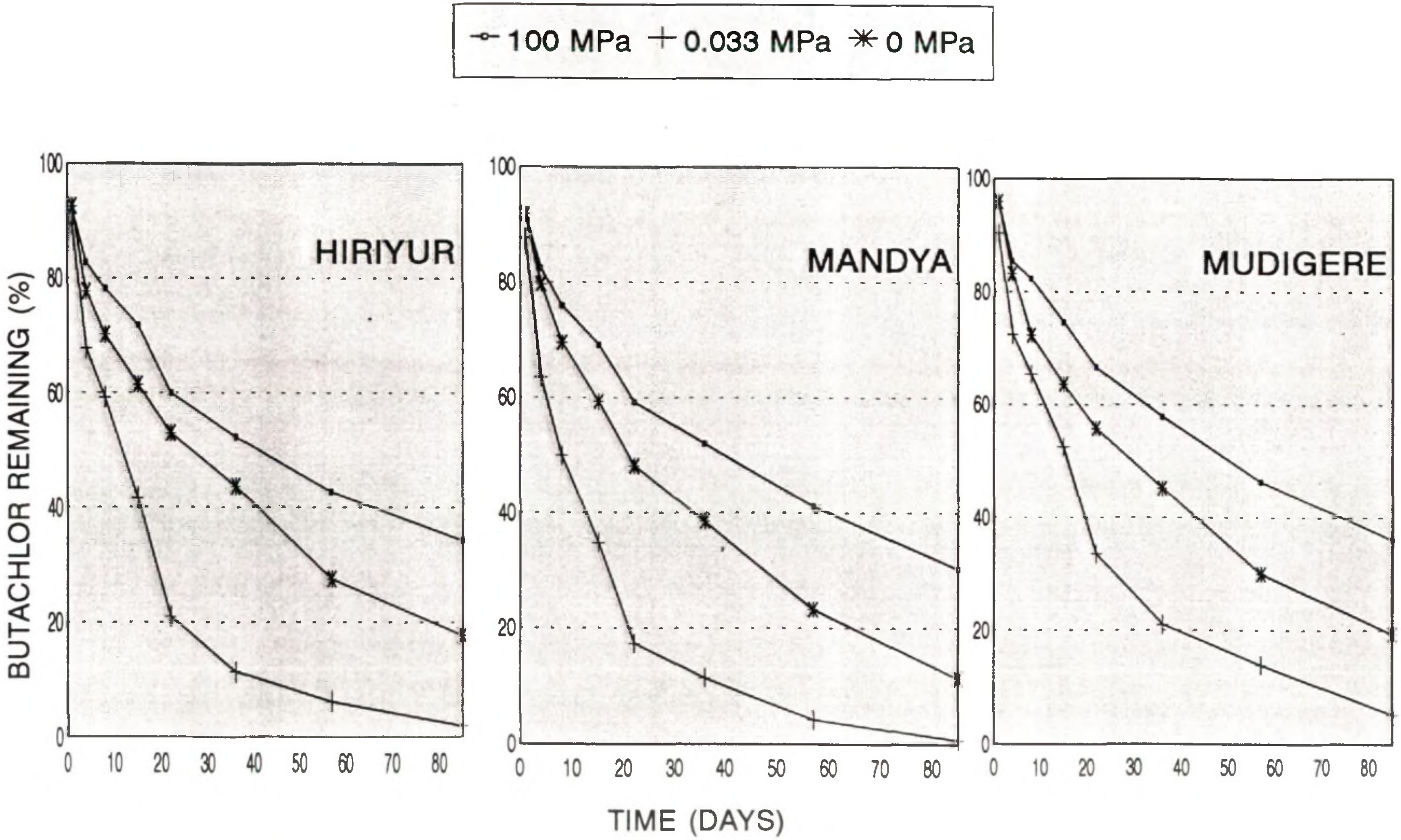


Fig.7 Persistence of Butachlor in soils under different moisture regimes

0.411 mg kg^{-1} on 85th day. At an initial concentration of 5 mg kg^{-1} the recovery of butachlor on 1st, 22nd and 85th day were 4.629, 2.648, and 0.883 mg kg^{-1} respectively.

The results presented in Table. 15. indicate the persistence of butachlor in Mandya soil at different moisture regimes at various intervals of incubation.

It was observed that persistence of butachlor in Mandya soil was less when compared to Hiriyur soil at all moisture regimes and application rates. Under airdry condition with 2.5 mg kg^{-1} level of application, the butachlor residues observed were 2.283 mg kg^{-1} on 1st day, 1.513 mg kg^{-1} on 22nd day and 0.411 mg kg^{-1} on 85th day. With 5.0 mg kg^{-1} application rate persistence of butachlor were 4.586, 2.961 and 1.516 mg kg^{-1} on 1st, 22nd and 85th day respectively. Incubation of soil under field capacity condition resulted in faster degradation when compared to airdry and submergence as seen in Hiriyur soil. The butachlor residues were 2.122, 0.325 mg kg^{-1} on 1st and 22nd day of incubation with the application rate of 2.5 mg kg^{-1}. At an application rate of 5.0 mg kg^{-1} the residues registered were 4.386, 0.867 and 0.036 mg kg^{-1} on 1st, 22nd and 85th day respectively.

Under submergence the degradation of butachlor was faster than airdry and slower than at field capacity condition. The residues observed on 1st, 22nd and 85th day were 2.268, 1.102 and 0.219 mg kg^{-1} respectively when the application rate was 2.5 mg kg^{-1} and 4.593, 2.406 and 0.568 mg kg^{-1} respectively when the application rate was 5.0 mg kg^{-1}.

The data in Table. 16. pertain to the persistence of butachlor in Mudigere soil at different moisture regimes.

The results indicated that persistence of butachlor was more when compared to Hiriyur and Mudigere soils. When the application rate was 2.5 mg kg^{-1}, the residues of butachlor observed were 2.459,1.713 and 0.628 mg kg^{-1} under airdry condition, 2.320, 0.722 and 0.035 mg kg^{-1} under field

Table - 15 Persistence of Butachlor (mg kg^{-1}) in Mandya soil at different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation							
		1	4	8	15	22	36	57	85
100	2.5	2.283	2.064	1.896	1.706	1.513	1.351	1.037	0.411
	5.0	4.586	4.123	3.795	3.460	2.961	2.600	2.059	1.516
0.033	2.5	2.122	1.582	1.021	0.728	0.325	0.125	0.035	ND
	5.0	4.386	3.174	2.497	1.739	0.867	0.370	0.210	0.036
0	2.5	2.268	1.976	1.695	1.338	1.102	0.799	0.495	0.219
	5.0	4.593	3.984	3.476	2.965	2.406	1.926	1.163	0.568

100 MPa = Air dry 0.033MPa = Field Capacity 0 MPa = Submergence

ND - Not Detected

Table - 16 Persistence of Butachlor (mg kg^{-1}) in Mudigere soil at different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation							
		1	4	8	15	22	36	57	85
100	2.5	2.459	2.208	2.108	1.906	1.713	1.486	1.160	0.628
	5.0	4.810	4.270	4.113	3.729	3.329	2.890	2.316	1.805
0.033	2.5	2.320	1.913	1.537	1.208	0.722	0.325	0.196	0.035
	5.0	4.519	3.621	3.269	2.626	1.677	1.052	0.695	0.260
0	2.5	2.398	2.119	1.835	1.591	1.365	1.025	0.790	0.515
	5.0	4.798	4.158	3.614	3.180	2.788	2.257	1.499	0.969

100 MPa = Air dry 0.033MPa = Field Capacity 0 MPa = Submergence

capacity and 2.398, 1.365 and 0.515 mg kg^{-1} on 1st, 22nd and 85th day under submergence.

Incubation of soil with 5.0 mg kg^{-1} herbicide registered a residue of 4.810 mg kg^{-1} on 1st day and it decreased to 3.329 mg kg^{-1} on 22nd day and to 1.805 mg kg^{-1} on 85th day under airdry condition. The residues observed under field capacity were 4.519, 1.677 and 0.260 mg kg^{-1} and 4.798, 2.788 and 0.969 mg kg^{-1} under submergence on 1st, 22nd and 85th day respectively.

4.4.1 PERSISTENCE OF BUTACHLOR IN SOILS WITH ORGANIC AMENDMENTS

Persistence of butachlor in soil was studied with FYM and paddy straw as organic matter amendments at one and two per cent (w/w) levels under field capacity and submergence condition. Butachlor application rate was 5 mg kg^{-1} and the residues were monitored on 1st, 4th, 8th, 15th, 22nd, 36th and 57th day of incubation.

The data on persistence of butachlor in Hiriyur, Mandya and Mudigere soils with organic amendments under two moisture regimes are presented in Tables. 17, 18 and 19 respectively. The Figs. 8 and 9 illustrate the persistence of butachlor (per cent remaining) in soils with organic amendments under field capacity and submergence respectively when applied at the rate of 5 mg kg^{-1}.

The data on persistence of butachlor in Hiriyur soil with organic amendments under field capacity and submergence are presented in Table. 17.

Incubation of soil with FYM at one per cent registered a residue of 4.212 mg kg^{-1} on 1st day and 0.454 mg kg^{-1} on 36th day, whereas with two per cent level, the residues were 4.108 and 0.219 mg kg^{-1} on 1st and 36th day respectively under field capacity condition. The soil treated with one per cent paddy straw under field capacity, the persistence of butachlor decreased from 4.181 mg kg^{-1} on 1st day to 0.104 mg kg^{-1} on 36th day and at two per cent paddy

Table - 17 Persistence of Butachlor (mg kg^{-1}) in Hiriyur soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation						
		1	4	8	15	22	36	57
0.033	CONTROL	4.476	3.388	2.961	2.082	1.046	0.568	0.307
	FYM1	4.212	3.176	2.460	1.740	0.898	0.454	ND
		(1.71)	**(3.97)**	**(5.52)**	**(7.09)**	**(8.92)**	**(9.88)**	
	FYM2	4.108	2.936	2.276	1.513	0.688	0.219	ND
		(0.97)	**(2.24)**	**(2.96)**	**(3.79)**	**(4.69)**	**(5.20)**	
	PS1	4.181	2.903	2.245	1.215	0.484	0.104	ND
		(0.57)	**(1.47)**	**(1.93)**	**(2.66)**	**(3.17)**	**(3.44)**	
	PS2	4.119	2.834	2.172	1.176	0.395	0.096	ND
		(0.31)	**(0.76)**	**(0.99)**	**(1.34)**	**(1.62)**	**(1.72)**	
0	CONTROL	4.629	3.886	3.510	3.074	2.648	2.185	1.374
	FYM1	4.558	3.808	3.470	2.963	2.336	1.918	0.944
		(0.96)	**(2.59)**	**(3.33)**	**(4.43)**	**(5.79)**	**(6.70)**	**(8.82)**
	FYM2	4.523	3.729	3.252	2.852	2.155	1.506	0.743
		(0.52)	**(1.38)**	**(1.90)**	**(2.33)**	**(3.09)**	**(3.74)**	**(4.63)**
	PS1	4.548	3.709	2.892	2.542	1.744	1.144	0.498
		(0.32)	**(0.91)**	**(1.48)**	**(1.72)**	**(2.28)**	**(2.71)**	**(3.16)**
	PS2	4.539	3.681	2.582	2.283	1.699	0.991	0.304
		(0.16)	**(0.46)**	**(0.85)**	**(0.95)**	**(1.16)**	**(1.41)**	**(1.65)**

0.033 MPa = Field Capacity, 0 MPa = Submergence

FYM - Farm Yard Manure 1 - One percent
PS - Paddy Straw 2 - Two percent
ND - Not Detected

(Figures in parenthesis indicate percent degradation per unit carbon of organic amendment) straw the residues were 4.119 and 0.096 mg kg^{-1} on 1st and 36th day respectively. In all the four treatments under field capacity condition, the residues were at non detectable limits on 57th day of incubation.

Under submergence the persistence of butachlor was 4.558, 2.336 and 0.944 mg kg^{-1} on 1st, 22nd and 57th day respectively when the soil was treated with one per cent FYM and 4.523, 2.155 and 0.743 mg kg^{-1} on 1st, 22nd and 57th day respectively when the soil was treated with two per cent FYM. Incubation of soil with one and two per cent of paddy straw under submergence decreased the persistence when compared to FYM treatments. Soil with one per cent paddy straw registered a residue of 4.548 mg kg^{-1} on 1st day, 1.744 mg kg^{-1} on 22nd day and 0.498 mg kg^{-1} on 57th day and with two per cent paddy straw the residues were 4.539, 1.699 and 0.304 mg kg^{-1} on 1st, 22nd and 57th day respectively. Soil without any amendment registered a residue of 4.476, 1.046 and 0.307 mg kg^{-1} under field capacity and 4.629, 2.648 and 1.374 mg kg^{-1} under submergence on 1st, 22nd and 57th day respectively.

The data presented in Table. 18. indicate that persistence of butachlor in Mandya soil decreased with FYM and paddy straw incorporation under both field capacity and submergence as compared to unamended soil. Incubation of soil with one per cent FYM registered a residue of 4.303 mg kg^{-1} on 1st day and 0.222 mg kg^{-1} on 36th day. The residues with two per cent FYM were 4.114 and 0.103 mg kg^{-1} on 1st and 36th day respectively under field capacity condition. Soils treated with paddy straw further decreased the residues of butachlor at both the levels. The persistence of butachlor in soil with one per cent paddy straw were 4.242 and 0.068 mg kg^{-1} and at two per cent were 4.208 and 0.025 mg kg^{-1} on 1st and 36th day respectively. The residues were non detectable on 57th day in all the four treatments under field capacity.

Under submergence the degradation of butachlor was increased with increase in FYM and paddy straw levels. With one per cent FYM, the residues were 4.513 mg kg^{-1} on 1st day, decreased to 2.259 mg kg-1 on 22nd day and to 0.656 mg kg^{-1} on 57th day and with two per cent FYM the registered residues

Table - 18 Persistence of Butachlor(mg kg^{-1}) in Mandya soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation						
		1	4	8	15	22	36	57
0.033	CONTROL	4.386	3.174	2.497	1.739	0.867	0.370	0.210
	FYM1	4.303	3.004	2.296	1.399	0.612	0.222	ND
		(1.52)	**(4.34)**	**(5.88)**	**(7.83)**	**(9.54)**	**(10.39)**	
	FYM2	4.114	2.858	1.895	1.036	0.515	0.103	ND
		(0.96)	**(2.33)**	**(3.38)**	**(4.31)**	**(4.88)**	**(5.32)**	
	PS1	4.242	2.892	2.219	0.985	0.380	0.068	ND
		(0.53)	**(1.48)**	**(1.95)**	**(2.82)**	**(3.24)**	**(3.46)**	
	PS2	4.208	2.805	2.014	0.924	0.334	0.025	ND
		(0.28)	**(0.77)**	**(1.05)**	**(1.43)**	**(1.64)**	**(1.75)**	
0	CONTROL	4.593	3.984	3.476	2.965	2.406	1.926	1.163
	FYM1	4.513	3.914	3.463	2.815	2.259	1.774	0.656
		(1.06)	**(2.36)**	**(3.34)**	**(4.75)**	**(5.96)**	**(7.01)**	**(9.44)**
	FYM2	4.483	3.755	3.125	2.624	2.038	1.362	0.533
		(0.56)	**(1.35)**	**(2.04)**	**(2.58)**	**(3.22)**	**(3.95)**	**(4.86)**
	PS1	4.508	3.735	2.839	2.337	1.573	0.943	0.346
		(0.35)	**(0.89)**	**(1.52)**	**(1.87)**	**(2.40)**	**(2.85)**	**(3.27)**
	PS2	4.512	3.725	2.595	2.174	1.237	0.714	0.146
		(0.17)	**(0.45)**	**(0.84)**	**(0.99)**	**(1.32)**	**(1.50)**	**(1.70)**

0.033 MPa = Field Capacity, 0 MPa = Submergence

FYM - Farm Yard Manure 1 - One percent
PS - Paddy Straw 2 - Two percent
ND - Not Detected

Figures in parenthesis indicate percent degradation per unit carbon of organic amendment were 4.483, 2.038 and 0.533 mg kg^{-1} on 1st, 22nd and 57th day respectively. Addition of paddy straw further decreased the residue of butachlor. At one per cent paddy straw application, the residues decreased from 4.508 mg kg^{-1} on 1st day to 1.573 mg kg^{-1} on 22nd day and to 0.346 mg kg^{-1} on 57th day. Soil with two per cent paddy straw noticed a residue of 4.512 mg kg^{-1} on 1st day, 1.237 mg kg^{-1} on 22nd day and 0.146 mg kg^{-1} on 57th day.

Table. 19. depicts the data on persistence of butachlor in Mudigere soil with organic amendments under field capacity and submergence.

Soil treated with FYM at one per cent noticed a residue of 4.403 mg kg^{-1} on 1st day and 0.760 mg kg^{-1} on 36th day and with two per cent FYM registered a residue of 4.297 and 0.504 mg kg^{-1} on 1st and 36th day respectively, under field capacity. Incubation of soil with paddy straw further decreased the residues from 4.329 mg kg^{-1} on 1st day to 0.314 mg kg^{-1} on 36th day at one per cent level and from 4.300 mg kg^{-1} on 1st day to 0.190 mg kg^{-1} on 36th day at two per cent level. The residue were below detectable limits on 57th day.

Under submergence, soil incubated with one per cent FYM registered a residue of 4.753,2.651 and 1.246 mg kg^{-1} on 1st, 22nd and 57th day respectively and with two per cent FYM residues decreased from 4.734 mg kg^{-1} on 1st day to 2.421 mg kg^{-1} on 22nd day and to 1.005 mg kg^{-1} on 57th day. Addition of paddy straw further decreased the levels and the residues noticed were 4.741, 2.240 and 0.799 mg kg^{-1} on 1st, 22nd and 57th day respectively. Soil treated with two per cent paddy straw under submergence further decreased the persistence of butachlor from 4.741 mg kg^{-1} on 1st day to 2.031 mg kg^{-1} on 22nd day and to 0.514 mg kg^{-1} on 57th day of incubation.

4.4.2 PERSISTENCE OF BUTACHLOR IN STERILE AND NONSTERILE SOILS

Persistence of butachlor in soils was monitored under sterile and nonsterile conditions to determine relative importance of chemical and microbial degradation in the case of butachlor.

Table - 19 Persistence of Butachlor (mg kg^{-1}) in Mudigere soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation						
		1	4	8	15	22	36	57
0.033	CONTROL	4.519	3.621	3.269	2.626	1.677	1.052	0.695
	FYM1	4.403	3.317	2.752	2.195	1.324	0.760	ND
		(1.30)	**(3.66)**	**(4.89)**	**(6.10)**	**(7.99)**	**(9.22)**	
	FYM2	4.297	3.704	2.634	1.948	1.016	0.504	ND
		(0.76)	**(1.95)**	**(2.57)**	**(3.65)**	**(4.33)**	**(4.89)**	
	PS1	4.329	3.257	2.594	1.645	0.795	0.314	ND
		(0.47)	**(1.23)**	**(1.69)**	**(2.35)**	**(2.95)**	**(3.29)**	
	PS2	4.300	3.216	2.417	1.511	0.583	0.190	ND
		(0.25)	**(0.63)**	**(0.90)**	**(1.22)**	**(1.55)**	**(1.69)**	
0	CONTROL	4.798	4.158	3.614	3.180	2.788	2.257	1.499
	FYM1	4.753	4.013	3.564	3.029	2.651	2.149	1.246
		(0.54)	**(2.15)**	**(3.12)**	**(4.28)**	**(5.11)**	**(6.20)**	**(8.16)**
	FYM2	4.734	3.935	3.443	2.954	2.421	1.987	1.005
		(0.29)	**(1.16)**	**(1.69)**	**(2.22)**	**(2.80)**	**(3.28)**	**(4.34)**
	PS1	4.741	4.000	3.334	2.740	2.240	1.752	0.799
		(0.18)	**(0.70)**	**(1.17)**	**(1.59)**	**(1.94)**	**(2.28)**	**(2.95)**
	PS2	4.741	3.960	3.231	2.536	2.031	1.346	0.514
		(0.09)	**(0.36)**	**(0.62)**	**(0.86)**	**(1.04)**	**(1.28)**	**(1.57)**

0.033 MPa = Field Capacity, 0 MPa = Submergence

FYM - Farm Yard Manure 1 - One percent

PS - Paddy Straw 2 - Two percent

ND - Not Detected

Figures in parenthesis indicates percent degradation per unit carbon of organic amendment

