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INFLUENCE OF AGRONOMIC FACTORS ON THE PERSISTENCE OF HERBICIDES - A REVIEW

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ABSTRACT

Herbicide persistence is very important because it determines the risk of carryover on succeeding crops. This is very difficult to predict, because the dissipation rate of herbicide depends on agronomic practices (selection of herbicides, rate and method of application, tillage, irrigation, addition of organic amendments, etc.,) apart from the herbicide characteristics and environmental conditions (rainfall and photoperiod). Therefore, a thorough understanding of agronomic factors may be useful in management of this phenomena to the advantage of crop production.

Herbicides are the major technological tools that are used in agriculture. Ever since the first discovery of two herbicides *viz.*, 2, 4-D and MCPA in 1945, their use has been increasing. In many advanced countries the average annual consumption of herbicides is 675-1350 g ha^{-1}. In Japan it is as high as 5000 g ha^{-1}. Against these figures, in India at present the average annual use is hardly 40 g ha^{-1}.

Majority of herbicides used in agriculture are soil active. Some foliage active herbicides are used as post emergent spray in some crops. The herbicides provide weed free condition right from the sowing of crop till the harvest in some areas. This is because of their persistence. The persistence of herbicide from the agronomic point of view can be defined as the time required for the biological activity in the soil to reach negligible levels or non-detectable levels.

The persistence of herbicide cannot be considered a positive or negative character in the absolute sense. In fact, the herbicides, especially those used in pre-emergence, should have a certain degree of persistence in order to keep the crop weed free for a sufficient amount of time to give it a competitive advantage. If the herbicide remains active for too long, and at concentrations higher than phytotoxicity threshold for weeds it can create, more or less, serious problems for the production of successive crop.

The persistence of herbicide in the soil is determined by the degree of its adsorption, the mobilization and the degradation. The adsorption of the herbicide by organic and inorganic collides of the soil temporarily removes the herbicide solution from the soil. This reduces the biological activity or concentration of the herbicide in the soil . The biological activity of herbicides is reduced by microbial decomposition, chemical inactivation, plant absorption and decomposition, volatilization, leaching and runoff.

Persistence of herbicides is not a fixed property but is influenced by several agronomic factors apart from chemical nature and weather conditions. The agronomic factors which affect the herbicide persistence are as under.

A. Soil type

Normally the dose of herbicide varies from one soil to another because of the variation in persistence of herbicide. Goetz *et al.* (1990) studied the residual content in silt loam and silty clay after imazethaper application at different time intervals. Both in the surface soil (0-7.5 cm) and subsurface soil (7.5-15 cm) the amount of herbicide residues left were more in silty clay soil. Fifty-two weeks after herbicide application 26% of the herbicide was left in silt loam soil and 34% in silty clay soil. The difference in residual herbicide is mainly due to the variation in clay content of the soils.

Atrazine persistence in sandy loam and clay loam soils revealed that atrazine residue was higher in clay loam soil. The increased persistence of atrazine in clay loam soil was due to the higher clay content which adsorbs the herbicide and avoids the immediate dissipation (Gan *et al.*, 1996).

Padmavati Devi *et al.* (1998) observed that germination and plant height of ragi were significantly reduced by the residual effect of oxyfluorfen when sowing was done on the same day of herbicide application, 20, 40 and 60 days after herbicide application but in red soil the germination and plant height were significantly affected when sowing was done on the day of herbicide application, 20 and 40 DAT. Thus, oxyfluorfen was found to persist for 60 days in black soil and for 40 days in red soils.

B. Tillage

Tillage, in particular, ploughing removes most of the active agent from the soil surface, diluting it along a layer of soil of varying thickness. The effect of this dilution on the risk of carry over depends on the ploughing depth. In the case of deep ploughing, a large part of the active ingredient is carried below the soil layer explored by plant roots, hence the growth of sensitive crops will not be affected. On the other hand, in case of shallow ploughing the active ingredient is only slightly buried and will therefore have a maximum concentration in the zone where seed germination and seedling development takes place.

In case of no tillage conditions the soil will have higher organic matter content and the residue cover on the surface reduces the runoff losses. Therefore, extent and type of tillage do affect the herbicide persistence.

Covarelli (1993) reported the loss of activity of herbicides by hoeing after the herbicide application. Hoeing dilutes the herbicide along a layer of soil of varying thickness. Compared to the control, more number of *Amaranthus* spp. and *Portulaca oleracea* were found in hoeing treatment because of the reduced activity of the herbicide and hoeing brought buried weed seeds to the soil surface and provided favorable conditions for germination.

