Herbicide Concentrations in Water Runoff from Nurseries in Northwestern Oregon

Garvin Crabtree, Marvin Montgomery and J. M. Schroeder

Container nursery stock is grown in a porous medium, often ground bark, in containers which are placed on beds graded to facilitate runoff. These beds are usually covered with several cm of gravel which may also cover a plastic film barrier. These crops are irrigated every 1 to 2 days during the summer months, with a total of 200 to 300 cm of irrigation water plus 100 cm of rainfall per year. Excess water enters the drainage system and often is caught in ponds for recycling within the nursery or is allowed to escape downstream. Herbicides are applied alone or in combinations up to 4 times per year for a total of up to 27 kg active ingredient per hectare per year. Compared to many crop production systems, this represents several times the usual per hectare application rates. Much of the herbicide that enters the container is adsorbed in the top portion of the growing medium and probably is degraded similarly to herbicides applied under field conditions. However, the herbicide that is spread outside the container lacks adsorption sites on the gravel or plastic. Consequently, these significant quantities of herbicide end up in a pond for recycling as irrigation water or are lost downstream.

Significant runoff can occur from nurseries producing field grown stock, especially during periods of high rainfall that may occur in northwestern Oregon during winter months. However, with lower annual usage of herbicides and irrigation water the amount of herbicide in the runoff water is expected to be less than that from container nurseries.

Researchers have long been aware of the potential problem of pesticide residues in water running off agricultural sites and have documented the extent of the problem with certain herbicides under certain conditions (1, 2, 3, 4, 5, 6, 7, 9, 12). Predictive models have also been developed to aid in the assessemnt of the problem as it exists with normal agricultural practices (8, 10, 11).

The research reported here was a preliminary study to assess the nature and extent of herbicides leaving the target area in runoff water when these materials are used in container nurseries, and with less emphasis, from nurseries growing field stock.

Specific objectives of this study were to:

1) Survey the extent of the problem in northwestern Oregon by analyzing runoff water from a sample of nursery sites.

2) Develop methodologies for further studies so that sampling and analysis of field sites could proceed in an orderly and efficient manner.

3) Develop methodologies for use in controlled experiments in which herbicide percolation in containers and container yard beds could be studied.

GENERAL SURVEY

Eighteen nursery sites in northwestern Oregon were selected with cooperators in this portion of the study. These nurseries did not represent a random sample but were selected on the basis of diversity in size and geographical location, willingness to cooperate and representing both field and container production systems. No information was available on potential problems with herbicide runoff and this was not a factor in site selections.

Sample dates were selected randomly from possible days from September through May for container nurseries and November through April for field grown nurseries. The nurseries identified for the survey were randomly assigned to the sample dates and samples taken on the scheduled date or the first date thereafter that runoff volume was sufficient for sampling. It was planned that three samples would be taken at each site (A) as close as possible to the runoff source, (B) an intermediate location, and (C) the farthest possible point from the source that runoff could be identified with that origin. Ultimately samples were collected from these locations at eight sites, from two locations at three sites, and from one location at seven sites. Samples and sample site information were identified by a number only to provide confidentiality for the nursery owners/managers. Samples were collected in 3.8 l glass containers, sealed with screw-top closures, and kept refrigerated until delivered to the laboratory, usually within 48 hours.

In the laboratory samples were kept in refrigerated storage and extracted within one week of arrival. All samples were analyzed for oxidiazon, oxyfluorfen, pronamide and simazine by appropriate gas-liquid chromatographic methods. Results of the analyses and information collected at each site are shown in Tables 1 and 2, respectively.

At seven of the 18 sites no herbicide was detected in runoff water. With incomplete information on herbicides used, no attempt was made to correlate runoff residues with any characteristics of the nursery sites. Residue levels and frequency of occurrence are believed to represent expected runoff herbicide concentrations sampled randomly from a cross section of the nurseries in northwestern Oregon.

Table 1. Levels of four herbicides in runoff water from a survey of 18 nurseries (concentration as ppb).

Site No.	Location[1] A				B				C			
	Oxid[2]	Oxyf	Pron	Sim	Oxid	Oxyf	Pron	Sim	Oxid	Oxyf	Pron	Sim
105	N[3]	N	N	N								
106	N	14	N	54	N	7.3	N	22	N	7.1	N	16
107	N	N	N	N	N	N	N	6.8				
109	N	1.4	N	3.8	N	1.5	N	13	2.5	1.4	N	29
110	N	N	N	1.2								
116	N	1.0	N	8.3								
117	N	N	N	2.0								
118	N	N	N	N	N	N	N	N	N	N	N	N
119	N	N	N	N	N	N	N	21	N	N	N	N
120	N	N	N	N								
126	N	N	N	N	N	N	N	N				
127	2.3	N	N	N	2.0	N	N	N	N	N	N	N
128	N	N	N	N	N	N	N	N				
129	N	50	N	42	N	71	N	39	N	39	N	40
130	N	N	N	N								
136	N	N	N	N								
137	N	N	1	1.0	N	N	1	1.1	N	N	N	3.3
138	N	12	N	13	N	13	N	15	N	4.4	N	23

1 Location at nursery with "A" closest to application site "B" intermediate, and "C" the furthest point from the source identifiable with the runoff origin.