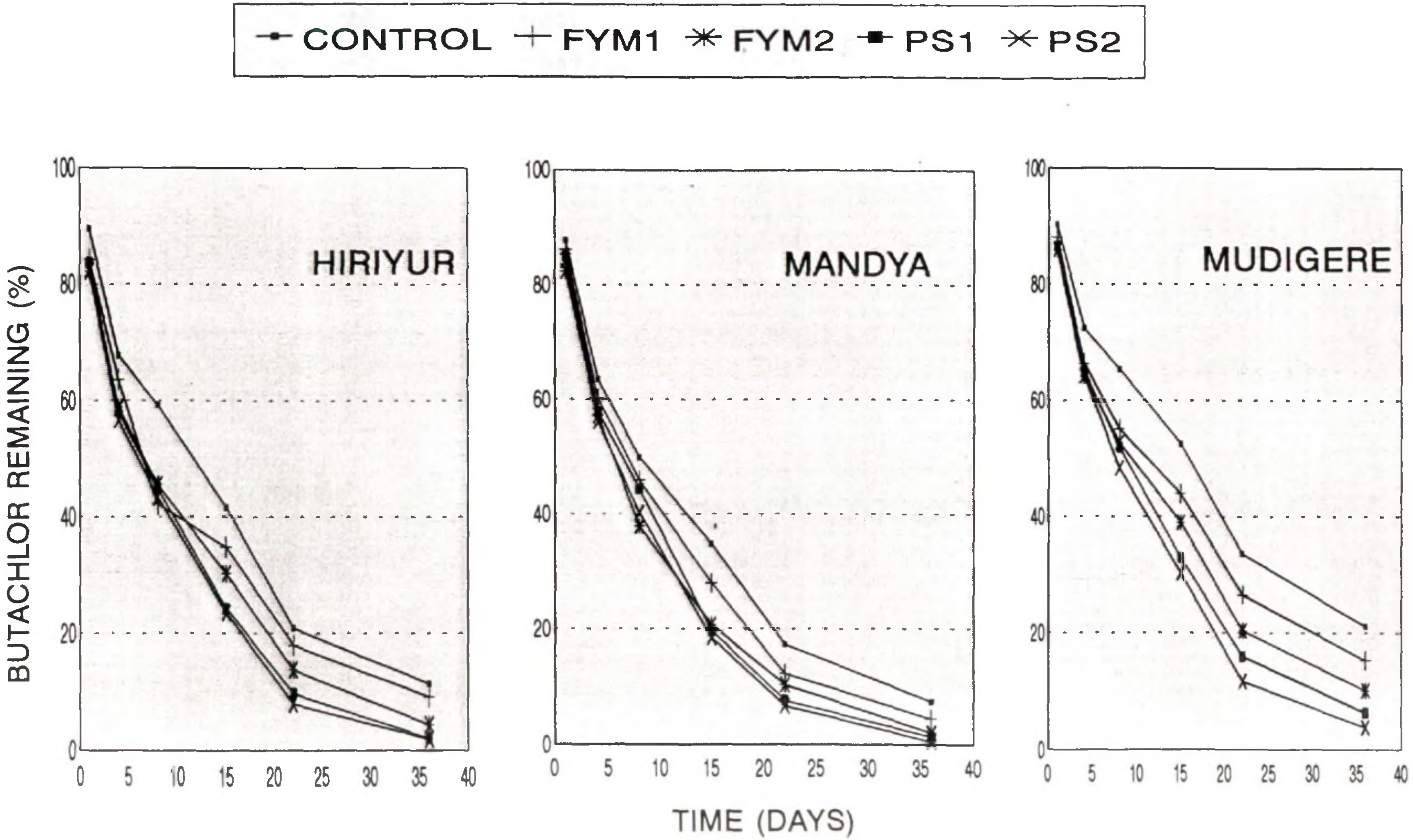


Fig.8 ***Persistence of Butachlor in soils with organic amendments under field capacity***

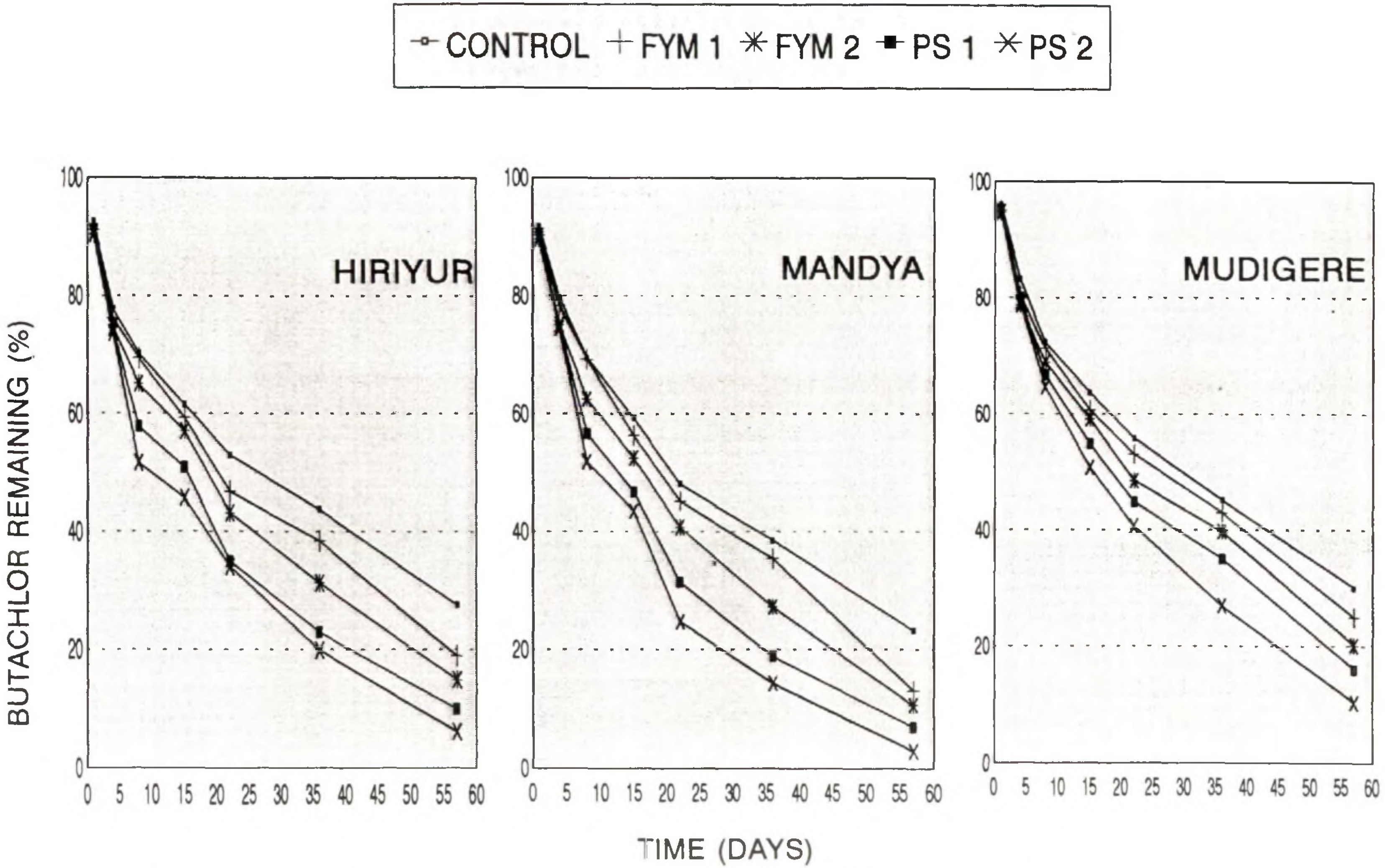


Fig.9 ***Persistence of Butachlor in soils with organic amendments under submergence***

The data on persistence of butachlor in sterile and nonsterile conditions in Hiriyur, Mandya and Mudigere soils under field capacity and submergence conditions are given in Table. 20. The residues were monitored upto 36 days with an application rate of 5 mg kg^{-1}.

The persistence of butachlor was comparatively more under both field capacity and submergence in sterile soils as compared to nonsterile soils. In the sterile soils of Hiriyur the residue levels of 4.756 mg kg^{-1} on 1st day and 4.273 mg kg^{-1} on 36th day under field capacity and 4.849 mg kg^{-1} on 1st day and 4.315 mg kg^{-1} on 36th day under submergence were noticed. The nonsterile soils registered a residue of 4.495 mg kg^{-1} on 1st day and 1.005 mg kg^{-1} on 36th day under field capacity and 4.673 mg kg^{-1} on 1st day and 2.206 mg kg^{-1} on 36th day under submergence.

In Mandya soil, the residues recovered were 4.731 mg kg^{-1} on 1st day, 4.196 mg kg^{-1} on 36th day for sterile soils under field capacity whereas 4.804 mg kg^{-1} on 1st day and 4.275 mg kg^{-1} on 36th day under submergence. Incubation of Mandya soil under nonsterile conditions showed residue of 4.401 and 0.406 mg kg^{-1} on 1st and 36th day respectively under field capacity and 4.610 and 1.968 mg kg^{-1} on 1st and 36th day respectively under submergence.

Mudigere soil registered slow degradation when compared to Hiriyur and Mandya soils under both field capacity and submergence. The soil under field capacity registered a residue of 4.819 and 4.311 mg kg^{-1} on 1st and 36th day respectively when incubated under sterile condition and 4.509 and 1.098 mg kg^{-1} on 1st and 36th day respectively for nonsterile condition. Under submergence the butachlor persistence were 4.849 mg kg^{-1} on 1st day and 4.424 mg kg^{-1} on 36th day for sterile soils and 4.765 mg kg^{-1} on 1st day and 2.288 mg kg^{-1} on 36th day for nonsterile soils.

4.4.3 DEGRADATION KINETICS OF BUTACHLOR IN SOILS

The data on the persistence and degradation of butachlor were fitted to first order equation in order to interpret the rate of degradation.

Table - 20 Persistence of Butachlor (mg kg^{-1}) in sterile and nonsterile soils under two moisture regimes

Moisture Regime (MPa)	Treatment	Days after incubation				
		1	8	15	22	36
		Hiriyur				
0.033	Sterile	4.756	4.589	4.469	4.349	4.273
	Nonsterile	4.495	3.001	1.475	1.289	1.005
0	Sterile	4.849	4.613	4.578	4.443	4.315
	Nonsterile	4.673	3.595	3.127	2.696	2.206
		Mandya				
0.033	Sterile	4.731	4.546	4.418	4.301	4.196
	Nonsterile	4.401	2.537	1.786	0.887	0.406
0	Sterile	4.804	4.638	4.546	4.398	4.275
	Nonsterile	4.610	3.506	2.991	2.495	1.968
		Mudigere				
0.033	Sterile	4.819	4.640	4.515	4.408	4.311
	Nonsterile	4.509	3.006	1.624	1.389	1.098
0	Sterile	4.849	4.710	4.604	4.515	4.424
	Nonsterile	4.765	3.649	3.230	2.806	2.288

0.033 MPa = Field Capacity   0 MPa = Submergence

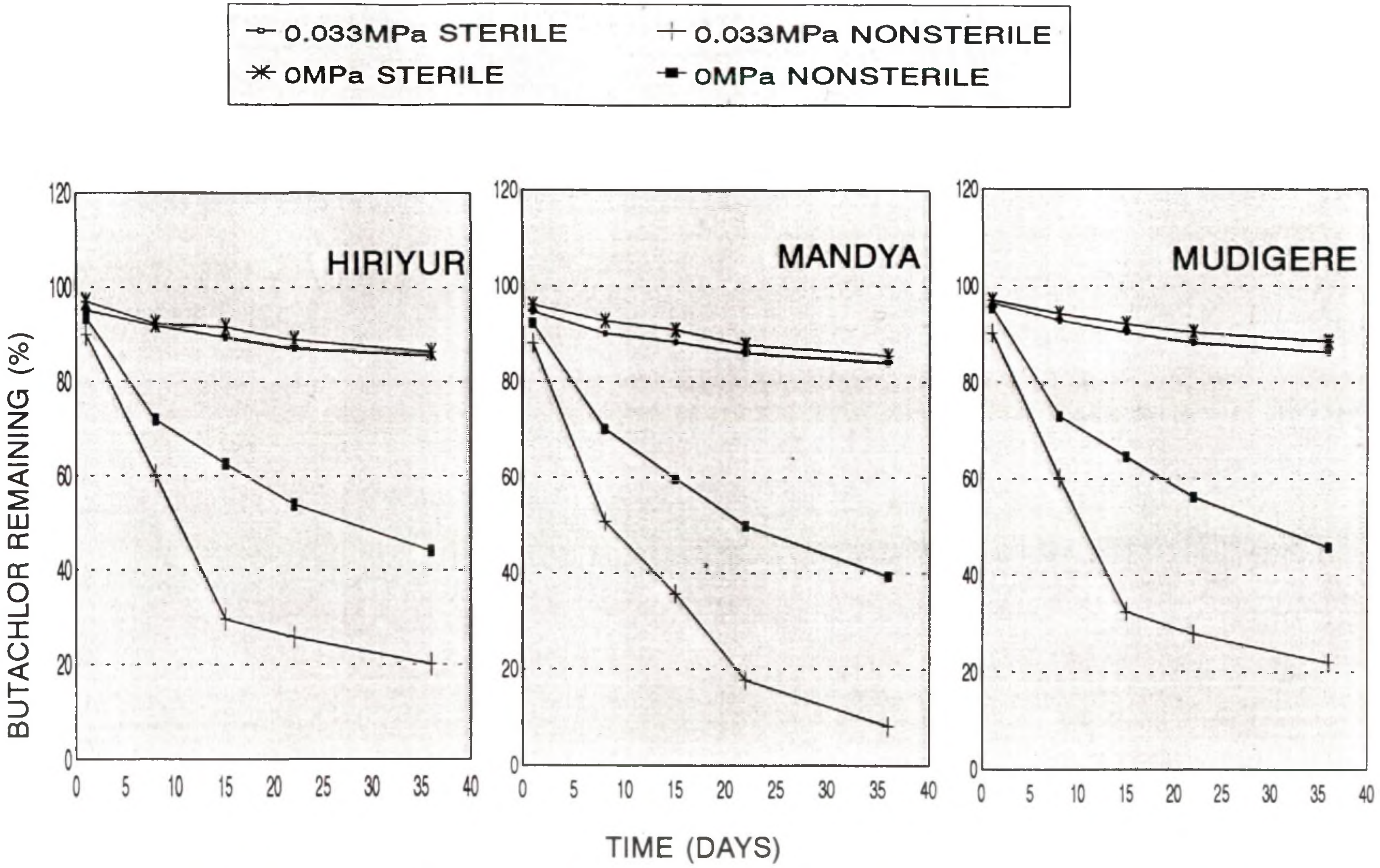


Fig. 10 ***Persistence of Butachlor in sterile and nonsterile soils under two moisture regimes***

The data pertaining to first order exponential rate constants (K_{deg}), half lives ($t_{1/2}$) and determination coefficients (r^2) for butachlor degradation in Hiriyur, Mandya and Mudigere soils at different moisture regimes are presented in Table. 21. The determination coefficient (r^2) values greater than 0.9561 indicated that the persistence data fitted to first order exponential equation.

The first order rate constants (K_{deg}) were higher at 2.5 mg kg^{-1} application in all the soils irrespective of moisture regimes. The rate constant values were higher at field capacity in all the soils when compared to airdry and submergence.

Higher rate constants for Mandya soils reveal faster degradation of butachlor as compared to other two soils. The degradation rate constants in Hiriyur soils were 0.0121, 0.0461 and 0.0196 day^{-1} under airdry, field capacity and submergence with an application rate of 5 mg kg^{-1} respectively. In Mandya soil the Kdeg values were 0.0132, 0.0561 and 0.0243 day^{-1} under airdry, field capacity and submergence at 5 mg kg^{-1} application respectively.

The half lives ($t_{1/2}$) of butachlor in Hiriyur soil were 42.98 and 57.11 days under airdry, 10.31 and 15.05 days under field capacity and 33.63 and 35.44 days under submergence at 2.5 and 5.0 mg kg^{-1} of application respectively. The time required for 50 per cent dissipation of butachlor in Mandya soil were low as compared to Hiriyur and Mudigere soils and the values were 37.40, 9.25 and 25.36 days respectively under airdry, field capacity and submergence at 2.5 mg kg^{-1} of application and 52.40, 12.35 and 28.48 days respectively under airdry, field capacity and submergence at 5.0 mg kg^{-1} of application. In Mudigere soil the butachlor half life values were 45.99 and 59.57 days under airdry, 14.27 and 20.58 days under field capacity and 38.02 and 39.20 days under submergence at 2.5 and 5.0 mg kg^{-1} of applications respectively.

In general, butachlor was found to follow two different phases of degradation under field capacity in all the three soils (Fig. 7). The first phase of degradation covers upto 22 days of incubation and the second phase from 22 day onwards.

Table - 21 First order rate constants (K_{deg}) Half lives ($t_{1/2}$) and Determination coefficients (r^2) for Butachlor degradation in soils at different moisture regimes.

Moisture regime	Qty. added (mg kg^{-1})	K_{deg} (day^{-1})	r^2	$t_{1/2}$ (days)
			Hiriyur	
Air dry (100 MPa)	2.5	0.0161	0.9810	42.98
	5.0	0.0121	0.9525	57.11
Field Capacity (0.033 MPa)	2.5	0.0672	0.9917	10.31
	I phase*	0.0762	0.9896	9.89
	II phase**	0.0571	0.9999	12.15
	5.0	0.0461	0.9786	15.05
	I phase	0.0658	0.9785	10.54
	II phase	0.0369	0.9765	18.76
Submergence (0MPa)	2.5	0.0206	0.9698	33.63
	5.0	0.0196	0.9835	35.44
			Mandya	
Air dry (100MPa)	2.5	0.0185	0.9561	37.40
	5.0	0.0132	0.9674	52.40
Field Capacity (0.033MPa)	2.5	0.0749	0.9905	9.25
	I phase	0.0874	0.9840	7.93
	II phase	0.0634	0.9989	10.93
	5.0	0.0561	0.9837	12.35
	I phase	0.0745	0.9849	9.30
	II phase	0.0485	0.9771	14.29
Submergence (0MPa)	2.5	0.0273	0.9916	25.36
	5.0	0.0243	0.9924	28.48
			Mudigere	
Air dry (100MPa)	2.5	0.0151	0.9837	45.99
	5.0	0.0116	0.9759	59.57
Field Capacity (0.033MPa)	2.5	0.0486	0.9899	14.27
	I phase	0.0534	0.9869	12.97
	II phase	0.0461	0.9728	15.04
	5.0	0.0337	0.9845	20.58
	I phase	0.0456	0.9738	15.20
	II phase	0.0288	0.9880	24.08
Submergence (0MPa)	2.5	0.0182	0.9750	38.02
	5.0	0.0177	0.9712	39.20

* I Phase - 0 to 22 days ** IIPhase - 22 day onwards

The first phase degradation rate constant (Kdeg) in Hiriyur soil were 0.0762 and 0.0658 day^{-1} at 2.5 and 5.0 mg kg^{-1} application rate respectively and the second phase degradation rate constants were 0.0571 and 0.0369 day^{-1} respectively at 2.5 and 5.0 mg kg^{-1} application rate.

In Mandya soil under field capacity condition the degradation rate constants were 0.0874 and 0.0634 day^{-1} at 2.5 mg kg^{-1} application and 0.0745 and 0.0485 day^{-1} at 5.0 mg kg^{-1} application for the first and second phases respectively. The lowest degradation rate constants were noticed for Mudigere soil at both the levels of application when compared to Hiriyur and Mandya soils. The Kdeg values were 0.0534 and 0.0461 day^{-1} at 2.5 mg kg^{-1} application and 0.0456 and 0.0288 day^{-1} at 5.0 mg kg^{-1} application for the first and second phase respectively.

The half lives for the first phase in all the soils were the lowest when compared to the second phase under field capacity condition. The $t_{1/2}$ values were 9.89 and 10.54 days for the first phase and 12.15 and 18.76 days for the second phase at 2.5 and 5.0 mg kg^{-1} rate of application respectively in Hiriyur soil. In Mandya soil the half lives of butachlor under field capacity moisture regime were 7.93 and 10.93 days at 2.5 mg kg^{-1} and 9.30 and 14.29 days at 5.0 mg kg^{-1} for the first and second phases respectively. Mudigere soils showed longer half lives for both first and second phases when compared to Hiriyur and Mandya soils at both the application rates and the values were 12.97 and 15.04 days at 2.5 mg kg^{-1} application and 15.20 and 24.08 days at 5.0 mg kg^{-1} application for the first and second phases respectively.

4.4.4 DEGRADATION KINETICS OF BUTACHLOR IN SOILS WITH ORGANIC AMENDMENTS

The data on the degradation rate constants, half lives and determination coefficients of butachlor in soils with organic amendments under field capacity and submergence at 5 mg kg^{-1} application are presented in Table.22. The determination coefficient (r^2) were found to be greater than 0.9799 in all the soils indicated better fit with first order exponential rate equation.

Table - 22 First order rate constants (K_{deg}), Half lives ($t_{1/2}$) and Determination coefficients (r^2) for Butachlor degradation in soils with different organic amendments

Moisture regime	Amendment	K_{deg} (day^{-1})	r^2	$t_{1/2}$ (days)
		Hiriyur		
Field Capacity (0.033 MPa)	FYM1	0.0658	0.9875	10.54
	FYM2	0.0842	0.9937	8.23
	PS1	0.1053	0.9952	6.58
	PS2	0.1087	0.9936	6.38
Submergence (0MPa)	FYM1	0.0271	0.9825	25.59
	FYM2	0.0315	0.9896	22.00
	PS1	0.0389	0.9902	17.80
	PS2	0.0463	0.9874	14.97
		Mandya		
Field Capacity (0.033MPa)	FYM1	0.0859	0.9943	8.06
	FYM2	0.1044	0.9973	6.64
	PS1	0.1180	0.9967	5.87
	PS2	0.1417	0.9833	4.89
Submergence (0MPa)	FYM1	0.0328	0.9799	21.14
	FYM2	0.0369	0.9912	18.78
	PS1	0.0453	0.9947	15.30
	PS2	0.0592	0.9899	11.70
		Mudigere		
Field Capacity (0.033 MPa)	FYM1	0.0509	0.9835	13.61
	FYM2	0.0625	0.9884	11.09
	PS1	0.0763	0.9953	9.09
	PS2	0.0905	0.9932	7.66
Submergence (0MPa)	FYM1	0.0229	0.9806	30.29
	FYM2	0.0263	0.9810	26.37
	PS1	0.0304	0.9845	22.84
	PS2	0.0382	0.9928	18.15

FYM - Farm Yard Manure
PS - Paddy straw

1 - One Percent
2 - Two Percent

The degradation rate constants (K_{deg}) increased with increasing level of FYM and paddy straw under both field capacity and submergence in all the soils. Paddy straw application recorded higher degradation rate compared to FYM in all the soils under both field capacity and submergence. The K_{deg} values were 0.0658 and 0.0842 day^{-1} at one and two per cent FYM application and 0.1053 and 0.1087 day^{-1} at one and two per cent paddy straw application for Hiriyur soil under field capacity condition. The degradation rate constants under submergence for Hiriyur soils were 0.0271 and 0.0315 day^{-1} with FYM at one and two per cent levels and 0.0389 and 0.0463 day^{-1} with paddy straw at one and two per cent levels respectively.