On a loam soil, after harvest of corn sprayed with atrazine at rates of 2 and 6 kg ha^{-1}, Covarelli (1993) compared the effect of three ploughing depths (20, 40 and 60 cm) on atrazine persistence. Residual effect on succeeding sugar beet revealed that 20 cm deep ploughing reduced the sucrose production to a greater extent than 40 cm and 60 cm deep ploughing.

Sadheghi and Isensee (1997) reported the effect of no tillage and conventional tillage on alachlor and lyanazine residues in soil at different depths (0-10, 10-20 and 20-50 cm). At any given time and soil depth more alachlor and lyanazine residues were found in convention-tilled plots than in no tilled plots. The decreased persistence in no tilled plots is attributed to the higher organic carbon content in the soil nearly 48.2% of the applied herbicide was recovered at 2 weeks after application in conventional tillage but it was only 28.6% in no tillage. Thus, Herbicides persist for a longer time in conventional tillage than in no tillage.

C. Herbicide formulations

A new approach to formulation of herbicides has caught attention in certain advanced countries. It is the production of slow release (SF) herbicide formulations to save a soil active herbicide from its rapid degradation and thus, protract their weed control period. One such latest technique is micro encapsulation (ME) where the herbicides are placed inside numerous microcapsules. These capsules are so minute that these can be applied like wettable powder. The herbicides are mainly available in wettable powder, emulsifiable concentrates, mixed liquids and granular formulations. These for differences between the two formulations in the top 10 cm layer (2.5 G/EC) increased to 28.7% and 25.8% at 2 and 4 weeks respectively and were still 3.0% higher after 21 week, reflecting greater mobility and lesser persistence of metolachlor in the EC formulation giving 50% disappearance times (DT_{50}) of 4.0 and 2.2 week, respectively.

Vail *et al.*, (1997) reported that DT_{50} of atrazine at an application rate of 1.1 kg ha^{-1} was extended over that of the commercial formulation by 2 week with SE small and by 6 week with SE large. Atrazine DT_{50} at 2.2 kg ha^{-1} was extended over that of the CF by 2 weeks with SE small and by 3½ week with SE large. No significant DT_{50} differences were observed at the application rate of 3.4 kg ha^{-1}. Oat injury was much higher in plots treated with SE atrazine than with CF atrazine at all rates . Maximum oat injury from CF atrazine was 19% and was not affected by application rate. SE atrazine formulations injured oats more severely (86% or more injury) at 2.2 and 3.4 than at 1.1 kg ha^{-1}. SE particle size did not influence oat injury at every rate tested. However, both SE formulations at 2.2 and 3.4 kg ha^{-1} rates caused nearly complete oat kill.

D. Method of Application

Method of application has a significant effect on herbicide persistence, especially if a compound is volatile or subject to photodecomposition Eg. Dinitroaniline herbicides. Application technique has little effect on the persistence of atrazine, which is a non-volatile compound.

Goetz *et al.* (1990) revealed that irradiation time significantly influenced the photodecomposition of 14C- imazethapyr, as irradiation time increased, significantly more photodecomposition of imazethapyr occurred.

Hance (1980) revealed the influence of management practices on volatilization of herbicides. When heptachlor was applied to bare moist soil surface, 90% of the applied herbicide was lost within 2-3 days, when the same herbicide was applied to the moist bare soil in the presence of vegetation 90% loss occurred in 30 days. When the heptachlor was incorporated to a depth of 7.5 cm in maize only 7% volatilization loss occurred in 167 days. Similarly, reduced volatilization loss of trifluralin and chlorpropham were noticed by their incorporation.

Compared to the residues of pre-emergence application, residues of preplant incorporated imazaquin significantly reduced the shoot length of corn grown the year after treatment of herbicides at 280 and 140 g ha^{-1}. Thus, these herbicides persist for a longer time when they are incorporated (Renner *et al.*, 1998).

Webster and Shaw (1996) reported significant reductions in wheat yield and higher injury by the residual effect of pre-plant incorporated pyrithiobac in previous cotton.

E. Herbicide dose

The degradation of herbicide is also dose dependent. Increased rate of degradation was noticed at low initial concentration.

Sandhu *et al.* (1994) revealed that atrazine content in soil decreased as the stage of sampling advanced, atrazine degradation was about 4 to 17% at 15 days, 20 to 64% at 4-5 days, 60 to 70% at 60 days and 82 to 89% at 80 days. Atrazine applied at 50, 75, 100 and 125 g/ha persisted up to 80 days and degraded to no detectable limits by 100 days. While, at 150, 175 and 200 g ha^{-1} persistence was about 9% indicating that it persisted for more than 100 days.

Soil residues of imazaquin applied sequentially PPI followed by post-reduced seed cotton yield on the clay soil. Micronaire index was reduced by the PPI followed by POST sequential treatment. The node of the first fruiting branch was increased by residues of imazaquin applied PPI, PRE and sequentially. These treatments elevated the node of the first sympodia by 0.8 to 1.3 nodes, showing a delay in the initiation of fruiting and reproductive development (Johnson and Talbert, 1996).