2 Herbicide abbreviations: Oxid = oxidiazon, Oxyf = oxyfluorfen, Pron = Pronamide, Sim = simazine.

3 N shows no detectable residue at a sensitivity of 1 ppb.

Table 2. Characteristics of sample sites for herbicide runoff survey.

Site No.	Nursery[1] size	Production system	Sampling date	Days since last rainfall or irrigation	Herbicide applied
105	small	container/bark	9/16/85	0	dichlobenil
106	small	container/bark	9/10/85	0	oxyfluorfen/ pendamethalin
107	--	field	1/16/86	0	
109	large	container/mix	1/16/86	0	
110	large	field	1/16/86	0	
116	large	container/mix	1/23/86	0	
117	large	container/mix	4/14/86	2	
118	small	container/bark + field	2/27/86	2	oxidiazon dichlobenil
119	large	container/bark	12/5/85	1	oxyfluorfen/ pendamethalin and diuron/ bromacil
120	large	container/mix + field	4/14/86	2	
126	large	container/bark + field	3/13/86	0	oxidiazon glyphosate
127	small	field	3/13/86	0	
128	small	field	3/13/86	0	
129	large	container/mix	5/28/86	0	
130	large	container/mix	4/14/86	3	
131	--	field	5/1/86	0	
137	small	field	5/1/86	0	
138	small	container/bark	5/15/86	0	

[1] Small nurseries had production areas of less than 8 ha, large nurseries had greater areas.

SAMPLING STUDY

Two nurseries not used in the survey reported above were selected for this study. The one designated as "Nursery I" was a container nursery with less than 8 ha of production area on a relatively steep slope. Gravel covered beds drained via tiles to a ditch at the base of the slope. Sampling location "A" was the confluence of a drain tile and the ditch, "B" was about 25 m downstream in the ditch, and "C" was another 25 m downstream where the ditch emptied into a pond. A combination of the herbicides oxidiazon and oxyfluorfen was applied on Augut 16, 1985 and samples taken on dates as shown in Table 3.

Table 3. Levels of two herbicides in runoff water in a sampling time study for "Nursery I" (concentration as ppb).

Sampling[2] Time	Location[1] A		B		C	
	Oxidiazon	Oxyfluorfen	Oxidiazon	Oxyfluorfen	Oxidiazon	Oxyfluorfen
Pre	8.4	3	2.5	N[3]	1.5	N
1 hr	14.0	19	7.4	15	7.4	15
2 hr	9.3	16	8.0	18	7.6	18
4 hr	5.3	8.3	1.6	5.3	1.9	5.7
1 day	8.4	19	10.0	27.0	10.0	24
4 days	10.0	20	3.1	6.8	2.9	6.1
10 days	5.3	7.6	N	1.3	N	1.0
17 days	6.1	12.0	4.8	9.6	4.9	9.5
24 days	6.8	9.3	1.5	2.1	1.1	19
31 days	N	N			N	N
47 days	2.3	8.0	2.5	8.3	1.1	15
59 days	5.3	6.5	N	N	N	N
152 days	1.9	1.4	N	N	N	N

1 Sampling location with "A" close to application area, "B" intermediate, and "C" furthest from source of application runoff.

2 Sampling time with "Pre" sampled prior to the herbicide application and other times relative to the first water runoff following herbicide application.

3 N shows no detectable residue at a sensitivity of 1 ppb.

"Nursery II" was a large (more than 8 ha of production area) container nursery, on a moderate slope, and using production methods as described for Nursery I. For sample location "A" a catchment basin was dug at the base of the slope and location "C" was from a drain tile, leading directly from the production area, as it emptied into a collection pond. No intermediate sampling location was established. Oxidiazon was applied on September 4, 1985 and samples taken on dates shown in Table 4.

Table 4. Levels of four herbicides in runoff water in a sampling time study for "Nursery II" (concentration as ppb).

Sampling[2] No.	Location[1] A Oxid[3]	A Oxyf	A Pron	A Sim	C Oxid	C Oxyf	C Pron	C Sim
Pre	1.5				1.3			
1 hr	1200				1.8			
2 hr	700				140			
4 hr	1400				400			
1 day	320				210			
6 days	850	N[4]	N	67	150			
13 days	370				61	4.5	N	29
20 days	160	N	N	79	78	N	N	9
32 days	120	7.7	N	47	29	18	N	40
44 days	18	2.9	N	47	4.2	1.2	N	8
137 days	1.9	1.4	N	N	N	N	N	N

1 Sampling location, with "A" close to application area and "C" furthest from point of application runoff.

2 Sampling time, with "Pre" sampled prior to the herbicide application and other times relative to the first herbicide runoff following herbicide application.