Mandya soil showed the highest degradation rate constants at both field capacity and submergence when compared to Hiriyur and Mudigere soils. The Kdeg values were 0.0859 and 0.1044 day^{-1} with FYM at one and two per cent levels and 0.1180 and 0.1417 day^{-1} with paddy straw at one and two per cent levels under field capacity and 0.0378 and 0.0369 day^{-1} with FYM at one and two per cent levels and 0.0453 and 0.0592 day^{-1} with paddy straw at one and two per cent levels under submergence respectively.

The degradation rate constants were the lowest in Mudigere soil when compared to Hiriyur and Mandya soils. The K_{deg} values were 0.0509 and 0.0625 day^{-1} under field capacity and 0.0229 and 0.0263 day^{-1} under submergence for soil with FYM. The rate constants were 0.0763 and 0.0905 day^{-1} under field capacity and 0.0304 and 0.0382 day^{-1} under submergence for the soil with paddy straw at one and two per cent respectively.

The time required for 50 per cent degradation of butachlor in soil with increasing levels of FYM were 10.54 and 8.23 days and soil with paddy straw were 6.58 and 6.38 days under field capacity for Hiriyur soil. The half lives under submergence for Hiriyur soil were 25.59 and 22.00 days for the soils with FYM and 17.80 and 14.97 days for the soils with paddy straw at one and two per cent levels.

The half life values were lowest in Mandya soil when compared to Hiriyur and Mudigere soils and the values were 8.06 and 6.64 days for soils with FYM and 5.87 and 4.89 days for soils with one and two per cent paddy straw under field capacity and 21.14 and 18.78 days for soils with FYM and 15.30 and 11.70 days for the soils with paddy straw at one and two per cent respectively under submergence.

The persistence of butachlor in Mudigere soil noticed the longest half lives under both field capacity and submergence when compared to Hiriyur and Mandya soils. The half lives were 13.61 and 11.09 days for soils with FYM and 9.09 and 7.66 days for the soils with paddy straw at one and two per cent levels under field capacity whereas, 30.29 and 26.37 days for soils with FYM and 22.84 and 18.15 days for soils with paddy straw at one and two per cent levels respectively under submergence.

In general, the half lives for all the soils under both moisture regimes were lower in the soils with paddy straw when compared to the soils with FYM at one and two per cent application levels. The duration of the experiment was only upto 36 days and the degradation of butachlor under both moisture regimes assumed to follow only a single phase.

4.5 PERSISTENCE OF ^{14} C PENDIMETHALIN IN SOILS

The persistence of ^{14}C pendimethalin was studied under three different moisture conditions namely airdry field capacity and submergence at two levels. The pendimethalin persistence was monitored at 1, 8, 15, 22, 36, 57 and 85 days after application. The data on persistence of pendimethalin in Hiriyur, Mandya and Mudigere soils are presented in Tables. 23, 24 and 25 respectively. The Fig. 11. illustrates the persistence of pendimethalin (per cent remaining) in soils under different moisture regimes when applied at 5 mg kg^{-1}.

The data on persistence of Pendimethalin in Hiriyur soil are presented in Table. 23. In airdry soil with 0.5 mg kg^{-1} application rate, 0.460 mg kg^{-1} of

Table - 23 Persistence of Pendimethalin (mg kg^{-1}) in Hiriyur soil under different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation						
		1	8	15	22	36	57	85
100	0.5	0.460	0.374	0.347	0.307	0.276	0.237	0.180
	5.0	4.640	3.887	3.763	3.645	3.398	2.981	2.073
0.033	0.5	0.438	0.355	0.292	0.226	0.191	0.145	0.095
	5.0	4.455	3.695	3.233	2.795	2.604	2.178	1.207
0	0.5	0.429	0.257	0.117	0.044	0.028	ND	ND
	5.0	4.394	2.617	1.128	0.502	0.223	0.126	0.075

100 MPa = Air dry, 0.033MPa = Field Capacity 0 MPa = Submergence

ND - Not Detected

pendimethalin persisted on 1st day, 0.307 mg kg^{-1} on 22nd day and 0.180 mg kg^{-1} on 85th day. With the application rate of 5 mg kg^{-1} soil, the pendimethalin persisted as 1st day was 4.64 mg kg^{-1}, which deceased to 3.645 mg kg^{-1} on 22nd day and 2.073 mg kg^{-1} on 85th day. Under field capacity moisture regime, the persistence of pendimethalin decreased, showing a faster degradation of the herbicide. The application rate with 0.5 mg kg^{-1}, resulted a residue of 0.438 mg kg^{-1} on the 1st day which decreased with incubation and it was 0.226 mg kg^{-1} on 22nd day and 0.095 mg kg^{-1} on 85th day. Increase in the application rate increased the persistence of pendimethalin. At 5 mg kg^{-1} of application, the residue left behind on 1st day was 4.455 mg kg^{-1}, while on 22nd and 85th day, residue levels of 2.795 and 1.207 mg kg^{-1} were noticed respectively. Submergence resulted in faster degradation when compared to higher moisture tensions at both the rates of application. With 0.5 mg kg^{-1} treatment, the residue recovered was 0.429 mg kg^{-1} on 1st day and 0.044 mg kg^{-1} on 22nd day. But, when the application rate was 5 mg kg^{-1}, the persistence of pendimethalin on the 1st day was 4.394 and it decreased to 0.502 mg kg^{-1} on 22nd day and 0.075 mg kg^{-1} on 85th day.

The data on persistence of pendimethalin in Mandya soil under three different moisture regimes *viz.* airdry, field capacity and submergence at two application rates of 0.5 and 5 mg kg^{-1} are presented in Table. 24.

The soil incubated under the moisture regime of airdry with 0.5 mg kg^{-1} treatment registered a residue of 0.460 mg kg^{-1} on the 1st day, 0.286 mg kg^{-1} on 22nd day and 0.159 mg kg^{-1} on 85th day. When the application rate was 5 mg kg^{-1} the residue left over was 4.661 mg kg^{-1} on 1st day, 3.199 mg kg^{-1} on 22nd day and 1.705 mg kg^{-1} on 85th day. The persistence of pendimethalin under field capacity with 0.5 mg kg^{-1} treatment was found to be less when compared to airdry moisture regime. The residue decreased from 0.445 mg kg^{-1} on the 1st day to 0.072 mg kg^{-1} on 85th day. When the application rate was 5 mg kg^{-1}, the pendimethalin remained on 1st day was 4.609 mg kg^{-1} and it decreased to 3.057 mg kg^{-1} on 22nd day and 1.064 mg kg^{-1} on 85th day. The pendimethalin persistence in soil maintained under submergence

Table - 24 Persistence of Pendimethalin (mg kg^{-1}) in Mandya soil under different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation						
		1	8	15	22	36	57	85
100	0.5	0.460	0.363	0.332	0.286	0.258	0.205	0.159
	5.0	4.661	3.789	3.495	3.199	2.877	2.712	1.705
0.033	0.5	0.445	0.343	0.264	0.209	0.171	0.125	0.072
	5.0	4.609	3.583	3.326	3.057	2.721	2.166	1.064
0	0.5	0.431	0.174	0.095	0.034	0.014	ND	ND
	5.0	4.433	1.972	1.113	0.363	0.224	0.109	0.057

100 MPa = Air dry, 0.033MPa = Field Capacity 0 MPa = Submergence

ND - Not Detected

showed a substantial reduction when compared to the soil maintained under field capacity and airdry conditions. When the soil was treated with 0.5 mg kg^{-1} the residue recovered was 0.431 mg kg^{-1} on the 1st day and 0.014 mg kg^{-1} on 36th day. Residue levels of 4.433 mg kg^{-1} on 1st day, 0.363 mg kg^{-1} on 22nd day and 0.057 mg kg^{-1} on 85th day were obtained for the soils treated with 5 mg kg^{-1} pendimethalin under submergence.

The data on persistence of pendimethalin in Mudigere soil under three moisture regimes are presented in Table 25.

The soil with 0.5 mg kg^{-1} treatment recorded a persistence of 0.481 mg kg^{-1} on the 1st day 0.331 mg kg^{-1} on 22nd day and 0.241 mg kg^{-1} on 85th day under airdry condition. At 5.0 mg kg^{-1} of application, the persistence values of pendimethalin were 4.936, 3.909 and 2.425 mg kg^{-1} on first, 22nd and 85th day respectively. The soils maintained under field capacity, recorded a persistence of 0.474 mg kg^{-1} on the 1st day 0.286 mg kg^{-1} on 22nd day and 0.128 mg kg^{-1} on 85th day at 0.5 mg kg^{-1} of pendimethalin. At the application rate of 5 mg kg^{-1}, the residues of pendimethalin obtained were 4.831, 3.376 and 1.521 mg kg^{-1} on 1st 22nd and 85th day respectively.

Incubation of soil under submergence at 0.5 mg kg^{-1} showed substantial decrease in the persistence of pendimethalin when compared to airdry and field capacity moisture regimes. The recovery of pendimethalin were 0.470 mg kg^{-1} on 1st day, and 0.012 mg kg^{-1} on 57th day at 0.5 mg kg^{-1} of application, whereas, 4.812 mg kg^{-1} on 1st day and 0.144 mg kg^{-1} on 85th day at 5.0 mg kg^{-1} of pendimethalin application.

4.5.1 PERSISTENCE OF PENDIMETHALIN IN SOILS WITH ORGANIC AMENDMENTS

Persistence of pendimethalin in Hiriyur, Mandya and Mudigere soils treated with FYM and paddy straw as organic amendments applied at one and two per cent levels were studied under field capacity and submergence.

Table - 25 Persistence of Pendimethalin (mg kg^{-1}) in Mudigere soil under different moisture regimes

Moisture regime (M Pa)	Quantity added (mg kg^{-1})	Days after incubation						
		1	8	15	22	36	57	85
100	0.5	0.481	0.411	0.378	0.331	0.307	0.264	0.241
	5.0	4.936	4.217	4.064	3.909	3.713	3.505	2.425
0.033	0.5	0.474	0.356	0.326	0.286	0.254	0.199	0.128
	5.0	4.831	3.634	3.482	3.376	3.069	2.431	1.521
0	0.5	0.470	0.325	0.199	0.073	0.045	0.012	ND
	5.0	4.812	3.295	2.241	0.705	0.474	0.239	0.144

100 MPa = Air dry, 0.033MPa = Field Capacity 0 MPa = Submergence

ND - Not Detected

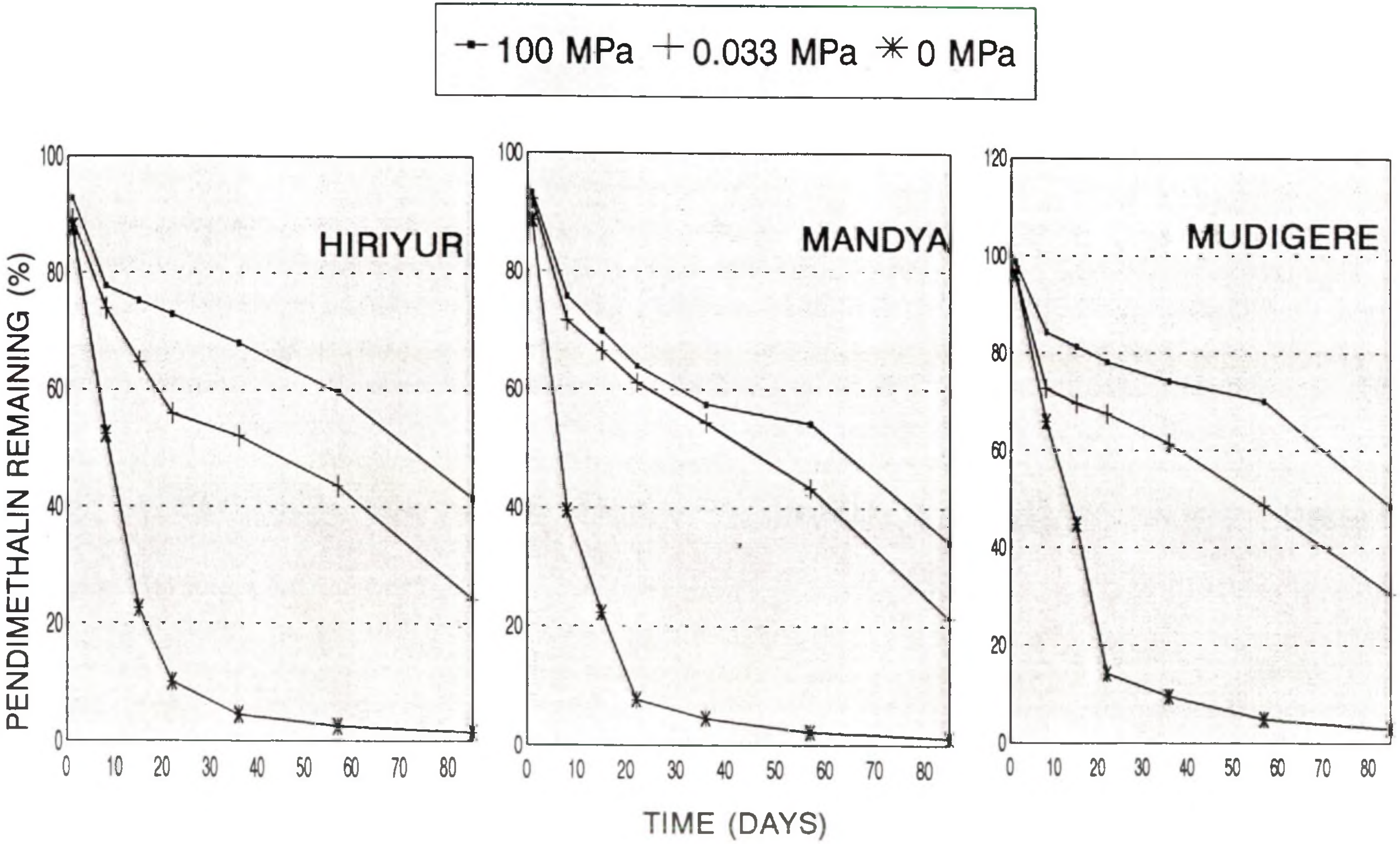


Fig.11 ***Persistence of Pendimethalin in soils under different moisture regimes***

The data on persistence of pendimethalin in Hiriyur soil treated with FYM and paddy straw under field capacity and submergence are given in Table. 26.

The persistence of pendimethalin under field capacity was more when compared to that under submergence. Addition of FYM and paddy straw enhanced the degradation in both the moisture regimes the pendimethalin recovered under field capacity moisture regime was 4.484 mg kg^{-1} on 1st day and 1.229 mg kg^{-1} on 36th day for the soil treated with one per cent FYM whereas 4.434 mg kg^{-1} on 1st day and 1.045 mg kg^{-1} on 36th day for the soil treated with two per cent FYM. Addition of paddy straw reduced the persistence of pendimethalin to a greater extent when compared to FYM. The pendimethalin residues recovered on 1st day and 36th day were 4.466 and 0.896 mg kg^{-1} for the soils treated with one per cent paddy straw and 4.435 and 0.705 mg kg^{-1} for the soils treated with two per cent paddy straw respectively.

When the incubation system was maintained under submergence, the persistence of pendimethalin was 4.394 and 0.434 mg kg^{-1} on the 1st and 22nd day respectively for the soils treated with one per cent FYM and 4.398 and 0.354 mg kg^{-1} for the soils treated with two per cent FYM. With the addition of one per cent paddy straw, the persistence was reduced from 4.30 mg kg^{-1} on the 1st day to 0.226 mg kg^{-1} on 22nd day whereas, for those at two per cent paddy straw the residues decreased from 4.397 mg kg^{-1} on the 1st day to 0.203 mg kg^{-1} on 22nd day. On 36th day residues were at non detectable level.

Soil without any amendment registered a residue of 4.455 and 2.604 mg kg^{-1} under field capacity and 4.394 and 0.223 mg kg^{-1} under submergence on 1st and 36th day respectively.

The data on persistence of pendimethalin in Mandya soil treated with FYM and paddy straw under field capacity and submergence are presented in Table. 27.

Table - 26 Persistence of Pendimethalin (mg kg^{-1})in Hiriyur soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation					
		1	4	8	15	22	36
0.033	CONTROL	4.455	-	3.695	3.233	2.795	2.604
	FYM1	4.484	4.239	3.544	2.356	1.854	1.229
		(1.12)	**(1.65)**	**(3.16)**	**(5.74)**	**(6.83)**	**(8.19)**
	FYM2	4.434	4.020	3.428	2.052	1.609	1.045
		(0.61)	**(1.06)**	**(1.70)**	**(3.20)**	**(3.69)**	**(4.29)**
	PS1	4.466	4.002	3.341	1.909	1.480	0.896
		(0.39)	**(0.70)**	**(1.16)**	**(2.17)**	**(2.47)**	**(2.88)**
	PS2	4.435	3.894	3.193	1.721	1.302	0.705
		(0.19)	**(0.38)**	**(0.63)**	**(1.15)**	**(1.29)**	**(1.50)**
0	CONTROL	4.394	-	2.617	1.128	0.502	0.223
	FYM1	4.394	3.959	2.870	0.679	0.434	ND
		(1.31)	**(2.26)**	**(4.63)**	**(9.39)**	**(9.92)**	
	FYM2	4.398	3.825	2.539	0.608	0.354	ND
		(0.65)	**(1.28)**	**(2.67)**	**(4.77)**	**(5.05)**	
	PS1	4.300	1.325	1.093	0.374	0.226	ND
		(0.49)	**(2.57)**	**(2.74)**	**(3.24)**	**(3.35)**	
	PS2	4.397	1.191	1.049	0.337	0.203	ND
		(0.21)	**(1.33)**	**(1.38)**	**(1.63)**	**(1.68)**	

0.033 MPa = Field Capacity

0 MPa = Submergence

FYM - Farm Yard Manure

1 - One Percent

PS - Paddy Straw

2 - Two Percent

ND - Not Detected

(Figures in the paranthesis indicate the percent degradation per unit carbon of organic amendment)

Table - 27 Persistence of Pendimethalin (mg kg^{-1}) in Mandya soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation					
		1	4	8	15	22	36
0.033	CONTROL	4.609	-	3.583	3.326	3.057	2.721
	FYM1	4.584	4.335	3.578	2.517	2.108	1.430
		(0.90)	**(1.45)**	**(3.09)**	**(5.40)**	**(6.29)**	**(7.76)**
	FYM2	4.558	4.150	3.497	2.213	1.850	1.202
		(0.48)	**(0.92)**	**(1.63)**	**(3.03)**	**(3.42)**	**(4.13)**
	PS1	4.554	3.988	3.289	2.023	1.562	0.892
		(0.31)	**(0.71)**	**(1.20)**	**(1.95)**	**(2.41)**	**(2.88)**
	PS2	4.547	3.856	3.037	1.845	1.400	0.746
		(0.16)	**(0.40)**	**(0.69)**	**(1.11)**	**(1.26)**	**(1.49)**
0	CONTROL	4.433	-	1.972	1.113	0.363	0.224
	FYM1	4.598	1.701	0.641	0.318	0.164	ND
		(0.87)	**(7.17)**	**(9.48)**	**(10.18)**	**(10.51)**	
	FYM2	4.594	1.556	0.640	0.293	0.151	ND
		(0.44)	**(3.74)**	**(4.74)**	**(5.12)**	**(5.27)**	
	PS1	4.598	0.915	0.566	0.284	0.136	ND
		(0.28)	**(2.87)**	**(3.11)**	**(3.31)**	**(3.41)**	
	PS2	4.587	0.811	0.468	0.280	0.124	ND
		(0.14)	**(1.47)**	**(1.59)**	**(1.66)**	**(1.71)**	

0.033 MPa = Field Capacity, 0 MPa = Submergence

FYM -Farm Yard Manure 1 - One Percent

PS - Paddy Straw 2- Two Percent

ND - Not Detected

(Figures in the paranthesis indicate the percent degradation per unit carbon of organic amendment)

The pendimethalin residues recovered under field capacity on the 1st day was 4.583 mg kg^{-1} and 1.430 mg kg^{-1} on 36th day for the soils treated with one per cent FYM. Whereas for the soils treated with two per cent FYM, the residues were 4.558 mg kg^{-1} on the 1st day and 1.202 mg kg^{-1} on 36th day. Addition of one per cent paddy straw reduced the persistence of pendimethalin from 4.554 mg kg^{-1} on the 1st day to 0.892 mg kg^{-1} on 36th day. The residues of pendimethalin recorded for the soil treated with two per cent paddy straw were 4.547 mg kg^{-1} on the 1st day and 0.746 mg kg^{-1} on the 36th day. Control soil recorded a residue of 4.609 and 2.721 mg kg^{-1} on 1st and 36th day under field capacity respectively.

The soil treated with one per cent FYM under submergence recorded 4.598 and 0.164 mg kg^{-1} of pendimethalin residues on the 1st and 22nd day respectively. Incorporation of two per cent FYM further increased the degradation and the values ranged from 4.594 mg kg^{-1} on the 1st day to 0.151 mg kg^{-1} on 22nd day.