F. Addition of organic amendments

The application of organic manures in the form of compost/farmyard manure/ crop residue is a common practice among farmers. The behaviour of soil-applied herbicides on addition of organic amendments varies. Because their addition increases the organic matter content, it increases the adsorption of herbicides to the organic manures. At the same time because of enhanced microbial activity during decomposition (by providing nutrients), the decomposition of herbicides may increase consequently reducing the agronomic persistence.

Topp *et al.* (1996) reported that in all the soil samples from the manure treated plot atrazine was quickly and completely removed after a variable lag phase. The lag phase varied from18 days for surface soil to 27 days for soil taken from a depth of 40-60 cm. In contrast, soil taken from the non-fertilized plot had a much longer lag before atrazine was quickly removed, or in some cases the atrazine was not removed at all.

Prakash *et al.* (2000) reported that disappearance of butachlor was more rapid under field capacity and that of pendimethalin under submergence condition. The addition of organic amendments hastened the degradation of both butachlor and pendimethalin in all the soils under both field capacity and submergence. Higher disappearance was noticed in all soils with paddy straw amendments compared to FYM.

Similarly, addition of corn stalks decreased the extraction efficiencies (Shelton *et al.*, 1995). Mineralisation of atrazine and 2, 4-D increased due to manure addition (Entry and Emmingham, 1995).

Patel *et al.* (1996) revealed that fluchloralin application in the absence of FYM showed the highest residue which significantly decreased with the addition of FYM for both the lower (l5 t ha^{-1}) and higher (30 t ha^{-1}) levels. The application of double the dose of fluchloralin without FYM showed the highest (0.625 ppm) residues, which was brought down to 0.336 ppm by the addition of FYM 30 t ha^{-1}.

In the absence of activated C, 0.2 kg diuron ha^{-1} did not depress top growth as measured by dry weight of harvested barley plants. With increasing rates of diuron, the toxicity increased and at 0.8 kg ha^{-1} only a few plants survived till the harvest. All rates of diuron 0.2, 0.4, 0.5, 0.8, 1.0, 2.0 and 3.0 kg/ha used in combination with activated -C caused a depression in dry weight of tops (Toth and Molham, 1975).

G. Water management

The herbicide persistence also varies with water management depending on the solubility of the formulation, runoff and leaching losses. Increase in rainfall enhances the dissipation of herbicide (Baughman *et al.*, 1996). Half-life period of chlorimuron ethyl was highest (38 days) in 1988 and least (13.5 days) in 1989. Increased half-life period of chlorimuron ethyl in 1988 was attributed to the lack of rainfall during first 30 days after herbicide treatment.

Flooding resulted in a significant increase in the dissipation rates of trifluralin, profluralin, fluchloralin and pendimethalin as compared to the dissipation rates in soil maintained near field capacity. Reduced half life of fluchloralin was noticed under flooded condition, which was 85% less than the half life under field capacity (Savage, 1978).

Smith *et al.* (1990) reported that thiameturon degraded rapidly with increase in moisture from 50% FC to 100% FC. Least recovery of thiameturon was observed at 100% FC. The decreased thiameturon concentration with increased moisture content was attributed to the degradation by hydrolysis.

Prakash *et al.* (2000) reported that butachlor and pendimethalin degradation was dependent on microbes. No or less degradation occurred in sterile soil under field capacity and submergence. The enhanced dissipation of butachlor under field capacity was due to the aerobic or facultative aerobic microorganisms decomposition of herbicide, whereas anaerobiosis is involved in pendimethalin degradation.

H. Vegetative filter strips and cover crops

Under slopy conditions the run off loss of water is high. Run off water along with dissolved herbicide reduces the agronomic persistence. Inclusions of filter strips have significant impact on reducing run off loss of herbicides.

Cover crops are characterized by short growing season therefore, they allow their insertion in between two principal crops. The cover crops absorb and metabolize some amount of herbicide and decreases herbicide residues. The rhizosphere effect of cover crops does affect the herbicide persistence.

Bottomley *et al.* (1999) reported that mineralisation of both 0.6 mg/kg and 6.0 mg 2, 4-D kg^{-1} increased more rapidly in soil from the cover crop treatment. Higher mineralisation of 2, 4-D was found in the rye cover cropped surface soil (0-20 cm).

I. Crop rotation

The persistence of the residues of weedicides for considerable time and their adverse effect is the most important limiting factor in the use of weedicides. The residue remained in the soil may not cause significant injury to all the succeeding crops.