Addition of paddy straw to the soils under submergence decreased the persistence to a greater extent than under field capacity. Soil incorporated with one per cent paddy straw indicated a residue of 4.598 mg kg^{-1} on the 1st day and 0.136 mg kg^{-1} on 22nd day while the soils with two per cent paddy straw registered a residue of 4.587 mg kg^{-1} on the 1st day and 0.124 mg kg^{-1} on 22nd day and it was non detectable on 36th day. Soil without any amendment noticed a residue of 4.433 and 0.224 mg kg^{-1} under submergence on 1st and 36th day respectively.

Addition of FYM and paddy straw enhanced the degradation under both field capacity and submergence in Mudigere soils (Table. 28). Soil without any amendment registered a residue of 4.831 and 3.069 mg kg^{-1} under field capacity and 4.812 and 0.474 mg kg^{-1} under submergence on 1st and 36th day respectively. Persistence of pendimethalin was less in the soils treated with paddy straw when compared to the soils treated with FYM. When the soils were treated with one per cent FYM and incubated at field capacity, the persistence

Table - 28 Persistence of Pendimethalin (mg kg^{-1}) in Mudigere soil with organic amendments under two moisture regimes

Moisture regime (M Pa)	Organic amendment	Days after incubation					
		1	4	8	15	22	36
0.033	CONTROL	4.831	-	3.634	3.482	3.376	3.069
	FYM1	4.823	4.577	3.612	3.017	2.639	2.014
		(0.38)	**(0.92)**	**(3.02)**	**(4.31)**	**(5.13)**	**(6.49)**
	FYM2	4.796	4.467	3.548	2.757	2.308	1.797
		(0.22)	**(0.58)**	**(1.58)**	**(2.44)**	**(2.93)**	**(3.48)**
	PS1	4.796	4.357	3.479	2.535	2.049	1.463
		(0.14)	**(0.45)**	**(1.07)**	**(1.73)**	**(2.07)**	**(2.48)**
	PS2	4.784	4.225	3.397	2.403	1.808	1.198
		(0.08)	**(0.27)**	**(0.56)**	**(0.91)**	**(1.12)**	**(1.33)**
0	CONTROL	4.812	-	3.295	2.241	0.705	0.474
	FYM1	4.898	4.364	3.236	1.887	0.995	ND
		(0.22)	**(1.38)**	**(3.83)**	**(6.77)**	**(8.71)**	
	FYM2	4.898	4.187	2.946	1.436	0.621	ND
		(0.11)	**(0.88)**	**(2.23)**	**(3.87)**	**(4.76)**	
	PS1	4.900	2.832	1.602	1.003	0.596	ND
		(0.07)	**(1.52)**	**(2.38)**	**(2.80)**	**(3.09)**	
	PS2	4.879	2.413	1.319	0.744	0.463	ND
		(0.04)	**(0.91)**	**(1.29)**	**(1.49)**	**(1.59)**	

0.033 MPa = Field Capacity,	0 MPa = Submergence
FYM - Farm Yard Manure	1 - One Percent
PS - Paddy Straw	2- Two Percent

ND - Not Detected

(Figures in the paranthesis indicate the percent degradation per unit carbon of organic amendment)

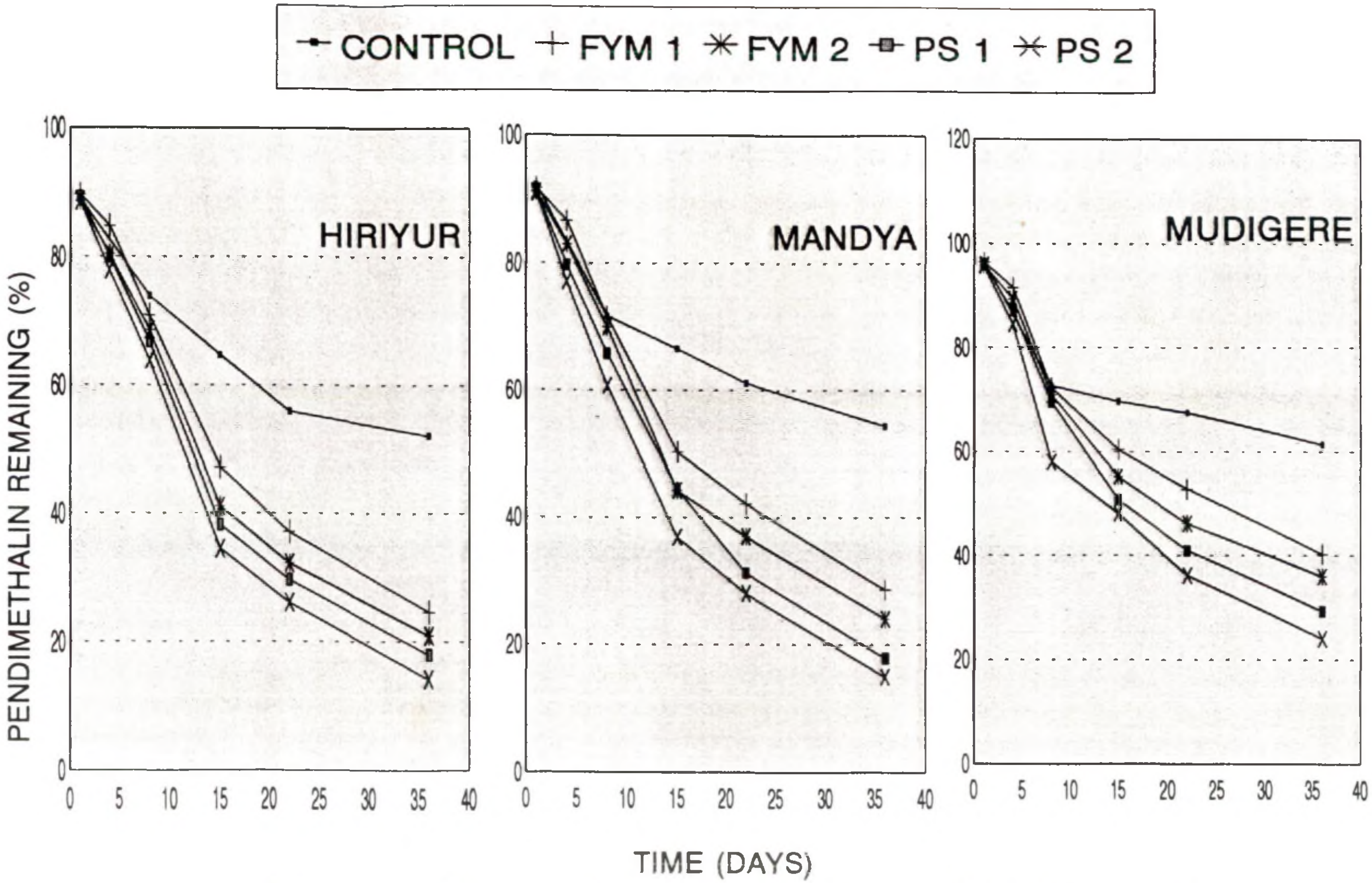


Fig.12 **Persistence of Pendimethalin in soils with organic amendments under field capacity**

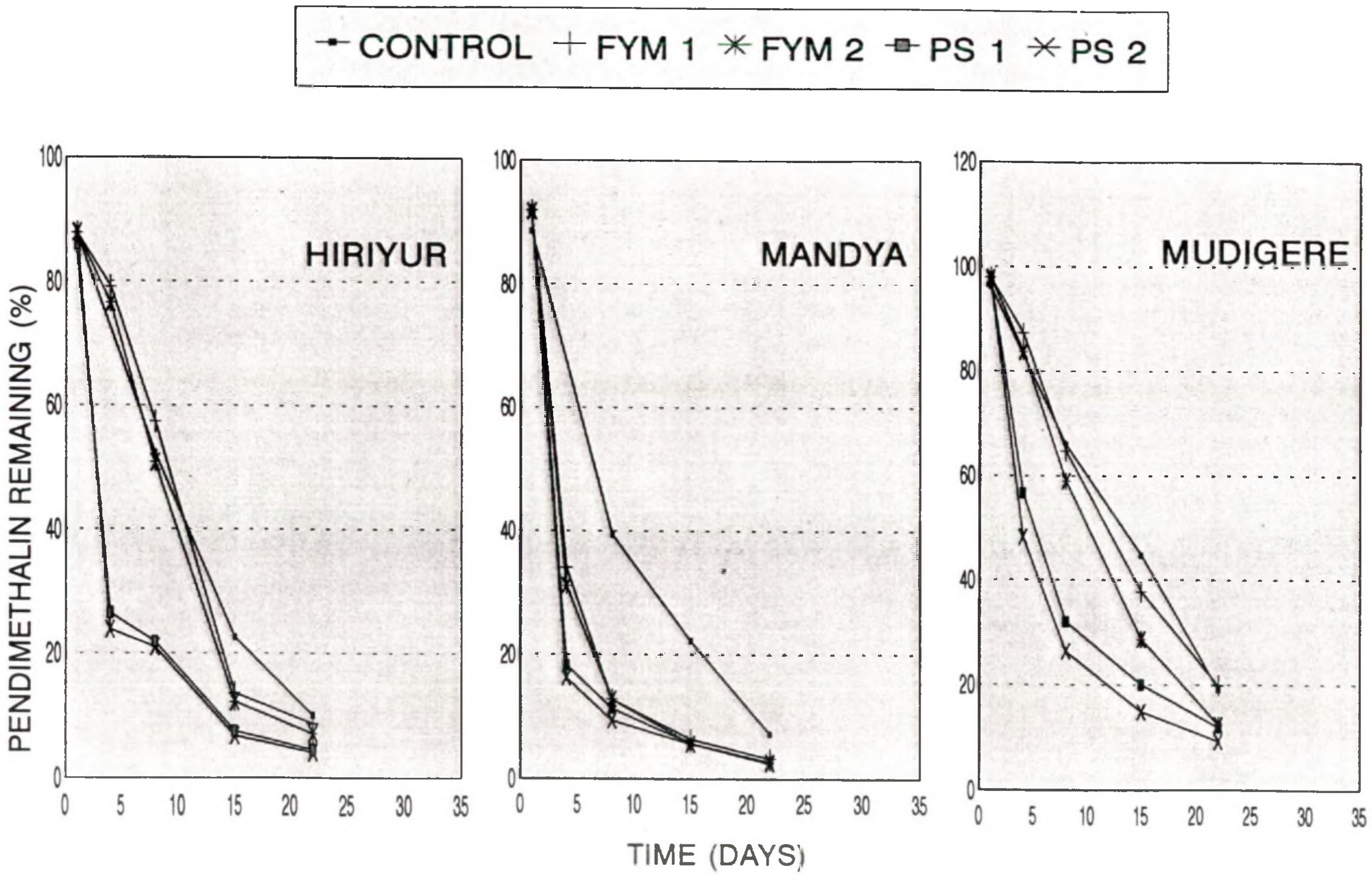


Fig.13 **Persistence of Pendimethalin in soils with organic amendments under submergence**

of pendimethalin was 4.823 mg kg^{-1} on the 1st day and 2.014 mg kg^{-1} on 36th day whereas 4.796 and 1.797 mg kg^{-1} on 1st day and 36th day respectively were recorded for the soils treated with two per cent FYM.

The persistence of pendimethalin ranged from 4.796 mg kg^{-1} on 1st day to 1.463 mg kg^{-1} on 36th day in the soils treated with one per cent paddy straw. When the soils incorporated with two per cent paddy straw the persistence of pendimethalin was 4.784 mg kg^{-1} on the 1st day and 1.198 mg kg^{-1} on 36th day.

Incubation of the soil incorporated with one per cent FYM at submergence indicated a residue of 4.898 mg kg^{-1} on the 1st day and 0.995 mg kg^{-1} on 22nd day while the soils with two per cent FYM registered a residue of 4.898 mg kg^{-1} on the 1st day and 0.621 mg kg^{-1} on 22nd day. The pendimethalin recovered from the soil treated with one per cent paddy straw were ranged from 4.900 mg kg^{-1} on the 1st day to 0.596 mg kg^{-1} on 22nd day. The persistence was less for the soils treated with two per cent paddy straw and the recovery ranged from 4.879 mg kg^{-1} on 1st day to 0.463 mg kg^{-1} on 22nd day.

4.5.2 PERSISTENCE OF PENDIMETHALIN IN STERILE AND NONSTERILE SOILS

In order to monitor whether the degradation of pendimethalin is dominated by chemical or biological, the persistence of pendimethalin in sterile and nonsterile soils of Hiriyur, Mandya and Mudigere were studied under two moisture regimes namely field capacity and submergence. The herbicide was applied at 5 mg kg^{-1} of soil.

The data on the results of the experiment are presented in Table. 29 and Fig. 14. The persistence of pendimethalin under both field capacity and submergence was very high in sterile soils when compared to nonsterile soils.

In Hiriyur soil, the residues recovered were 4.684 mg kg^{-1} on 1st day and 4.320 mg kg^{-1} on 36th day of incubation for sterile soil under field capacity

Table - 29 Persistence of Pendimethalin (mg kg^{-1}) in sterile and nonsterile soils under two moisture regimes

Moisture regime (MPa)	Treatment	Days after incubation				
		1	8	15	22	36
		Hiriyur				
0.033	Sterile	4.684	4.611	4.516	4.488	4.320
	Nonsterile	4.515	3.704	3.291	2.857	2.542
0	Sterile	4.505	4.479	4.454	4.432	4.301
	Nonsterile	4.402	2.725	1.326	0.617	0.302
		Mandya				
0.033	Sterile	4.711	4.678	4.611	4.588	4.507
	Nonsterile	4.670	3.622	3.329	3.030	2.680
0	Sterile	4.673	4.582	4.512	4.475	4.436
	Nonsterile	4.557	1.582	1.059	0.375	0.133
		Mudigere				
0.033	Sterile	4.894	4.835	4.802	4.738	4.630
	Nonsterile	4.869	3.806	3.542	3.332	3.056
0	Sterile	4.902	4.813	4.738	4.710	4.607
	Nonsterile	4.845	3.377	2.334	0.876	0.511

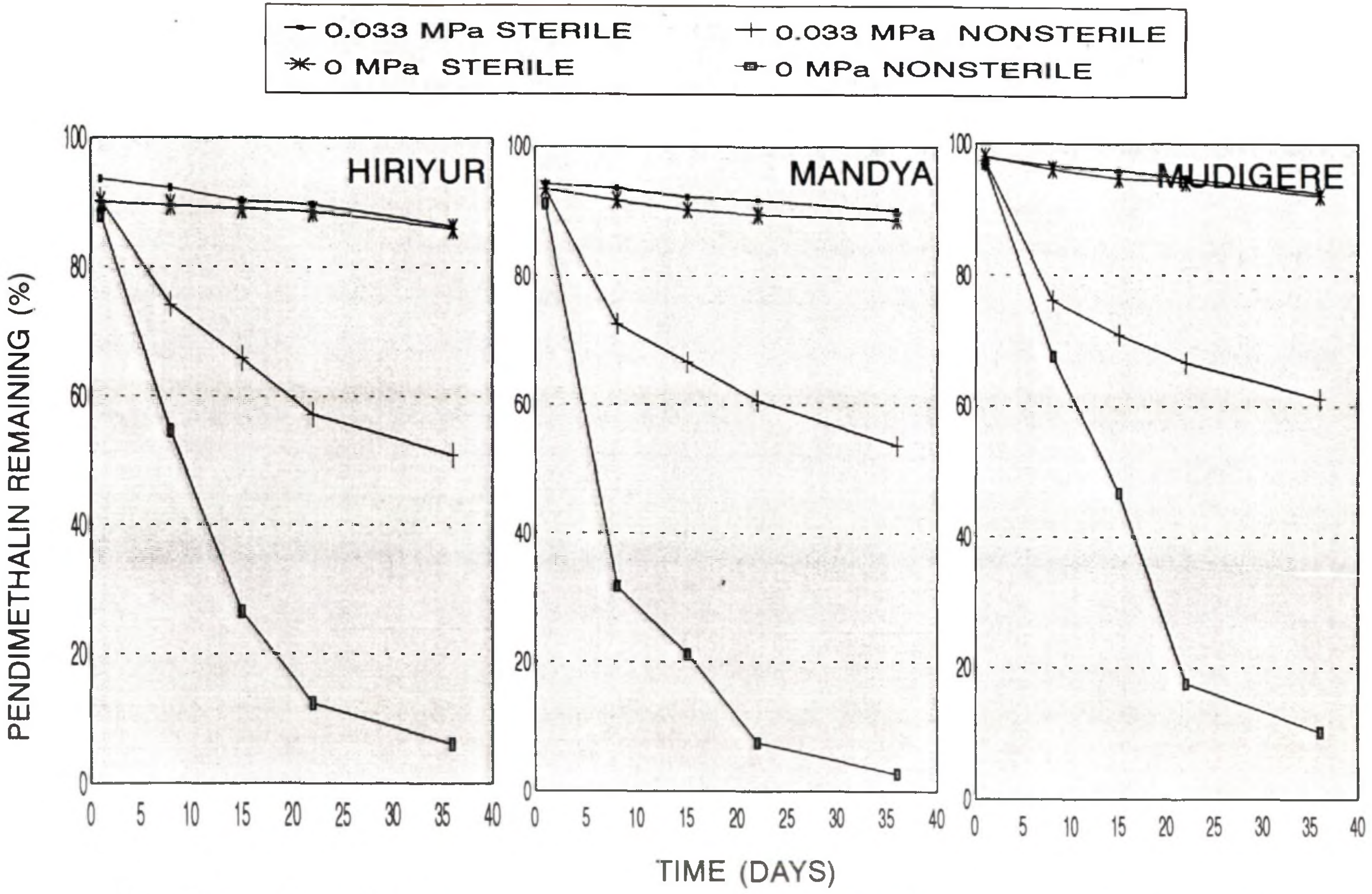


Fig.14 *Persistence of Pendimethalin in sterile and nonsterile soils under two moisture regimes*

whereas, 4.505 mg kg^{-1} on 1st and 4.301 mg kg^{-1} on 36th day under submergence. Incubation of soils under nonsterile conditions showed a residue of 4.515 mg kg^{-1} on 1st day and 2.542 mg kg^{-1} on 36th day under field capacity whereas 4.402 mg kg^{-1} on 1st day and only 0.302 mg kg^{-1} on 36th day under submergence.

The sterile Mandya soils recorded a residue of 4.711 mg kg^{-1} on the 1st day and 4.507 mg kg^{-1} on 36th day under field capacity whereas under submergence the data recorded were 4.673 mg kg^{-1} on the 1st and 4.436 mg kg^{-1} on 36th day. The soils under field capacity registered a residue of 4.670 mg kg^{-1} on the 1st and 2.680 mg kg^{-1} on 36th day in nonsterile soils, whereas 4.557 and 0.133 mg kg^{-1} on the 1st and 36th day respectively under submergence.

Mudigere soil showed slow degradation when compared to Hiriyur and Mandya soils. The soil monitored under field capacity indicated residues of 4.894 mg kg^{-1} on the 1st day and 4.630 mg kg^{-1} on 36th day for sterile soils, while 4.869 mg kg^{-1} on 1st day and 3.056 mg kg^{-1} on 36th day for nonsterile soils. Under submergence, the pendimethalin recovered were 4.902 and 4.607 mg kg^{-1} on 1st and 36th day respectively for sterile soils whereas, 4.845 and 0.511 mg kg^{-1} on 1st and 36th day for nonsterile soils respectively.

4.5.3 DEGRADATION KINETICS OF PENDIMETHALIN IN SOILS

The results of the persistence and degradation of pendimethalin were fitted to first order exponential equation in order to interpret the rate of degradation. The results presented in the Table. 30 depict the rate constants (K_{deg}), determination coefficients (r^2) and half lives ($t_{1/2}$) for pendimethalin degradation in Hiriyur, Mandya and Mudigere soils at different moisture regimes. The determination coefficients (r^2) were greater than 0.8879 in all the soils indicating that the data of pendimethalin persistence and degradation followed first order exponential equation.

It was found that the rate constants were higher at 0.5 mg kg^{-1} rate of application when compared to 5.0 mg kg^{-1} rate of application in all the soils

Table - 30 First order rate constants (K_{deg}) Half lives ($t_{1/2}$) and Determination coefficients (r^2) for Pendimethalin degradation in soils at different moisture regimes.

Moisture regime	Quantity added (mg kg^{-1})	k_{deg} (day^{-1})	r^2	$t_{1/2}$ (days)
			Hiriyur	
Air dry (100 MPa)	0.5	0.0110	0.9388	63.03
	5.0	0.0089	0.9432	78.15
Field Capacity (0.033 MPa)	0.5	0.0185	0.9524	37.45
	5.0	0.0143	0.9308	48.59
Submergence (0MPa)	0.5	0.0852	0.9557	8.14
	I phase*	0.1068	0.9859	6.49
	II phase**	0.0323	1.0000	21.47
	5.0	0.0513	0.8879	13.52
	I phase	0.1032	0.9920	6.71
	II phase	0.0282	0.9333	24.27
			Mandya	
Air dry (100 MPa)	0.5	0.0126	0.9388	54.94
	5.0	0.0109	0.9314	63.27
Field Capacity (0.033 MPa)	0.5	0.0215	0.9592	32.19
	5.0	0.0156	0.9349	44.52
Submergence (0MPa)	0.5	0.1018	0.9815	6.81
	I phase	0.1185	0.9938	5.85
	II phase	0.0634	1.0000	10.94
	5.0	0.0532	0.8900	13.03
	I phase	0.1145	0.9880	6.05
	II phase	0.0297	0.9898	23.36
			Mudigere	
Air dry (100 MPa)	0.5	0.0084	0.8966	82.11
	5.0	0.0073	0.9256	94.50
Field Capacity (0.033 MPa)	0.5	0.0148	0.9624	46.92
	5.0	0.0125	0.9532	55.53
Submergence (0MPa)	0.5	0.0667	0.9807	10.39
	I phase	0.0825	0.9510	8.40
	II phase	0.0525	0.9785	13.21
	5.0	0.0443	0.9071	15.66
	I phase	0.0824	0.9212	8.41
	II phase	0.0256	0.9823	27.12

* I phase = 0 to 22 days ** II phase = 22 day onwards

irrespective of moisture regimes. The rate constants were very high under submergence and least under airdry condition in all the soils. In Hiriyur soil, the rate constants were 0.0110 and 0.0089 day^{-1} under airdry condition, 0.0185 and 0.0143 day^{-1} under field capacity and 0.0852 and 0.0513 day^{-1} under submergence at 0.5 and 5.0 mg kg^{-1} application rate respectively.

The rate constants in Mandya soil were 0.0126 and 0.0109 day^{-1} under airdry, 0.0215 and 0.0156 day^{-1} under field capacity and 0.1018 and 0.0532 day^{-1} under submergence at 0.5 and 5.0 mg kg^{-1} application rate respectively. It was observed that the rate constants were higher in Mandya soil under all the moisture regimes when compared to Hiriyur and Mudigere soils.

In Mudigere soil the rate constants were 0.0084, 0.0148 and 0.0667 day^{-1} at 0.5 mg kg^{-1} application and 0.0073, 0.0125 and 0.0443 at 5.0 mg kg^{-1} application under airdry, field capacity and submergence respectively. The Kdeg values in Mudigere soil were lower than that in Hiriyur and Mandya soils.

The time required for 50 per cent degradation were found to be lower at 0.5 mg kg^{-1} application rate than at 5.0 mg kg^{-1} application rate in all the soils irrespective of moisture regimes. The half lives were higher at airdry moisture regime and decreased with increasing moisture regime and showed very low values under submergence in all the soils irrespective of application rate.

In Hiriyur soil, the half lives were 63.03, 37.45 and 8.14 days at 0.5 mg kg^{-1} application and 78.15, 48.59 and 13.52 days at 5 mg kg^{-1} application under airdry, field capacity and submergence respectively. Mandya soil showed the lowest half lives when compared to Hiriyur and Mudigere soils and the values were 54.94 and 63.27 days under airdry, 32.19 and 44.52 days under field capacity and 6.81 and 13.03 days under submergence at 0.5 and 5.0 mg kg^{-1} respectively. The half lives in Mudigere soils were highest when compared to other two soils and the values were 82.11, 46.92 and 10.39 days at 0.5 mg kg^{-1} application and 94.50, 55.53 and 15.66 days at 5.0 mg kg^{-1} application under airdry, field capacity and submergence respectively.

In general all the three soils under submergence were found to follow two different phases of degradation (Fig. 11). The first phase of degradation covers upto 22 days and the second phase from 22 day onwards. The degradation rate constants and the half lives for the first phase in Hiriyur soil under submergence were 0.1068 day^{-1} and 6.49 days at 0.5 mg kg^{-1} application and 0.1032 day^{-1} and 6.71 days at 5 mg kg^{-1} application. The second phase rate constants were lower than the first phase and the half lives were higher than the first phase indicating the faster degradation at the initial stage. The rate constants for the second phase in Hiriyur soil were 0.0323 and 0.0282 day^{-1} at 0.5 and 5.0 mg kg^{-1} application respectively and the respective half lives were 21.47 and 24.27 days.

The rate constants in Mandya soil under submergence for the first and second phases were 0.1185 and 0.0634 day^{-1} at lower application rate and 0.1145 and 0.0297 day^{-1} at higher application rate. The half lives were 5.85 and 10.94 days at 0.5 mg kg^{-1} application and 6.05 and 23.36 days at 5.0 mg kg^{-1} for the first and second phases respectively.

In Mudigere soil the lowest degradation rate constants were recorded in the first and the second phases when compared to those in Hiriyur and Mandya soils and the values were 0.0825 and 0.0525 day^{-1} at 0.5 mg kg^{-1} and 0.0824 and 0.0256 day^{-1} at 5.0 mg kg^{-1} respectively. The time required for 50 per cent degradation of pendimethalin under submergence for the first and second phases were 8.40 and 13.21 days at 0.5 mg kg^{-1} application and 8.41 and 27.12 days at 5.0 mg kg^{-1} application respectively.

4.5.4 DEGRADATION KINETICS OF PENDIMETHALIN IN SOILS WITH ORGANIC AMENDMENTS

The data on first order rate constants, half lives and determination coefficients for pendimethalin degradation in soils with organic amendments under field capacity and submergence at 5.0 mg kg^{-1} application are presented in Table. 31. The determination coefficients (r^2) were found to be greater than 0.8681 in all the soils even with organic amendments.

Table - 31 First order rate constants (K_{deg}), Half lives ($t_{1/2}$) and Determination coefficients (r^2) for Pendimethalin degradation in soils with different organic amendments

Moisture regime	Organic amendment	K_{deg} (day^{-1})	r^2	$t_{1/2}$ (days)
		Hiriyur		
Field Capacity (0.033MPa)	FYM1	0.0397	0.9835	17.45
	FYM2	0.0445	0.9759	15.59
	PS1	0.0489	0.9791	14.17
	PS2	0.0554	0.9838	12.50
Submergence (0MPa)	FYM1	0.1194	0.9580	5.81
	FYM2	0.1283	0.9703	5.40
	PS1	0.1399	0.9338	4.95
	PS2	0.1449	0.9246	4.78
		Mandya		
Field Capacity (0.033MPa)	FYM1	0.0353	0.9829	19.64
	FYM2	0.0404	0.9780	17.17
	PS1	0.0485	0.9890	14.30
	PS2	0.0533	0.9896	13.02
Submergence (0MPa)	FYM1	0.1583	0.9387	4.38
	FYM2	0.1617	0.9399	4.29
	PS1	0.1599	0.8906	4.34
	PS2	0.1619	0.8681	4.28
		Mudigere		
Field Capacity (0.033MPa)	FYM1	0.0258	0.9686	26.82
	FYM2	0.0284	0.9619	24.38
	PS1	0.0354	0.9769	19.56
	PS2	0.0410	0.9865	16.91
Submergence (0MPa)	FYM1	0.0741	0.9872	9.35
	FYM2	0.0957	0.9850	7.24
	PS1	0.0985	0.9655	7.03
	PS2	0.1110	0.9513	6.25

FYM - Farm Yard Manure
PS - Paddy Straw

1 - One Percent
2 - Two Percent

The degradation rate constants were higher under submergence when compared to that under field capacity in all the soils with organic amendments. The higher degradation rates were noticed in the soil with higher application rates of FYM and paddy straw.

The rate constants in Hiriyur soil with FYM at one and two per cent were 0.0397 and 0.0445 day^{-1} and with one and two per cent paddy straw were 0.0489 and 0.0554 day^{-1} respectively, under field capacity. The Kdeg values under submergence were 0.1194 and 0.1283 day^{-1} for the Hiriyur soil with FYM and 0.1399 and 0.1449 day^{-1} for soil with paddy straw.

In Mandya soil the rate constants were 0.0353 and 0.0404 day^{-1} under field capacity and 0.1583 and 0.1617 day^{-1} under submergence with one and two per cent FYM respectively. The Kdeg values were highest under submergence with FYM and paddy straw amendments. The rate constants for the soil with paddy straw were 0.0485 and 0.0533 day^{-1} under field capacity and 0.1599 and 0.1619 day^{-1} under submergence.

The rate constants were found to be lowest in Mudigere soil even with organic amendments under both field capacity and submergence when compared to Hiriyur and Mudigere soils. The Kdeg values were 0.0258 and 0.0284 day^{-1} under field capacity and 0.0741 and 0.0957 day^{-1} under submergence for the soil with one and two per cent FYM respectively. The application of paddy straw resulted in rate constants of 0.0354 and 0.0410 day^{-1} under field capacity and 0.0985 and 0.1110 day^{-1} under submergence.

The half lives ($t_{1/2}$) for pendimethalin decreased with increased application rates of FYM and paddy straw in all the soils irrespective of moisture regimes and the values were lower in the soils treated with paddy straw when compared to those with FYM. The half lives were lower under submergence than under field capacity in all the soils with organic amendments.

The time required for 50 per cent degradation in Hiriyur soil with FYM at one and two per cent were 17.45 and 15.59 days under field capacity and 5.81 and 5.40 days under submergence. In soils with paddy straw half lives of 14.17 and 12.50 days under field capacity and 4.95 and 4.78 days under submergence were noticed.

The time required for 50 per cent degradation of Pendimethalin in Mandya soil with FYM at one and two per cent were 19.64 and 17.17 days under field capacity and 4.38 and 4.29 days under submergence respectively. The soils with paddy straw registered half lives of 14.30 and 13.02 days under field capacity and 4.34 and 4.28 days under submergence.

The half lives in Mudigere soil with organic amendments were higher than those in Hiriyur and Mandya soils under both field capacity and submergence. The $t_{1/2}$ values under field capacity were 26.82 and 24.38 days for the soil with one and two per cent FYM and 19.56 and 16.91 days for the soil with one and two per cent paddy straw respectively. The half lives under submergence were 9.35 and 7.24 days for the soil with FYM and 7.03 and 6.25 days for the soil with paddy straw respectively.

4.6 LEACHING/MOBILITY OF BUTACHLOR IN SOIL COLUMNS

The leaching/mobility of butachlor was studied in three soils namely Hiriyur, Mandya and Mudigere. The details of the experiment are presented in 3.9.3 and 3.9.4.

4.6.1 MOBILITY STUDY - I

The results of distribution of butachlor in different depths and leaching losses at different intervals in soil columns are presented in Table. 32. and Fig. 15. The data reveal that the distribution of butachlor was maximum in the 0-7.5 cm depth in all the soils at all the intervals. The distribution of butachlor increased in the 7.5-15.0 cm depth after 72 hrs in all the soils.

Table - 32 Distribution of Butachlor in different depths of soil column and leaching losses at different intervals - Mobility study - I

(Butachlor added = 5 mg, Soil column used - air dry)

Depth (cm)	6 hrs		24 hrs		72 hrs	
	mg	%	mg	%	mg	%
			Hiriyur			
0-7.5	3.803	83.99	3.270	73.88	2.740	65.49
7.5-15.0	0.520	11.48	0.713	16.11	0.780	18.64
15.0-22.5	0.205	4.53	0.283	6.39	0.313	7.48
22.5-30.0	--	--	0.120	2.71	0.245	5.86
leaching losses	--	--	0.040	0.90	0.106	2.53
			Mandya			
0-7.5	3.528	79.44	2.965	67.79	2.270	55.94
7.5-15.0	0.610	13.74	0.738	16.87	0.895	22.06
15.0-22.5	0.303	6.82	0.393	8.98	0.508	12.52
22.5-30.0	--	--	0.220	5.03	0.230	5.67
leaching losses	--	--	0.058	1.33	0.155	3.82
			Mudigere			
0-7.5	3.470	72.96	2.568	55.87	2.038	44.52
7.5-15.0	0.733	15.41	1.008	21.93	1.223	26.71
15.0-22.5	0.463	9.74	0.623	13.56	0.730	15.95
22.5-30.0	0.090		0.315	6.85	0.368	8.04
leaching losses	--		0.082	1.78	0.219	4.78

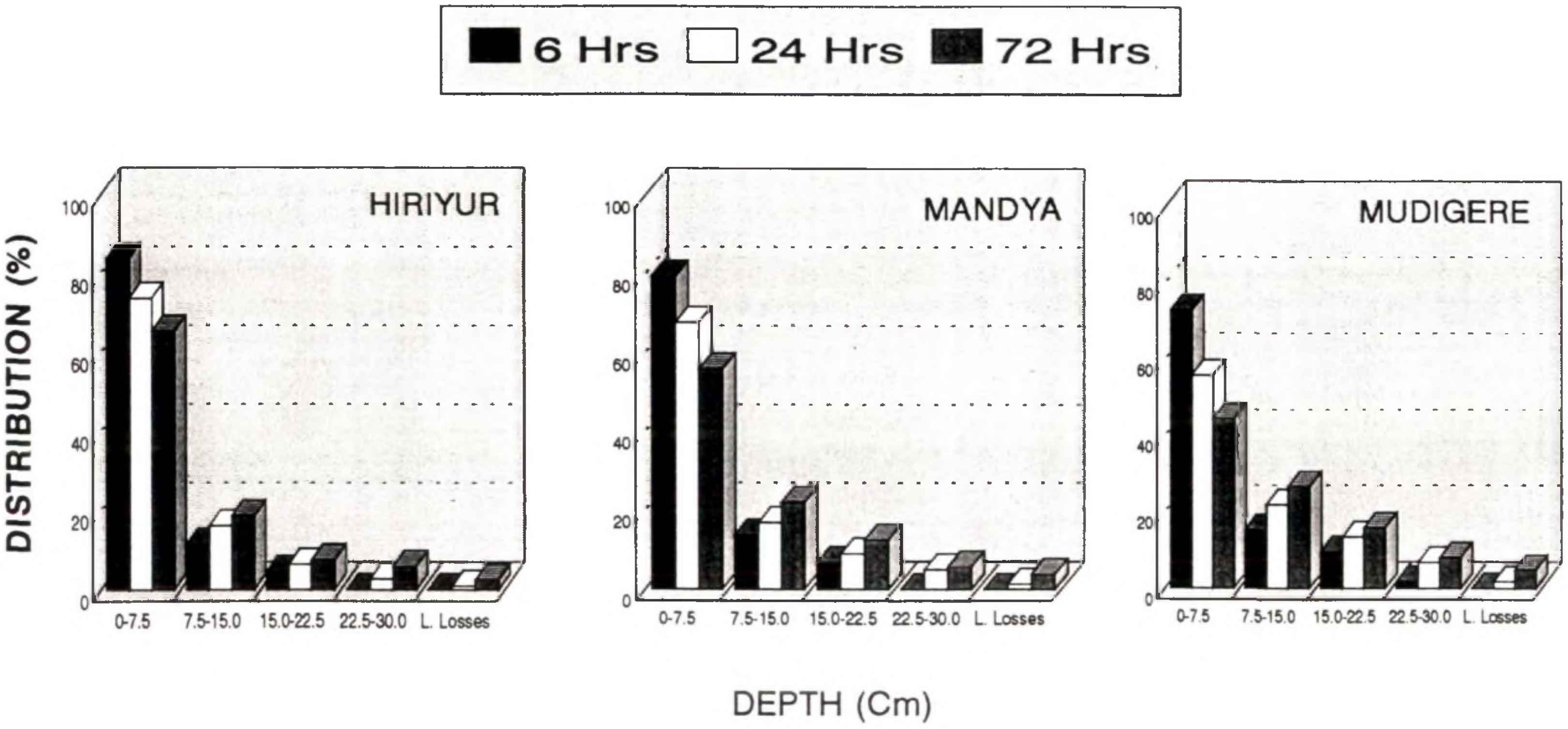


Fig.15 ***Distribution of Butachlor in different depths of soil column and leaching losses at different intervals***

The distribution of butachlor in Hiriyur soil was 3.803, 3.270 and 2.740 mg in the 0-7.5 cm depth after 6, 24 and 72 hrs interval which corresponded to 83.99, 73.88 and 65.49 per cent of the recovered butachlor in the soil column respectively. In 7.5-15.0 cm depth the distribution was 0.520, 0.713 and 0.780 mg which accounted to 11.48, 16.11 and 18.64 per cent after 6, 24 and 72 hrs respectively. The distribution was very less in 15.0-22.5 and 22.5-30.0 cm depth and the values were 0.313 (7.48 %) and 0.245 mg (5.86%) after 72 hrs respectively.

The study on mobility of butachlor in Mandya soil indicated higher levels of butachlor in the 0-7.5 cm depth at all the intervals and the distribution was lower than that in Hiriyur soil. In the 0-7.5 cm depth the butachlor distribution was 3.528 (79.44%), 2.965 (67.79%) and 2.270 (55.94%) mg of the applied herbicide after 6, 24 and 72 hrs respectively. The distribution in 7.5-15.0 cm depth was 0.610, 0.738 and 0.895 mg after 6, 24 and 72 hrs which accounted to 13.74, 16.87 and 22.06 per cent respectively. The distribution was very less in 15.0-22.5 and 22.5-30.0 cm depth and the recovered values were 0.508 and 0.230 mg after 72 hrs which corresponded to 12.52 and 5.67 per cent respectively.

The mobility of butachlor in Mudigere soil was more when compared to Hiriyur and Mandya soils. The distribution in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depth were 3.470, 0.733, 0.463 and 0.090 mg after 6 hrs, 2.568, 1.008, 0.623 and 0.315 mg after 24 hrs and 2.038, 1.223, 0.730 and 0.368 mg of applied herbicide after 72 hrs respectively.

The data on leaching losses of butachlor indicated more leaching in Mudigere soil and least in Hiriyur soil. There was absolutely no leaching by 6 hrs since the soil columns were provided with only field capacity moisture. The leaching losses were 0.040, 0.058 and 0.082 mg of applied herbicide corresponding to 0.90, 1.33 and 1.78 per cent of the recovered herbicide after 24 hrs in Hiriyur, Mandya and Mudigere soil respectively. The quantity lost in the leachate after 72 hrs were 0.106 (2.53 %), 0.155 (3.82 %) and 0.219 (4.78 %) mg of applied herbicide in Hiriyur, Mandya and Mudigere soil respectively.

4.6.2 MOBILITY STUDY - II

The data presented in the Table. 33. indicate the distribution and leaching losses of butachlor in different depths of saturated soil columns after 24 hrs. The distribution of butachlor was 2.568, 0.713, 0.343 and 0.210 mg of applied herbicide in Hiriyur soil at 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths corresponding to 62.31, 17.30, 8.32 and 5.10 per cent respectively. The quantity of butachlor distributed in respective depths were 1.960 (47.58 %), 0.913 (22.17 %), 0.595 (14.45 %) and 0.320 (7.77 %) mg of applied herbicide in Mandya soil and 1.580 (37.37 %), 0.983 (23.25 %), 0.715 (16.91 %) and 0.485 (11.47 %) mg of applied herbicide in Mudigere soil.

The quantity of butachlor present in the top 0-7.5 cm depth was more in all the soils when compared to lower depths. The mobility of butachlor was higher in Mudigere soil than in Hiriyur and Mandya soils. The leaching losses were higher in Mudigere soil than in Hiriyur and Mandya soils. The quantity lost were 0.287, 0.331 and 0.465 mg of applied herbicide which accounted to 6.96, 8.04 and 11.00 per cent respectively in Hiriyur, Mandya and Mudigere soils.

4.7 LEACHING/MOBILITY OF PENDIMETHALIN IN SOIL COLUMNS

The leaching/mobility of pendimethalin was also studied in in three soils namely Hiriyur, Mandya and Mudigere. The details of the experiment were presented in the chapter 3.9.3 and 3.9.4.

4.7.1 MOBILITY STUDY - I

The data on distribution of pendimethalin in different depths and

Table - 33 Distribution of Butachlor in different depths of soil column and leaching losses after 24 hrs - Mobility study - II

(Butachlor added = 5mg, Soil column used - saturated)

Depths (cm)	HIRIYUR		MANDYA		MUDIGERE	
	mg	%	mg	%	mg	%
0-7.5	2.568	62.31	1.960	47.58	1.580	37.37
7.5-15.0	0.713	17.30	0.913	22.17	0.983	23.25
15.0-22.5	0.343	8.32	0.595	14.45	0.715	16.91
22.5-30.0	0.210	5.10	0.320	7.77	0.485	11.47
leaching losses	0.287	6.96	0.331	8.04	0.465	11.00

leaching losses in soil columns at different depths are presented in Table. 34. and Fig. 16.

The distribution of pendimethalin was higher in the 0-7.5 cm depth in all the soils studied at all the intervals when compared to lower depths. The quantity of pendimethalin distributed in Hiriyur soil were 4.373, 0.213 and 0.040 mg after 6 hrs of leaching study which accounted to 94.53, 4.60 and 0.86 per cent of recovered herbicide in 0-7.5, 7.5-15.0 and 15.0-22.5 cm depths respectively. No herbicide was accumulated in the 22.5-30.0 cm depth. The pendimethalin detected in the 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths were 3.965, 0.380, 0.113 and 0.040 mg which accounted to 87.86, 8.42, 2.50 and 0.89 per cent of recovered herbicide after 24 hrs of leaching and 3.708, 0.463, 0.168 and 0.090 mg of applied herbicide which accounted to 82.95, 10.36, 3.76 and 2.01 per cent of recovered herbicide after 72 hrs of leaching respectively.

In Mandya soil, pendimethalin was more mobile than in Hiriyur soil and the accumulation in 0-7.5, 7.5-15.0 and 15.0-22.5 depths were 4.063, 0.245 and 0.060 mg corresponding to 93.02, 5.61 and 1.37 per cent of recovered herbicide after 6 hrs. There was no movement to 22.5-30.0 cm depth after 6 hrs of leaching. The distribution of pendimethalin in Mandya soil after 24 hrs were 3.585, 0.463, 0.123 and 0.065 mg of applied herbicide which accounted to 84.63, 10.93, 2.90 and 1.53 per cent of recovered herbicide in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. After 72 hrs of leaching the distribution of pendimethalin were 3.438, 0.505, 0.163 and 0.088 mg which accounted to 80.99, 11.90, 3.84 and 2.07 per cent of recovered herbicide in corresponding depths.