Covarelli (1993) reported that 73 to 60% damage was caused to the lentil by the residual effect of rimsulfuron when sowing was done on the day of herbicide application and 25 days after herbicide treatment. When lentil was sown 40 days after herbicide treatment only 4% damage was noticed.In other words the rimsulfuron, which is recommended for corn, needs 40 or more days to reduce its phytotoxicity on lentil.

Covarelli (1993) reported the persistence of some selective herbicides for weed control in wheat on some succeeding crops. Barley and Vetch dry matter was significantly reduced by the residual effect of chlorsulfuron 15 g ha^{-1} when sown two months after treatment; forage beet and clover were affected when sown four months after treatment. Corn, sorghum, bean and soybean were affected by the residual effect of chlorsulfuron 15 g ha^{-1} when sown five months after treatment. Residual effect of isoproturon 2250 g ha^{-1} was noticed on bean when sown 5 months after treatment.

Webster and Shaw (1996b) observed the less loss of herbicide in the presence of filter strips. Mean of 3 years indicated that 95.37 g of metolachlor was lost in run off water in the absence of filter strip but it was 26.23 g in the presence of filter strip. The loss of metribuzin both in the presence and absence of filter strip was less in metribuzin than metolachlor because of the lower solubility.

Mersie *et al.* (1999) reported that run off loss of atrazine and metolachlor were 48 and 41% of the original quantity in the presence of switch grass filter strip. The runoff loss of atrazine and metolachlor was 59 g and

56% of the original quantity in the absence of switch grass. The amounts of atrazine and metolachlor retained in the soil were higher in the presence of switch grass and make them to persist for longer time.

Hall *et al.* (1983) noticed that 65 to 91% decrease in the run off loss of atrazine under oat stripped tiers over non stripped tiers. Therefore, absence of filter strips under slopy soil condition decreases the biological activity of herbicides.

Higher dissipation rate constant and least half-life of fluometuron was noticed under no till. Vetch cover crop system. Decreased persistence of fluometuron was attributed to the higher organic matter content under no till soils and absorption and metabolism of herbicide by the cover crop (Brown *et al.*, 1996).

Except pea all the tested crops *viz.*, soft wheat, barley, oats, oilseeds rape, vetch were affected by the residual effect of neburon 3300 g ha^{-1} when sown 2 months after treatment. Similarly alfa-alfa was unaffected by the residual effect of neburon when sown four months after treatment whereas bean was affected by the residual effect when sown five months after treatment.

Monks and Banks (1993) noticed the higher cotton injury in tilled plots due to residual effect of imazaquin and imazethapyr. Significantly lower seed cotton yield and higher number of closed bolls were observed by the residual effect of 0.42 kg imazaquin ha^{-1}.

Webster and Shaw (1991a) reported that significantly lower yield of soybean was obtained by the residual effect of preplant incorporated pyrithiobac 140 g/ha. Application of 140 g pyrithiobac as PRE, PHS and FB had not caused significant reduction in soybean yield, which was grown one year after herbicide treatment.

One year after application of imazethapyr at 75 and 100 g ha^{-1} reduced mean wheat yields. Canola yields were reduced by imazethapyr rates >25 g ha^{-1}, potato yield was also reduced by imazethapyr rates >25 g/ha. Two years after application wheat and canola yields were not reduced by imazethapyr. Imazethapyr at rates >50 g ha^{-1} reduced potato yield. Three years after application marketable potato yields were reduced by imazethapyr at rates >75 g ha^{-1} (Moyer and Esau, 1996).

Sunflower herbicide residues did not damage the succeeding crops. except pendimethalin, which induced phytotoxicity symptoms on sorghum, and corn was damaged by metolachlor. Covarelli (1993) observed that, no crop could be seeded 35 days after atrazine treatment. while the persistence of cyanazine allowed sorghum seeding and pendimethalin allowed bean, lettuce and tomato seeding. Alachlor and eptam + safener did not show any significant damage to the succeeding crops.

J. Microbial Inoculation

There is growing concern over the potential for contamination of surface and ground water and carry over effect to the succeeding crops by herbicides. Therefore reliable cost effective methods for the remediation of herbicide contamination in soil are needed in order to minimize the potential adverse effects. Isolation of efficient microbes and their inoculation may avert this problem.

Assaf and Turco (1994) reported that mixed microbial culture degraded the atrazine in 30 days whereas the same atrazine took 150 days for degradation without mixed microbial culture. Inoculation of soil with *Streptomyces* strain (PS 1/5) resulted in extensive transformation of atrazine; approximately 78% of atrazine was bio transformed after 28 days. Atrazine concentrations in the sterile control were stable throughout most of the incubation, indicating losses of atrazine due to volatilization were insignificant (Shelton *et al.*, 1996).

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