Mudigere soil recorded more mobility of pendimethalin when compared to Hiriyur and Mandya soils at all the intervals. The distribution were 4.003 (89.77 %), 0.373 (8.37 %) and 0.083 (1.86 %) mg of pendimethalin in 0-7.5, 7.5-15.0 and 15.0-22.5 cm depths respectively and there was no accumulation in the 22.5-30.0 cm depth after 6 hrs of leaching. The pendimethalin accumulation

Table - 34 Distribution of Pendimethalin in different depths of soil column and leaching losses at different intervals - Mobility study - I

(Pendimethalin added = 5 mg Soil column used - air dry)

Depth (cm)	6 hrs		24 hrs		72 hrs	
	mg	%	mg	%	mg	%
			Hiriyur			
0-7.5	4.373	94.53	3.965	87.86	3.708	82.95
7.5-15.0	0.213	4.60	0.380	8.42	0.463	10.36
15.0-22.5	0.040	0.86	0.113	2.50	0.168	3.76
22.5-30.0	--	--	0.040	0.89	0.090	2.01
leaching losses	--	--	0.015	0.33	0.041	0.92
			Mandya			
0-7.5	4.063	93.02	3.585	84.63	3.438	80.99
7.5-15.0	0.245	5.61	0.463	10.93	0.505	11.90
15.0-22.5	0.060	1.37	0.123	2.90	0.163	3.84
22.5-30.0	--	--	0.065	1.53	0.088	2.07
leaching losses	--	--	0.017	0.40	0.051	1.20
			Mudigere			
0-7.5	4.003	89.77	3.473	79.89	3.118	72.23
7.5-15.0	0.373	8.37	0.563	12.95	0.673	15.59
15.0-22.5	0.083	1.86	0.218	5.01	0.340	7.88
22.5-30.0	--	--	0.073	1.68	0.120	2.78
leaching losses	--	--	0.020	0.46	0.066	1.53

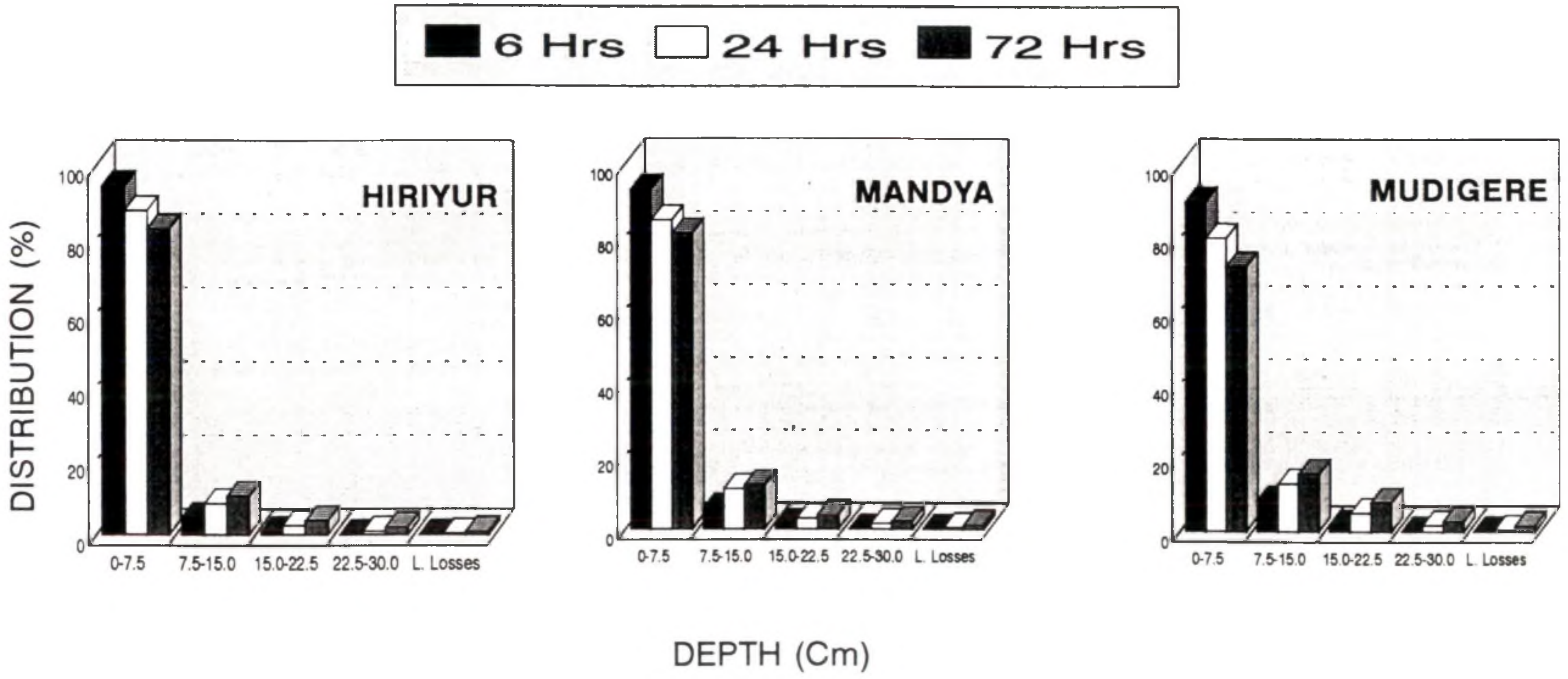


Fig.16 Distribution of Pendimethalin in different depths of soil column and leaching losses at different intervals

in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths were 3.473, 0.563, 0.218 and 0.073 mg of applied herbicide which corresponded to 79.89, 12.95, 5.01 and 1.68 per cent of recovered herbicide after 24 hrs. After 72 hrs, 3.118, 0.673, 0.343 and 0.120 mg of herbicide which corresponded to 72.23, 15.59, 7.88 and 2.78 per cent of herbicide were recovered.

There was absolutely no leaching losses by 6 hrs of leaching in all the soils. The quantity of pendimethalin lost in leaching were 0.015 and 0.090 mg which accounted to 0.89 and 2.01 per cent in Hiriyur soil after 24 and 72 hrs of leaching respectively. Comparatively higher leaching losses were noticed in Mandya and Mudigere soils than in Hiriyur soil. The pendimethalin lost in the leachate was 0.017 (0.40 %) and 0.051 (1.20 %) mg in Mandya soil and 0.020 (0.46 %) and 0.066 (1.53 %) mg in Mudigere soil after 24 and 72 hrs of leaching study respectively.

4.7.2 MOBILITY STUDY - II

The data on distribution of pendimethalin in different depths of saturated soil columns and leaching losses after 24 hrs are furnished in Table. 35.

The Hiriyur soil column had higher accumulation of pendimethalin in the 0-7.5 cm depth when compared to Mandya and Mudigere soils. In Mudigere soil the lowest accumulation was noticed in the 0-7.5 cm depth. The distribution of applied pendimethalin in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths were 3.418, 0.480, 0.195 and 0.163 mg in Hiriyur soil, 3.163, 0.598, 0.263 and 0.215 mg in Mandya soil, 2.463, 0.793, 0.573 and 0.335 mg in Mudigere soil respectively. The per cent accumulation of recovered pendimethalin were 76.77, 10.78, 4.38 and 3.66 in Hiriyur soil, 69.87, 13.21, 5.81 and 4.75 in Mandya soil, 54.23, 17.46, 12.62 and 7.38 in Mudigere soil in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively.

The leaching losses of pendimethalin in the saturated column after 24 hrs were 0.196, 0.288 and 0.378 mg of applied herbicide which corresponded

Table - 35 Distribution of Pendimethalin in different depths of soil column and leaching losses after 24 hrs - Mobility study - II

(Pendimethalin added = 5mg, Soil column used - saturated)

Depths (cm)	HIRIYUR		MANDYA		MUDIGERE	
	mg	%	mg	%	mg	%
0-7.5	3.418	76.77	3.163	69.87	2.463	54.23
7.5-15.0	0.480	10.78	0.598	13.21	0.793	17.46
15.0-22.5	0.195	4.38	0.263	5.81	0.573	12.62
22.5-30.0	0.163	3.66	0.215	4.75	0.335	7.38
leaching losses	0.196	4.40	0.288	6.36	0.378	8.32

to 4.40, 6.36 and 8.32 per cent in Hiriyur, Mandya and Mudigere soils respectively. Comparatively higher leaching losses were observed in Mudigere soil than in Hiriyur and Mandya soils.

4.7.3 BIOASSAY

The results presented in the Table. 36. depict the fresh weight of ten day old ragi seedlings as influenced by butachlor distribution in different depths of soil columns at different intervals of mobility studies I and II.

The fresh weight of ragi seedlings in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths of soil column with herbicide were 1.53, 1.83, 1.80 and 1.73 g after 6 hrs of leaching, 1.44, 1.73, 1.70 and 1.65 g after 24 hrs of leaching and 1.38, 1.52, 1.50 and 1.48 g after 72 hrs of leaching as compared to 2.18, 2.22, 2.25 and 2.12 g in control soils of corresponding depths in mobility study - I. The fresh weights in saturated soil column (mobility study - II) after 24 hrs were 0.45, 1.41, 1.48 and 1.55 g respectively in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths.

The fresh weight of ragi seedlings in Mandya soil without herbicide were 1.96, 2.05, 2.09 and 2.11 g in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. The fresh weight in the columns of mobility study - I with butachlor were 1.81, 2.03, 2.05 and 2.15 g after 6 hrs, 1.73, 1,82, 1.80 and 1,83 g after 24 hrs and 1.80, 1.90, 1.91 and 1.86 g after 72 hrs in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. In the saturated soil column (mobility study - II), after 24 hrs, the fresh weight of ragi seedlings recorded were 0.57, 1.71, 1.85 and 1.94 g in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. In general the fresh weights in all the depths at respective leaching intervals in Mudigere soil were lower than in Hiriyur and Mandya soil and the values were 1.29, 1.65, 1.68 and 1.71 g after 6 hrs, 1.05, 1.42, 1.55 and 1.63 g after 24 hrs and 1.36, 1.45, 1.64 and 1.65 g after 72 hrs of leaching in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. The fresh weight of ragi seedlings in the saturated soil columns as influenced by

Table - 36 Fresh weight (g) of ten day old ragi seedlings as influenced by Butachlor distribution in soil columns.

Depth (cms)	Mobility study - I				Mobility study - II
	Control	6 hrs	24 hrs	72 hrs	24 hrs
			Hiriyur		
0-7.5	2.18	1.53	1.44	1.38	0.45
7.5-15.0	2.22	1.83	1.73	1.52	1.41
15.0-22.5	2.25	1.80	1.70	1.50	1.48
22.5-30.0	2.12	1.73	1.65	1.48	1.55
			Mandya		
0-7.5	1.96	1.81	1.73	1.80	0.57
7.5-15.0	2.05	2.03	1.82	1.90	1.71
15.0-22.5	2.09	2.05	1.80	1.91	1.85
22.5-30.0	2.11	2.15	1.83	1.86	1.94
			Mudigere		
0-7.5	1.87	1.29	1.05	1.36	0.33
7.5-15.0	1.92	1.65	1.42	1.45	0.86
15.0-22.5	1.93	1.68	1.55	1.64	1.63
22.5-30.0	1.95	1.71	1.63	1.65	1.68

distribution of butachlor in different depths were 0.33, 0.86, 1.63 and 1.68 g respectively.

In general the fresh weight of ragi seedling were affected to a greater extent in the top 0-7.5 cm depth than the lower depths in all the soils at all the intervals in both the mobility studies.

The data on fresh weight of ragi seedlings as influenced by pendimethalin distribution in soil columns are presented in Table 37.

The results indicated that the fresh weight of ragi seedlings in soil columns with no herbicides were 2.18, 2.22, 2.25 and 2.12 g in Hiriyur, 1.96, 2.05, 2.09 and 2.11 g in Mandya and 1.87, 1.92, 1.93 and 1.95 g in Mudigere soil in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively.

The seedlings weight as influenced by pendimethalin distribution in Hiriyur soil columns of mobility study - I were 0.13, 1.83, 1.90 and 1.87 g after 6 hrs, 0.17, 1.44, 1.87 and 1.91 g after 24 hrs and 0.24, 1.05, 1.76 and 1.80 g after 72 hrs in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively. The fresh weight of ragi seedlings in Mandya soil columns were 0.36, 2.01, 2.05 and 1.97 g after 6 hrs, 0.15, 1.89, 1.81 and 1.80 g after 24 hrs and 0.57, 1.77, 1.81 and 1.84 g after 72 hrs in respective depths. In Mudigere soil, the fresh weight of ragi seedlings in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths were 0.22, 1.23, 1.73 and 1.81 g after 6 hrs, 0.11, 0.97, 1.58 and 1.78 g after 24 hrs, 0.43, 0.55, 1.21 and 1.47 g after 72 hrs of leaching study respectively.

In saturated soil columns (mobility study - II) the seedlings weight were 0.44, 1.67, 1.75 and 1.83 g in Hiriyur, 0.85, 1.80, 1.86 and 1.88 g in Mandya and 0.25, 0.89, 1.53 and 1.76 g in Mudigere soils in 0-7.5, 7.5-15.0, 15.0-22.5 and 22.5-30.0 cm depths respectively.

The data presented in the Table. 38. reveal the fresh weight of ten day old ragi seedlings as influenced by graded concentrations of butachlor and

Table - 37 Fresh weight (g) of ten day old ragi seedlings as influenced by Pendimethalin distribution in soil columns.

Depth (cm)	Mobility study - I				Mobility study - II
	Control	6 hrs	24 hrs	72 hrs	24 hrs
			Hiriyur		
0-7.5	2.18	0.13	0.17	0.24	0.44
7.5-15.0	2.22	1.83	1.44	1.05	1.67
15.0-22.5	2.25	1.90	1.87	1.76	1.75
22.5-30.0	2.12	1.87	1.91	1.80	1.83
			Mandya		
0-7.5	1.96	0.36	0.15	0.57	0.85
7.5-15.0	2.05	2.01	1.89	1.77	1.80
15.0-22.5	2.09	2.05	1.81	1.81	1.86
22.5-30.0	2.11	1.97	1.80	1.84	1.88
			Mudigere		
0-7.5	1.87	0.22	0.11	0.43	0.25
7.5-15.0	1.92	1.23	0.97	0.55	0.89
15.0-22.5	1.93	1.73	1.58	1.21	1.53
22.5-30.0	1.95	1.81	1.78	1.47	1.76

Table - 38 Fresh Weight (g) of ten day old ragi seedlings as influenced by graded concentrations (ppm w) of Butachlor & Pendimethalin in soils

Concentration (ppm w)	Hiriyur	Mandya	Mudigere
		Butachlor	
Control	0.89	0.90	0.87
0.5	0.89	0.94	0.86
1.0	0.90	1.00	0.71
2.0	0.96	0.98	0.74
4.0	1.00	0.83	0.67
8.0	0.83	0.81	0.63
		Pendimethalin	
Control	0.89	0.90	0.87
0.5	0.15	0.58	0.10
1.0	NG	0.26	0.08
2.0	NG	NG	NG
4.0	NG	NG	NG
8.0	NG	NG	NG

NG - NO GERMINATION

pendimethalin applied to soil. The concentrations used were 0, 0.5, 1.0, 2.0, 4.0 and 8.0 ppm (w/w) and the experimental details are presented in the chapter 3.9.6. The weight of ragi seedlings in Hiriyur, Mandya and Mudigere soils with no herbicides were 0.89, 0.90 and 0.87 g respectively and there was no much difference in the fresh weight among different concentrations of butachlor in Hiriyur and Mandya soils and a little difference in the growth were observed in Mudigere soil.

The fresh weight of ragi seedlings in the soil with 0.50 ppm of pendimethalin concentrations were affected to a greater extent and the effect was more in Hiriyur and Mudigere soil than in Mandya soil. No germination was observed in the soils with 2.0 ppm and more than 2.0 ppm of pendimethalin concentration in all the soils.

DISCUSSION

VI. DISCUSSION

The results of adsorption-desorption, persistence and degradation and mobility of butachlor and pendimethalin in three selected soil series of Karnataka are discussed in this chapter.

5.1 ADSORPTION-DESORPTION OF BUTACHLOR IN SOILS

Adsorption-desorption phenomena occupy a central position in controlling the distribution of herbicides in soils, which controls the quantity of herbicide in soil solution and thus determine its biological activity, mobility in soil water and volatility. Inorganic and organic surfaces make up the soil adsorption complex (Calvet, 1980).

The data on adsorption and desorption of butachlor in Hiriyur, Mandya and Mudigere soils and when these soils were amended with two and four per cent FYM as organic amendment are presented in Tables. 6, 7 and 8. The data revealed that the amount of butachlor adsorbed by all the soils continued to increase at a decreasing rate, with each increase in solution concentration. This suggests that adsorption sites were not saturated at any concentration considered in this study.

The adsorption of butachlor in different soils decreased in the order of Mandya > Hiriyur > Mudigere, which is also the order of decreasing organic carbon in the soils. Hence, higher adsorption of butachlor in Mandya soil could be mainly attributed to higher organic carbon content than other two soils. The positive effect of organic matter on the adsorption of organic chemicals has been well established by Brightwell and Rueppel (1978), Weber and Peter (1982) and Sato *et al.* (1987).

Soils amended with two and four per cent FYM further increased the adsorption of butachlor in all the soils suggesting the influence of organic carbon on adsorption. However no definite trend in the increase was observed, with incremental addition of organic matter. The magnitude and mechanisms of adsorption are influenced by the type of organic matter, the extent of decomposition of organic matter as well as clay organic matter interactions. Similar observations were also made by Strek and Weber (1982) for alachlor and metolachlor.

The cumulative desorption and per cent desorption was found to increase with increasing initial concentration in all the soils and also in soils with additional organic matter, However, the desorption of butachlor in soils decreased in the order of Mudigere > Hiriyur > Mandya which is also in the increasing order of soil organic carbon. The per cent desorption was found to decrease in all the soils with two and four per cent FYM indicating stronger adsorption of butachlor by organic matter. In Mudigere soil out of 43.90 mg kg^{-1} of adsorbed butachlor, 16.2 mg kg^{-1} was desorbed accounting for 38.09 per cent of the applied 100 mg kg^{-1}. However at the same level of application there was increase in adsorption with lesser per cent desorption with organic matter incorporation.

The values for 1/n (slopes) were < 1.0 and indicated a non linear relationship between herbicide concentration and adsorption and can be characterized as L type of adsorption isotherm. The L shaped isotherm signify that the soil has a high affinity for the herbicides. The adsorption occurred in a planar configuration and bonding was multifunctional. Weber and Peter (1987) characterized alachlor and metolachlor adsorption isotherm as L shaped on organic matter and S-shaped on montomorillonite.

The Freundlich equation provided a good fit ($r^2 > 0.98$) to the adsorption data in all the soils (Table. 9). Soil adsorption of most of the chloroacetanilide herbicides is better described by Freundlich than by Langmuir equations (Obrigawitch *et al*, 1981, Sato *et al*, 1987; Wood *et al*, 1987). The Freundlich equation is empirical and imposes no limits on adsorption, while the Langmuir equation is based on theoretical considerations and shows maximum adsorption when a monolayer covers all surfaces. The Freundlich equation relates adsorbed and solution phase concentration at equilibrium.

The Freundlich constant K values ranged from 4.599 to 14.181 and found to increase with the addition of FYM at two and four per cent (w/w) levels in all the soils. The K values followed the order Mandya > Hiriyur > Mudigere soils which is also in decreasing order of organic carbon. Brightwell and Rueppel (1978) reported K values ranging from 3.5 to 20.0 and Sato *et al* (1987) noticed a range of 14.8 to 38.9 for butachlor adsorption on soils. A significant correlation ($r = 0.9695$) between Freundlich K and organic carbon content of soil indicated major role played by the organic carbon in butachlor adsorption. Hence, the absolute quantity of butachlor adsorbed by unit quantity of organic carbon content of soil was calculated. The sorption coefficient K_{oc} is commonly a measure of pesticide sorption to soil organic carbon. Association with soil organic matter is commonly assumed to be a major mechanism of pesticide sorption in soils. Butachlor, a member of chloroacetanilide group, also exhibits high affinity towards organic phase. The K_{oc} values ranged from 1289 to 1757. Though the absolute quantity of butachlor adsorbed in Mandya soil per unit of soil is highest, the contribution towards adsorption per unit of organic carbon is less as observed by the lowest K_{oc} values among the soils. This may be due to higher organic matter-clay interaction and subsequent stabilization of organic matter, thereby, reducing the number of adsorption sites on the native organic fraction. However, when extraneous organic matter is added in the form of partially decomposed FYM, comparatively higher adsorption per unit of carbon was observed as revealed by higher K_{oc} values with the increased FYM content. The variability in K_{oc} values may be due to differences in sorptive efficiency of soil organic carbon among soils and a poor relationship ($r = -0.0228$) was observed between organic carbon content of soil and K_{oc}. Chesters *et al* (1989) reported that the K_D values of alachlor and metolachlor adsorption did not show parallel increase with organic matter and clay content.

The adsorption desorption isotherms of butachlor in Hiriyur, Mandya and Mudigere soils and these soils with two and four per cent FYM are presented in Figs. 1, 2 and 3. Adsorption isotherms were generally L shaped and this is a common feature for the adsorption of organic chemicals in mineral soils.

Decrease in the amount of herbicide desorbed from the soil in comparison to that adsorbed, and with successive desorption steps, are referred to as the hysteresis effect (Braverman *et al*, 1990). The desorption process exhibited pronounced hysterisis in all the soils and for every level of initially adsorbed butachlor which was subjected to desorption. This is evident from the desorption isotherms corresponding to each initial butachlor concentration. The hysteresis was more pronounced when the desorption was carried out from higher levels of adsorbed butachlor. Thus, when the adsorption was carried out from soils where only 5 to 11 mg kg^{-1} of butachlor was present, the desorption isotherms were very close to the adsorption isotherms. This shows that the degree of irreversibility in the adsorption process increases with increase in sorbed butachlor. Similar features were also observed by Murray *et al* (1975) for dipropetryn and prometryn, Aharonson and Kafkafi (1975) for thiabendazole and Wu *et al* (1975) for napropamide and Raman *et al* (1988) for atrazine.

The main cause of hysterisis during desorption is the presence of a number of heterogeneous adsorbing sites of varying energy levels on soils. In addition to this, are the modifications that take place in the soil itself during the adsorption-desorption process (Clavet, 1980). Thus, the desorption methodology itself imposes an inbuilt lacuna, in that, the adsorption-desorption data are obtained under continuously changing conditions like surface area and aggregate size. Also, as Koskinen *et al* (1979) pointed out, some times, biochemical or chemical degradation can also destroy adsorption-desorption isotherms and result in effects apparently but not truly due to hysterisis. However, the exact causes of this effect are still in dispute (Braverman *et al.*, 1990).

5.2 ADSORPTION - DESORPTION OF PENDIMETHALIN IN SOILS

The dinitroaniline herbicides have low water solubility and are relatively non polar and essentially nonionic. Their properties suggest that adsorption would be associated with hydrophobic and lipophilic organic surfaces in soils. The data presented in the Tables. 10, 11 and 12 indicated that the adsorption of pendimethalin increased with increasing initial concentration and the per cent adsorption decreased with increasing concentration. The low concentration range (89 X $10^{-2}$to 356 X 10^{-2}uM kg^{-1}) used in the adsorption study was due to its very low water solubility (0.3 ppmv at 20°C). Higher concentration would result in precipitation of the herbicide in water. The hydrogen bonding can be formed between nitro groups of pendimethalin molecules and alkyl groups of neighbouring molecules resulting in lipophilic structure, which can resist solvation into the water structure. Weber (1987) reported that the dinitro groups are responsible for decreasing the water solubility of dinitroaniline herbicides.

All the soils showed very high adsorption of pendimethalin when compared to butachlor. This may be due to its low water solubility, high potential for hydrogen bonding and low concentration range used in the study.

The pendimethalin adsorption in soil was found to be in the order of Mandya > Hiriyur > Mudigere. This trend could be mainly attributed to organic carbon content of soils. The results in this study confirm the finding of Lambert (1968), who observed a high correlation between sorption of two dinitroanilines on 23 soils and the organic matter content of the soils. Weber (1972) also found very high adsorption of a related dinitroaniline, trifluralin by soil organic matter. Weber and Monaco (1972) suggested that the dinitroaniline herbicides probably associated with hydrophobic sites on soil organic matter.

The organic matter contains saturated and unsaturated cyclic and heterocyclic ring structures, alcohols, proteins, carboxyls and carbohydrate residues. Polymerization of these constituents yields molecular weights as high as 3,00,000 (Stevenson, 1972). Certain portions of these polymers are highly aromatic and hydrophobic. Compounds of low water solubility are preferentially adsorbed to these hydrophobic areas and are removed from solution.

Incorporation of FYM at two and four per cent had considerably increased the adsorption of pendimethalin in all the soils. The added organic matter could have provided additional sites for adsorption. This can be compared with the observations of Weber (1972) and Wheeler *et al.* (1979). Pendimethalin molecules can bind with the soil particles by hydrogen bonds between nitro groups in its structure and proteinaceous sites in the soil organic matter. This can be attributed to the charge transfer bonds between high charge density aromatic rings in soil humic substances and low charge density aromatic rings of the pendimethalin as observed by Weber (1987). Van Bladel and Moreale (1977) and Jacques and Harvey (1979) also reported similar results with other dinitroanilines.

The cumulative desorption and the per cent desorption of pendimethalin increased with increasing initial concentration in all the soils and with two and four per cent FYM. It is assumed that at lower concentration, the adsorbed pendimethalin molecules could be strongly held when compared to those at higher concentration, where the competition between pendimethalin molecules for the limited adsorption site could have left more number of molecules in loosely bound positions and these molecules can be easily removed by desorption. The cumulative desorption and per cent desorption of pendimethalin decreased in all the soils with two and four per cent FYM than in the soils without FYM. The lowest per cent desorptions were noticed in all the soils with four per cent FYM. This may be attributed to the low solubility of pendimethalin after the formation of hydrophobic bonds with soil or charge transfer bond with organic substance which resist solvation into water. Thus high affinity of herbicides towards the organic molecules resisted the desorption process. Similar findings were also observed by wheeler *et al* (1979) for trifluralin herbicide.

The higher cumulative desorption and the per cent desorption in Mudigere soil than in Hiriyur and Mandya soils may be attributed to lower organic carbon content in Mudigere soil than in other two soils. Desorption studies add further evidence that hydrophobic bondings are involved in adsorption of nonionic chemicals, since, the less soluble compounds like dinitroaniline herbicides were also difficultly desorbed from the organic matter surface. In agreement with Weber and Monaco (1977) the adsorption of dinitroanilines was due to physical adsorbate-adsorbent attractions and was not due to cation exchange mechanisms, since there was very little difference in desorption between water and 1 N $CaCl_2$ solution.

The adsorption desorption isotherms are given in Figs. 4, 5 and 6. The adsorption isotherms of pendimethalin can be classified under L type, since the slope (1/n) values were less than unity in all the soils and also with FYM application. Adsorption of pendimethalin studied by Jacques and Harvey (1979) also noticed L-type and sorption increased with increasing organic matter.

No much deviation was observed between desorption and adsorption isotherms in Hiriyur and Mandya soil, while a little deviation can be seen in Mudigere soil. The deviation can be attributed to hysteresis. The hysteresis was more pronounced when the desorption was carried out from organic amended soils. The desorption isotherms close to adsorption isotherms indicate the degree of irreversibility. This can be observed when the desorption was carried out from soils at all the concentrations and can be attributed to very low concentration range used in this study. Similar features were also observed by Murray *et al.* (1975) for dipropetryn and prometryn, Aharonson and Kafkafi (1975) for thiabendazole and Wu *et al.* (1975) for napropamide and Raman *et al.* (1988) for atrazine.

The sorption data of pendimethalin can be better explained by Freundlich equation as in the case of butachlor. The data presented in the Table. 13. indicate the order of decreasing values of K as Mandya > Hiriyur > Mudigere soil. The Freundlich K values for pendimethalin were higher than that observed for butachlor in these soils and may be attributed to very high adsorption of pendimethalin than butachlor. The higher values of Freundlich K (68.659) in Mandya soil than the other two soils may be due to high soil organic carbon content. The addition of organic matter further increased the K values in all the soils. Peter and Weber (1985) also reported high adsorption of dinitro anilines with the soils having high organic matter. The correlation coefficients between

Freundlich K and soil organic carbon was found to be very high (r = 0.9873).

Mudigere soil adsorbed greater amounts of pendimethalin per unit of organic carbon as noticed by higher K_{oc} than other two soils. Though the difference between the K_{oc} values among the soils was not marked, the correlation coefficient between K_{oc} and the organic carbon content of soil was very less (r = -0.2203) and no definite trend was observed with respect to the organic carbon content of the soil. The addition of FYM at two and four per cent drastically reduced the K_{oc} values in Mudigere soil and this trend was not observed in other two soils. The variation in pendimethalin adsorption per unit carbon (K_{oc}) values in soils and with two and four per cent FYM may be attributed to the differences in the mineral matter, clay-organic matter interaction and pH of the soils.

As organic matter decomposes, the per cent of organic fraction consisting of humic acid increases and adsorptive capacity among organic materials is greatest with humic acid (Adams, 1973). Furthermore, in soils with high organic carbon contents, the organic matter may be more aggregated resulting in a decrease in the available adsorptive surface per unit weight of organic carbon and the variations in K_{oc} values may also be due to differences in sorptive efficiency of soil organic carbon content among soils.

5.3 PERSISTENCE OF BUTACHLOR IN SOILS

The persistence of herbicides depend on many factors, most important among them are soil type, soil moisture and temperature. Organic matter and clay content of soil also affect the persistence of herbicides in soil by adsorbing on the colloidal surface thus rendering it unavailable to the biosystem and decreasing its effectiveness in controlling weeds. However, it is difficult to mention any one major factor responsible for butachlor persistence and degradation.

The persistence and degradation of butachlor was studied in Hiriyur, Mandya and Mudigere soils under three different moisture regimes namely air dry (100 MPa), field capacity (0.033 MPa) and submergence (0 MPa). The persistence data of butachlor at 2.5 and 5.0 mg kg^{-1} application are presented in Tables. 14, 15 and 16. The parameters of degradation kinetics of butachlor are presented in Table. 21.

Increased application rate increased the persistence of butachlor in all the soils irrespective of moisture regimes. The persistence data indicated a close correspondence to first order degradation kinetics ($r^2 > 0.9561$). The rate constants and half lives were derived by linear regression analysis of residual concentration on a logarithmic scale against time of incubation for each soil. With first order kinetics, rate constants should be independent of initial concentration. But for many herbicides, rates of loss decreased as initial concentration increased (Hurle and Walker, 1980). The reduced degradation rates at higher initial concentrations might result from a limitation in the number of reaction sites in soil (Hance and Mc Kone, 1971) and toxic effects on micro organisms or enzyme inhibition (Hurle, 1981). However, Kulshrestha (1987) reported that the rate of degradation of butachlor was not affected by the rate of application in the field condition. Chen and Chen (1978), Kulshrestha (1987) and Chakraborty *et al* (1990) also observed first order kinetics for the butachlor degradation in soil.

Degradation of butachlor was faster under field capacity (0.033 MPa) than under air dry (100 MPa) and submergence (0 MPa) in all the soils irrespective of application rates. The data presented in the Table. 20. reveal that the degradation of butachlor is mainly biological and the factors favourable for microbial degradation are pH, temperature, moisture and organic matter. It was found that soil moisture played an important role in the degradation of butachlor. The half lives of butachlor ranged from 52.40 to 59.57 days under air dry, 12.25 to 20.58 days under field capacity and from 28.48 to 39.20 days under submergence at 5 mg kg^{-1} application rate. Mabbayad *et al.* (1984) also noticed faster dissipation of butachlor under 90 per cent field capacity than at lower field capacity moisture content. Contradictorily, Chakraborty *et al* (1990) noticed higher degradation under submergence than under field capacity and air dry conditions and their half lives ranged from 8.29 to 12.19 days for air dry, 7.93 to 11.74 days for field capacity and 7.66 to 11.31 days for submergence conditions in four different soils of West Bengal and the values indicated very negligible differences between moisture regimes. Beestman and Deming (1974) reported short half lives for butachlor which ranged from 9.4 to 14.4 days under warm moist field condition. Jayakumar and Sree Ramulu (1993) reported 19 days for the 50 per cent degradation of butachlor in field condition.

When compared among the soils, persistence of butachlor was least in Mandya soil followed by Hiriyur and Mudigere soils. The lower persistence of butachlor in Mandya soil may be due to high organic matter and neutral pH, which could favour the degradation of butachlor. Leela (1987a) indicated that the inactivation of butachlor in natural soil is mainly due to high organic matter content. The higher persistence in Hiriyur soil when compared to Mandya soil may be due to low organic matter and higher pH. Since, the degradation of butachlor was found to be mainly microbial (Table. 20), higher degradation in Hiriyur soil than in Mudigere soil under field capacity may be attributed to greater amount of water at a given field capacity and its clayey nature. Zimdahl and Clark (1982) suggested that more rapid degradation of metolachlor herbicide in clay loam (pH 8.0 and 2.5 % organic matter) than sandy soil (pH 7.8 and 1.1 % organic matter) may be due to either greater amount of water at a given field capacity in the clay loam or a higher level of microbial activity in the clay loam. However, the first reason suggested by them is plausible in view of the observed effect of moisture content on rate of degradation of butachlor. The different range of pH did not affect the degradation of butachlor in the present study which is in conformity with the findings of Chen and Chen (1979). The observed persistence of butachlor in these three soils is a manifestation of all these factors operating at different levels.

In general all the three soils under field capacity were found to follow two different phases of degradation (Fig. 7). The first phase of degradation covered upto 22nd day of incubation and the second phase from 22nd day onwards and both the phases could be adequately described by first order kinetics (Table. 21). The calculated half lives ranged from 7.93 to 12.97 days and 9.30 to 15.20 days at 2.5 and 5.0 mg kg^{-1} level of application for the first phase whereas those for the second phase in the two levels ranged from 10.93 to 15.04 days and 14.29 to 24.08 days respectively.

5.3.1 PERSISTENCE OF BUTACHLOR IN SOIL WITH ORGANIC AMENDMENTS

The data on degradation of butachlor under field capacity and submergence with the addition of FYM and paddy straw as organic amendments are presented in Tables. 17, 18 and 19 and Figs. 8 and 9. The addition of organic amendments hastened the degradation of butachlor in all the soils under both field capacity and submergence. Since the degradation of butachlor is mainly microbial (Table. 20), the addition of easily degradable organic substrates result in a spontaneous increase in microbiological activity and one would expect enhanced degradation by such treatments. Thus, addition of organic amendments showed priming effect and increased the degradation of butachlor. Wolf and Martin (1974) noticed that addition of maize and bean straw enhanced the degradation of bromacil and terbacil. Hance (1973) compared the degradation of atrazine in two different soils and reported that FYM or straw accelerated atrazine degradation in one soil whereas, mineral fertilizers (N, P and K) or fertilizers plus straw accelerated degradation in both soils. Hurle (1981) also found that straw enhanced degradation of atrazine but nitrogen inhibited rates of loss. However, the effect of straw plus nitrogen was dependent on straw to nitrogen ratio.

The degradation of butachlor in all the three soils was rapid under field capacity than under submergence even with the addition of FYM and paddy straw as organic amendments. Higher degradation was noticed in all soils amended with paddy straw amendment compared to FYM. Half lives ranged from 5.87 to 9.09 days at one per cent and 4.89 to 7.66 days at two per cent paddy straw under field capacity, whereas those under submergence for the same levels ranged from 15.30 to 22.84 days and 11.70 to 18.15 days respectively. However, it is unusual for degradation to be more rapid in soils with paddy straw amendments compared to FYM, since the ratio of C:N is very wide. But the per cent degradation per unit carbon of FYM was found to be two to four times higher than paddy straw in all the soils under both field capacity and submergence at all the intervals.

5.3.2 PERSISTENCE OF BUTACHLOR IN STERILE AND NONSTERILE SOILS

To monitor the relative importance of chemical and microbial degradation, the persistence of butachlor was studied under sterile (autoclaved) and nonsterile (nonautoclaved) conditions. The persistence of butachlor was higher in sterile condition of all the soils under both field capacity and submergence than in nonsterile condition, suggesting major pathway of degradation of butachlor as microbiological (Table. 20. and Fig. 10). The per cent degradation in sterile soils after 36th day ranged from 13.78 to 16.08 per cent under field capacity and 11.52 to 14.5 per cent under submergence, whereas, those for the nonsterile soils, ranged from 78.04 to 91.88 per cent under field capacity and 54.24 to 60.64 per cent under submergence respectively.

The present study was suggestive that, the lesser degradation in sterile soil was due to the suppression of microbial activity, though it is also known that autoclaving can alter the soil organic and mineral matter sufficiently to inhibit several important classes of abiotic and soil reactions (Wolf *et al* 1989).

Beestman and Deming (1974), Chen and Chen (1977), Chen and Wu (1978) and Lee (1978) also reported that the major pathway of degradation of butachlor was by microorganisms. However, Chen and Chen (1978), Chen and Chen (1979) and Chen (1981) reported, photodecomposition and volatilization as other pathways in addition to microbial degradation for butachlor.

Most researchers observed higher dissipation of butachlor under submergence in field condition and attributed to photodecomposition, volatilization, microbial degradation, leaching and runoff. The higher degradation of butachlor under field capacity compared to submergence in the present study may be attributed to the rapid degradation by aerobic and facultative aerobic microorganisms.

5.4 PERSISTENCE OF PENDIMETHALIN IN SOILS

The persistence of pendimethalin in soils is also influenced by various factors like soil moisture, temperature, organic matter content and microbial activity.

The data on persistence of pendimethalin in Hiriyur, Mandya and Mudigere soils are presented in Tables. 23, 24 and 25 respectively, and the parameters of first order degradation kinetics are presented in Table. 30.

It was found that initial concentration (0.5 and 5.0 mg kg^{-1}) affected the degradation rate kinetics in all the soils. Reduced degradation rates at higher initial concentrations have been attributed to possible toxic effects on microorganisms or enzyme inhibition (Hurle, 1981). Since the application rate used in the present study was very wide, the half lives obtained also varied greatly. However, Barrett and Lavy (1983) noticed no significant influence of application of pendimethalin at the rate of 0.5, 1.0 and 2.0 mg kg^{-1} soil on the rate of dissipation. Tewari *et al* (1994) observed that increased dose of pendimethalin application increased the persistence in the field condition and residue persisted for 15 days when applied at 0.5 kg ha^{-1}, 21 days with 1.5 kg ha^{-1} and 40 days with 2.5 kg ha^{-1}. Edwards (1972) claimed that in the fields, only unusually high rates of herbicide application would produce such an effect.

Increase in moisture content increased the degradation of pendimethalin in all the soils. Pendimethalin degradation was most rapid under submergence

(0 MPa) followed by field capacity (0.33 MPa) and air dry (100 MPa) conditions. In air dry soil, the degradation of pendimethalin was very less, obviously due to low moisture content. Since the degradation of pendimethalin was mainly microbial (Table. 29), moisture becomes a limiting factor and this has been reflected in higher persistence and half lives compared to field capacity and submerged conditions. Walker and Bond (1977), Savage (1978), Smith *et al* (1979), Barrett and Lavy (1983), Zimdahl *et al* (1984), Nalayini *et al* (1991), Yadav *et al* (1993) and Vouzounis and Americanos (1994) also observed the effect of moisture on degradation of pendimethalin.

The half lives for pendimethalin under airdry, field capacity and submerged conditions ranged from 63.27 to 94.50, 44.57 to 55.53 and 13.03 to 15.66 days respectively at 5 mg kg^{-1} of application. It is very interesting to note that the difference in the half lives between the soils narrowed from air dry (nearly 30 days) to submergence (nearly 3 days) suggesting soil anaerobiosis as major factor responsible for degradation of pendimethlain. Savage *et al* (1978) noticed 37 and 99 days of half lives for pendimethalin in flooded and field capacity respectively. Barrett and Lavy (1983) reported 59, 63 and 30 days of halflives under airdry, continuously flooded and alternately flooded treatments respectively. However, they failed to attribute any reason for higher persistence observed under continuously flooded condition than under airdry condition. As reported by Yadav *et al* (1993), the half lives of pendimethalin in the field conditions were 76, 92 and 122 days at the level of six, four and two irrigations respectively.

The degradation of pendimethalin was faster in Mandya soil followed by Hiriyur and Mudigere soils under all moisture regimes irrespective of application rates. However, the difference in the persistence of pendimethalin among the soils was less, though the soils belong to different textural classes and with different soil properties, Zimdahl *et al* (1984) reported that moisture, organic matter, temperature and microbial activity appeared to be major factors which influence the degradation of pendimethalin in soils. The lower persistence of pendimethalin in Mandya soil may be due to high organic carbon content of soil compared to other two soils. Since the degradation of pendimethalin was mainly microbial (Table. 29), organic matter enhanced the degradation of the chemical by activating microorganisms. Walker and Bond (1977), Berayan (1982) and Eleftherohorinos (1985) reported that organic matter had greater influence on degradation of pendimethalin and persistence of pendimethalin increased with decrease in organic matter content of soil.

The data on persistence of pendimethalin as monitored by residue analysis indicated an initial rapid degradation followed by a slower rate of loss in all the soils under all moisture regimes. The slope of these degradation curves (Fig. 11) was indicative of first order kinetics. The significant determination coefficients (r^2) presented in Table. 30. indicate statistical conformity of the degradation data to first order kinetics. Walker and bond (1977) and Savage (1978) also reported first order degradation kinetics for pendimethalin in soils. However, Barrett and Lavy (1983) used quadratic model to explain pendimethalin degradation in soils.

The degradation of pendimethalin in soil under submerged condition was found to follow two different phases. It is evident from the Fig. 11 that initial degradation under submergence was very rapid and nearly 70 to 80 per cent of pendimethalin degradation occurred within 15 to 20 days (first phase). The half lives of pendimethalin lie within this first phase (0 to 22nd day). Very slow degradation was observed in the second phase (from 22nd day onwards). These two sets of data pertaining to first phase (0 to 22 days) and second phase (from 22nd day onwards) were treated as two separate first order reactions and their associations with first order kinetics was confirmed by determination coefficients (r^2).

The half lives for pendimethlain under submerged condition for these three soils ranged from 5.85 to 8.40 days and 6.05 to 8.41 days at 0.5 and 5 mg kg^{-1} application for first phase and those for second phase, the half lives ranged from 10.94 to 13.21 days and 23.36 to 27.12 days respectively. The half lives for the first phase was not significantly affected by the wide range of applications, which is a characteristic of true first order reaction. The degradation kinetics pertaining to second phase showed a marked difference in the half lives with applications, which shows a slight deviation from the first order kinetics and can be considered as a pseudo first order kinetics. These observations were well in accordance with the dissipation of some dinitroanilne herbicides in soil as noticed by Savage and Jordan (1980). Guha *et al.* (1992) observed two pseudo first order degradation steps involved in the dissipation of fluchloralin in paddy soils of West Bengal, and half lives varied from 5.13 to 5.22 days in the first phase and 11.23 to 11.80 days in the second phase.

5.4.1 PERSISTENCE OF PENDIMETHALIN IN SOILS WITH ORGANIC AMENDMENTS

Persistence and degradation of pendimethalin in soil are greatly influenced by organic matter and microbial activity. The data presented in Tables. 26, 27 and 29 revealed that the degradation of pendimethalin was faster under both field capacity and submergence even with the addition of organic amendments like FYM and paddy straw. Since biodegradation of most herbicides is controlled to a larger extent by microbial activity, the addition of a readily available energy source, would result in a nearly instantaneous increase in microbial activity, which is expected to result in enhanced herbicide degradation (Yaron *et al*, 1985).

The addition of glucose, nutrient broths, ground vetch tops, corn and bean straw resulted in the enhanced degradation of many herbicides (Mc Clure, 1970; Savage, 1977 and Wolf and Martin, 1974). Doyle *et al* (1978) observed an increase in microbial activity when sewage sludge and dairy manure was applied to soils, but the former inhibited degradation, while the latter increased it. Hance (1973) reported that FYM and paddy straw increased the degradation of atrazine in one soil while N, P and K fertilizers alone or with straw accelerated degradation in both soils. Duah-Yentumi and Kuwatsuka (1982) reported that soils amended with rice straw, compost and chemical fertilizers hastened the degradation of MCPA. However, these amendments or N, P, K fertilizers did not affect the first lag period but strongly affected the second lag periods.

Degradation of pendimethlain was faster under submerged condition along with organic amendments than under field capacity (Fig. 12 and 13). However, the difference in the half lives between the amendments and levels under field capacity and submergence corroborates the importance of soil anaerobiosis in the degradation of pendimethalin. These results are similar to those reported for DDT (Parr *et al*, 1970) where addition of an organic substrate markedly increased the degradation of DDT under soil anaerobiosis but had little effect in moist aerated soil. Parr and Smith (1973) reported that trifluralin degradation was associated with microbiological activity as evidenced by the lack of degradation in autoclaved systems and enhanced degradation upon the addition of alfalfa meal as substrate.

When compared among the soils without any amendments higher degradation was observed in Mandya soil irrespective of moisture regime. However in Hiriyur soil, a slight increase in degradation was observed under field capacity when amended with FYM and/or paddy straw as compared with other two soils under similar treatments.

The half lives of pendimethalin ranged from 14.17 to 19.56 days with one per cent and 12.50 to 16.91 days with two per cent paddy straw under field capacity whereas those under submergence varied from 4.34 to 7.03 days and 4.78 to 6.25 days respectively at 5 mg kg^{-1} level of application.

The trend of degradation revealed that there was not much difference in the degradation between control and amended soils at the initial stages of incubation, more so there was a slight inhibition in the amended soils. However the rate of degradation increased from 4th day onwards in all amended soils. Though higher degradation of pendimethain was noticed in the soils amended with paddy straw, the per cent degradation per unit carbon content was two to four times higher in FYM than in paddy straw both under field capacity and submergence at all the intervals.

5.4.2 PERSISTENCE OF PENDIMETHALIN IN STERILE AND NONSTERILE SOILS

In order to monitor the relative importance of chemical or biological degradation of pendimethalin, the persistence of pendimethalin was studied under autoclaved (sterile) and nonautoclaved (nonsterile) soils. The data presented in Table. 29. suggest that soil microbes play an important role in degradation of pendimethalin in soils both under field capacity and submergence.

Though in natural soil, moisture played a major role in the degradation of pendimethalin in the sterile condition, the moisture regime had no significant role with respect to degradation. For example, the per cent pendimethalin which remained on 36th day in Mandya soil under sterile condition at field capacity was 90.14 whereas, under nonsterile condition the per cent of chemical which remained was 53.60. Under flooded condition the quantity of herbicide remained on 36th day was 88.72 per cent in sterile condition whereas, in nonsterile condition the chemical remained was 2.66 per cent.

Barua *et al* (1990), Singh and Kulshrestha (1991) and Tripathi *et al* (1993) also explained the major role of microorganisms in the degradation of pendimethalin in soils. As with many other expectations, many exceptions were found in the importance of microbial degradation of dinitroanilines in soils (Helling, 1976). Camper *et al* (1980) found that sterilization of three soils totally inhibited the degradation of the dinitroaniline herbicides; profluralin and trifluralin under both anaerobic and aerobic conditions. Savage (1973) did not observe any significant differences in the degradation of pendimethalin in autoclaved and nonautoclaved soils under both flooded and at field capacity.

The present study conclusively proves that pendimethalin degradation is favored under flooded condition and is mainly attributed to microbial activity.

5.5 LEACHING/MOBILITY OF BUTACHLOR IN SOILS

The leaching/mobility of butachlor was studied, as given in 3.9, in soil columns. The data pertaining to the distribution of butachlor in different depths and leaching losses at different intervals in mobility studies I and II are presented in Tables. 32 and 33 respectively. The data on fresh weight of ten day old ragi seedlings as influenced by the distribution of butachlor in different depths of soil column are presented in Table. 36.

The leaching study revealed that butachlor distribution was maximum in 0-7.5 cm depth in all the soils at all the intervals. The distribution in 0-7.5 cm depth ranged from 72.96 to 83.99, 55,87 to 73.88 and 44.52 to 65.49 per cent after 6, 24 and 72 hrs respectively in columns of mobility study I (Fig. 15) and from 37.37 to 62.31 per cent after 24 hrs in columns of mobility study II. The higher butachlor residues in top layers is attributed to high adsorption and less water solubility.

Adsorption-desorption study of butachlor in these soils as described in section 4.2 reveal high per cent adsorption in soils. In general the per cent adsorption ranged from 47.56 to 75.49 at an application rate of 12.5 mg kg^{-1}. Moreover butachlor has a water solubility of only 23 mg L^{-1} at 24°C. Hence, high adsorption combined with low water solubility resulted in very low mobility and subsequent high retention in the top layers. Gerber *et al* (1974), Spillner *et al* (1983) and Peter and Weber (1985) noticed adsorption and solubility of chloroacetanalide herbicides as the major factors influencing the mobility of these herbicides. Even under field situation, the butachlor was retained in the top 10 cm according to Kulshrestha *et al* (1987), which they attributed to low solubility of butachlor in water.

The present study revealed that the mobility of herbicide was also governed by the texture of soils. It was found that mobility of butachlor was less in Hiriyur soil followed by Mandya and Mudigere soils. Lower mobility in Hiriyur soil may be due to higher clay content (45.85 %) and low hydraulic conductivity

(0.56 cm hr^{-1}), and higher mobility in Mudigere soil may be due to lower clay content (20.13 %) and high hydraulic conductivity (2.95 cm hr^{-1}). The lower mobility in Hiriyur soil may also be due to heavy texture dominated by montmorillonite clay, which on addition of water could expand to make the column impervious thus hindering the herbicide movement. Though the per cent sand content was higher in Mandya soil than in Mudigere soil, the distribution of butachlor in 0-7.5 cm depth was higher in Mandya soil than in Mudigere soil which may be due to high organic carbon content which can adsorb higher butachlor. This study corroborates the findings of Obrigawitch *et al* (1981). They reported higher mobility of metolachlor in sandy loam soils than in clay loam soils. Chen and Chen (1979) correlated leaching of butachlor with leaching rate and noticed 9.63 ppm of butachlor in 0-2.0 cm depth and less than 0.5 ppm in the lower depths of soil column with an application of 4.19 kg ha^{-1} and 2.32 mm hr^{-1} leaching rate.

No leachate could be collected from all the soils in the first six hrs of leaching, since the herbicide was allowed to distribute in the soil columns by the addition of water required to maintain only field capacity. However, the addition of more water resulted in leaching by 24 hrs, which further increased with more addition of water upto 72 hrs. In general, leaching losses ranged from 0.90 to 1.78 per cent after 24 hrs and 2.53 to 4.78 per cent after 72 hrs in columns of mobility study I and 6.96 to 11.00 per cent after 24 hrs in saturated soil columns (mobility study II). Mudigere soil registered higher leaching losses than Hiriyur and Mandya soils which may be due to low organic carbon and clay content and high hydraulic conductivity.

Ragi was used as testing system to monitor the bioavailability of butachlor residues in terms of seedlings fresh weight on 10th day after sowing in the other half of soil column used for leaching study as described in 3.9.6. The Plates. 2, 3, 4, 5 and 6 illustrate the seedlings growth in three soils without herbicide and with herbicide at different intervals in both the mobility studies. It can be clearly seen from the Plates that the distribution of butachlor was mainly in the top 2 to 3 cm depth as noticed by inhibition of germination and growth of seedlings. However the fresh weight of the seedling was not much

Plate-2. Growth of ragi seedlings in control soil columns

Plate-3. Growth of ragi seedlings in soil columns with butachlor after 6hrs (Mobility Study - I)

Plate-4. Growth of ragi seedlings in soil columns with butachlor after 24 hrs (Mobility Study - I)

Plate-5. Growth of ragi seedlings in soil columns with butachlor after 72 hrs (Mobility Study - I)

Plate-6. Growth of ragi seedlings in soil columns with butachlor after 24 hrs (Mobility Study -II) affected in the lower depths in both airdry and saturated column. Cornelius *et al* (1976) also noticed mobility of alachlor and metolachlor residues were restricted to 8 cm depth as judged by a bioassay. Valliappan *et al* (1990) reported higher inhibition of black gram at 0-4 cm depth of soil column for butachlor leaching applied at 1.25 kg ha^{-1}.

The data on fresh weight of ragi seedlings as influenced by the graded levels of butachlor concentration (Table. 38) indicated that even at 8 ppm (w/w), the seedling weight was not affected to a greater extent. This can be due to insensitivity of ragi crop to butachlor and may also be due to degradation of butachlor over a period of 10 days. The lower fresh weight of ragi seedlings in 0-7.5 cm depth is attributed to higher residue level which ranged from 13.88 to 15.21 mg kg^{-1} after 6 hrs, 10.27 to 13.08 mg kg^{-1} after 24 hrs and 8.15 to 10.96 mg kg^{-1} after 72 hrs in mobility study I and 9.85 to 13.67 mg kg^{-1} after 24 hrs in saturated column. However, the residue levels may still be higher in the 0-2 or 3 cm depth where maximum inhibition of growth was noticed.

5.6 LEACHING/MOBILITY OF PENDIMETHALIN IN SOILS

The leaching/mobility of pendimethalin was also studied in soil columns of Hiriyur, Mandya and Mudigere soils. Tables. 34 and 35 depict the data on distribution of pendimethalin at different depths and leaching losses at different intervals. The data on fresh weight of ragi seedlings as influenced by the distribution of pendimethalin in different depths of soil columns are presented in Table. 37.

The distribution of pendimethalin was very high in 0-7.5 cm depth in all the soils at all the intervals. This may be due to high adsorption and low mobility of pendimethalin in soils as in the case of butachlor. The distribution of pendimethalin in 0-7.5 cm depth ranged from 89.77 to 94.53 per cent after 6 hrs, 79.89 to 87.86 per cent after 24 hrs and 72.23 to 82.95 per cent after 72 hrs in mobility study I (Fig. 16) and 54.23 to 76.77 per cent after 24 hrs in saturated soil columns (mobility study II).

More retention of pendimethalin on top layer may be due to many factors. The pendimethalin molecules are strongly adsorbed on soil particles with lesser desorption as described in section 4.4 and the per cent adsorption ranged from 76.99 to 92.41 at an application rate of 89 X 10^{-2} uM kg^{-1}. Moreover this dinitroaniline herbicide has very low water solubility (0.3 ppm at 20°C) also resulted in lesser mobility.

The increased distribution in the lower depths after 24 and 72 hrs than after 6 hrs may be attributed to additional volume (100 mL each time) of water added to the columns. Higher retention of pendimethalin in upper layer observed in the present study corroborates with the findings of laboratory and field studies of Savage and Jordan (1980), Berayan and Mer Cado (1983), Kulshrestha and Yaduraju (1987), Ankegowda *et al* (1993) and Tewari *et al* (1994).

Among the soils studied, Hiriyur soil registered low mobility of pendimethalin than in Mandya and Mudigere soils which can be due to high clay content dominated by montomorillonite and low hydraulic conductivity. Mandya soil with high organic carbon content resulted in higher pendimethalin adsorption, though the per cent sand content was higher in Mandya soil than in Mudigere soil and thereby high distribution in 0-7.5 cm depth.

No leachate could be collected from all the soils after six hrs of leaching since the herbicide was allowed to distribute in the soil columns by the addition of water required to maintain just field capacity. However the leaching losses of pendimethalin increased with the intervals in all the soils because of additional volume of water. Higher leaching losses were noticed in saturated soil columns than in airdry columns mainly due to more addition of water. Similar observations were also noticed in the case of butachlor in the present study. The leaching losses were higher in Mudigere soil than in other two soils which was attributed to less adsorption and higher mobility of pendimethalin. However, the leaching losses were very less compared to butachlor and ranged from 0.33 to 0.46 per cent after 24 hrs and 0.92 to 1.53 per cent after 72 hrs in mobility study I and from 4.40 to 8.32 per cent after 24 hrs in mobility study II. Present study corroborates the results of Signori and Deuber (1979) who noticed higher leaching of pendimethalin in loamy soils than in clay soils.

The presence of pendimethalin at different depths was indicated by reduced/inhibited growth of ragi seedlings. The data on fresh weight of ragi seedlings taken on 10th day (Table. 37) were used for better understanding of pendimethalin mobility. The Plates. 2, 7, 8, 9 and 10 illustrate the ragi seedling growth in three soils without and with herbicide at different intervals. The germination of ragi seedlings in the 0-7.5 cm depth was very much affected in all the soils at all the intervals supporting the results of chemical assay of pendimethalin. The fresh weight of ragi seedlings were affected to a greater extent in Mudigere soil at all the intervals when compared to Hiriyur and Mandya soils because of low adsorption of pendimethalin and high hydraulic conductivity.

In case of butachlor the growth of ragi seedlings were affected mainly in 0 to 2 or 3 cm depth, whereas in case of pendimethalin, it can be clearly seen from the Plates that germination of ragi seedlings were affected even at 7.5 to 15.0 cm depth after 24 and 72 hrs interval. Though higher pendimethalin residue were noticed at 0-7.5 cm depth, than in lower depths, the higher inhibition of ragi seedlings by pendimethalin than that of butachlor may be attributed to higher toxicity of pendimethalin to ragi which is found to be a very sensitive testing system. The data presented in Table. 38 and the Plate. 12, 15 16 show a drastic reduction in fresh weight of ragi seedlings at 0.5 ppmw. No germination was observed at 1.0 ppmw in Hiriyur soil and at 2.0 ppmw and onwards in Mandya and Mudigere soils indicating toxicity of pendimethalin residue. This study corroborates the findings of Leela (1987b), who reported that ragi was not germinated even at lowest concentration immediately after fluchloralin application to the soil.

The present study of using ragi as a testing system to know the distribution of herbicides in different depths of soil columns revealed that ragi

Plate-7. Growth of ragi seedlings in soil columns with pendimethalin after 6 hrs (Mobility Study - I)

Plate-8. Growth of ragi seedlings in soil columns with pendimethalin after 24 hrs (Mobility Study - I)

Plate-9. Growth of ragi seedlings in soil columns with pendimethalin after 72 hrs (Mobility Study - I)

Plate-10. Growth of ragi seedlings in soil columns with pendimethalin after 24 hrs (Mobility Study - II)

Plate-11. Growth of ragi seedlings as influenced by graded concentrations of butachlor

Plate-12. Growth of ragi seedlings as influenced by graded concentrations of pendimethalin can be used effectively for pendimethalin even at very low concentrations. However, for butachlor ragi can not be used for bio-assay since it was found to be very tolerant.

PRACTICAL UTILITY

1. Organic matter content of soil influences both adsorption and degradation of herbicides there by its bioavailability. Present study reveals the importance of organic matter.

2. Efficiency of any herbicides applied to soil depend on the resident time of the herbicide in the soil. The soil moisture regime determines the half lives of these two herbicides. The present study gives an insight to the fate of herbicides in the soil with respect to moisture regimes.

3. The groundwater contamination is least by these two herbicides as they are less mobile associated with short half lives.

SUMMARY

VI. SUMMARY

In order to study the interaction of butachlor *[N-(Butyoxy methyl)-2-chloro-N-2',6'-diethyl acetanilide]* and pendimethalin *[N-(1-ethyl propyl)-3-4-dimethyl-2,6-dinitrobenzene amine]* in soils, three soils were selected namely Hiriyur *(fine mixed isohyperthermic chromic haplusterts - Hiriyur series)*, Mandya *(fine loamy mixed isohyperthermic typic ustropepts - Mangala series)* and Mudigere *(loamy skeletal kaolinitic isothemic ustic kanhaplo humult - Mudigere series)* soils of Karnataka. The adsorption-desorption of butachlor and pendimethalin in natural as well as organic matter amended soils, persistence and degradation under three different moisture regimes (airdry, field capacity and submergence) and also with different organic amendments (FYM and paddy straw), and mobility in soil columns at different intervals were studied to monitor the behaviour of these herbicides in soils. In order to know the importance of biological degradation, persistence of butachlor and pendimethalin was monitored in sterile and nonsterile soils. The salient features of the present investigation are summarised as below.

1. Adsorption of butachlor and pendimethalin were mainly influenced by the soil organic carbon content. Adsorption of both the herbicides in soils decreased in the order of Mandya > Hiriyur > Mudigere, which was also the order of decreasing organic carbon content. Incorporation of soils with two and four per cent FYM as organic amendment further increased the adsorption of both butachlor and pendimethalin in all the soils. However, the per cent adsorption of pendimethalin was higher than that of butachlor in all the soils.

2. Freundlich equation provided a good fit ($r^2 = 0.9$) to the adsorption data of butachlor and pendimethalin on all the soils. Freundlich constant K values for pendimethalin were higher than those of butachlor in all the soils and ranged from 4.599 to 14.181 for butachlor and from 20.179 to 68.659 for pendimethalin. The addition of FYM increased the K values in all the soils for both the herbicides. The highest K values were noticed in Mandya soil and the lowest in Mudigere soil. The values for 1/n (slopes) were < 1.0 for both butachlor

and pendimethalin and indicated a non linear relationship between herbicide concentration and adsorption and can be characterized as L type of adsorption isotherm. The sorption coefficients for organic carbon (K_{oc}) were higher for pendimethalin than butachlor in all the soils and ranged from 1289 to 1757 for butachlor and 5840 to 6726 for pendimethalin. No definite relationship was observed between K_{oc} and organic carbon content of soils.

3. The cumulative desorption and per cent desorption of butachlor and pendimethalin increased with increasing initial concentration in all the soils. The cumulative desorption and per cent desorption decreased with the addition of FYM in all the soils. The highest cumulative desorption and per cent adsorption was noticed in Mudigere soil followed by Hiriyur and Mandya soil. Cumulative desorption and per cent desorption for pendimethalin were lower than butachlor in both amended and unamended soils.

4. The persistence of butachlor and pendimethalin indicated a close correspondence to first order exponential degradation kinetics in soils and mainly influenced by soil organic matter and moisture. Faster degradation of butachlor was noticed under field capacity followed by submergence and airdry conditions while, the degradation of pendimethalin was faster under submergence followed by field capacity and airdry conditions in all the soils.

5. Persistence of butachlor and pendimethalin was lower in Mandya followed by Hiriyur and Mudigere soils under all moisture regimes. Half lives for butachlor under field capacity and submergence were 15.05 and 35.44 days in Hiriyur, 12.35 and 28.48 days in Mandya and 20.58 and 39.20 days in Mudigere soils respectively. Half lives for pendimethalin under field capacity and submergence were 48,59 and 13.52 days in Hiriyur, 44.52 and 13.03 days in Mandya and 55.53 and 15.66 days in Mudigere soils respectively. Under field capacity, butachlor followed two phases of degradation, while pendimethalin followed two phases of degradation under submergence and both the phases were described by first order degradation kinetics.

6. Addition of FYM and paddy straw hastened the degradation of both butachlor and pendimethalin under both field capacity and submergence. Though the degradation of butachlor and pendimethalin was higher in paddy straw than in FYM amended soils, the per cent degradation per unit carbon of FYM was two to four per cent higher than paddy straw in all the soils.

7. The persistence of butachlor and pendimethalin was higher in sterile soils than in nonsterile soils under both field capacity and submergence indicating major pathways of degradation as microbiological. Butachlor degradation was mainly due to aerobic and facultative aerobic microorganisms, while pendimethalin degradation was due to anaerobic microorganisms.

8. Mobility of pendimethalin was lesser than butachlor in all the soils at all the intervals. Butachlor and pendimethalin distribution was maximum in the top 0-7.5 cm in all the soil columns. Mobility of both butachlor and pendimethalin was less in Hiriyur soil compared to Mandya and Mudigere soils.

9. The major factors which influenced the mobility of herbicides in soil columns were water solubility, adsorption, soil texture, quantity of water added and hydraulic conductivity of soils.

10. Leaching losses of butachlor and pendimethalin were higher in Mudigere soil than in Mandya and Hiriyur soils.

11. Use of ragi as a testing system for mobility of herbicides in soil columns was found to perform better for pendimethalin than butachlor in all the soils. Ragi was sensitive for pendimethalin herbicide even at 0.5 ppmw and can be recommended as a test crop for pendimethalin bioassay, whereas it was insensitive to butachlor even at 8 ppmw.

12. The fresh weight of ragi seedlings was affected to a greater extent in the 0-7.5 cm depth in all the soils at all the intervals for both butachlor and pendimethalin.

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Originals not seen.