3 Herbicide abbreviations: Oxid = oxidiazon, Oxyf = oxyfluorfen, Pron = Pronamide, Sim = simazine.

4 N shows no detectable residue at a sensitivity of 1 ppb.

For both sites in this study, samples were collected, handled, and analyzed as described earlier for the survey study.

At Nursery I the water samples taken prior to the herbicide application showed the presence of herbicides, apparently from prior applications. These herbicide levels were increased moderately after the herbicide application and, with aberrations from the general trend, decreased over the sampling period. After two months, oxidiazon and oxyfluorfen were not detected in samples taken from locations in the runoff stream after it left the immediate nursery site.

With the large nursery as the subject Nursery II, again some residual oxidiazon was present in the pre-sample. Relatively large amounts of the herbicide (greater than 1 ppm in two samples) were present in the early runoff samples. After the early sample analyses it was decided to include tests for other herbicides and, even though they were not applied with the oxidiazon on September 4, measurable amounts of oxyfluorfen and simazine were present in the runoff water, presumably from earlier applications of these herbicides. As at Nursery I, this test indicated reduced levels of herbicide in the runoff water after relatively short travel from the application site.

PERCOLATION STUDY

To better understand the movement of herbicide from the point of application in a container nursery, a trial, conducted under laboratory conditions, was used to evaluate effects of time, water volume and media. Replicated one gallon plastic pots containing gravel, aged, pulverized fir bark, or a mixture (50/50) of bark and peat were arranged so that drainage from each could be collected in a sample bottle. The bark and mixture represented typical porous growing media used in container nurseries and the gravel represented the bed in a nursery on which the containers rest.

Media in the containers was wet to field capacity 24 hours prior to the herbicide application. Oxidiazon was distributed evenly over the surface of each container at the rate of 0.41 g of Ronstar 4G (4.6 ai kg/ha oxidiazon). After 1 hour, 360 ml (2 cm depth) of water was added to each pot by sprinkling uniformly over the surface three increments of 120 ml at 12 minute intervals. The water moving through the containers was collected so that the first 36 ml (10% of the volume applied), the next 145 ml (40% of the volume) and remaining volume collected in 30 minutes, were kept as separate samples. The leaching procedure was repeated after 24 hours using the same herbicide treated pots of media. Samples were treated as in the previous studies and analyzed for oxidiazon.

Results of the percolation study are shown in Table 5. Readily apparent from these is that only small amounts of the herbicide are moved through the media normally used in container production. The relative importance of the herbicide in runoff from gravel in an actual nursery will vary with the cultural practices. In a nursery with "can-tight" arrangement, containers will occupy appoximately 90% of the bed surface but as containers are spaced to allow plants to grow, this percentage can become much less, thereby permitting a greater portion of the applied herbicide to fall on the gravel bed.

Table 5. Concentrations and amounts of oxidiazon recovered, from laboratory percolation study simulating container nursery conditions (means of 4 replications).

Day	Percolation Volume	Media					
		Gravel		Bark		Bark/Peat	
		(ppb)	(ug)	(ppb)	(ug)	(ppb)	(ug)
1	10%	745	24	0	0	8	<1
	40%	962	130	<1	<1	0	0
	Remainder	918	76	0	0	0	0
2	10%	3602	121	0	0	0	0
	40%	2195	326	0	0	0	0
	Remainder	4852	453	<1	<1	<1	<1

The oxidiazon present in the water moving through the herbicide treated gravel was found in higher concentrations (4X) one day after the herbicide was applied as compared to leaching the gravel immediately after the herbicide application. Oxidiazon concentrations in the percolated water did not vary greatly between the aliquots of first, intermediate or last collection from a water application. Recovery of oxidiazon through the two leachings of the gravel in this study varied among the four replications from 4 to 9% (Ave = 7%) of the amount applied.

SUMMARY AND CONCLUSIONS

An evaluation was made of potential problems resulting from use of herbicides in northwest Oregon nurseries. A survey showed that occasionally significant quantities of herbicide can be measured in runoff water from nurseries. The amount of herbicide present in the runoff water is dependent on the length of time since the herbicide was last applied and the distance from the point of herbicide application. For nurseries producing container grown nursery stock, herbicide applied between the containers to the gravel beds on which the containers rest is likely the principle source of herbicide in the runoff water.

Literature Cited

1. Baker, J.L. 1981. Herbicide runoff as affected by application method and use of conservation tillage. Proc. North Cent. Weed Cont. Conf. 36:10-11.

2. Baldwin, F.L., P.W. Santelmann, and J.M. Davidson. 1975. Movement of fluometuron across and through the soil. Jour. Environ. Qual. 4:191-194.

3. Barnett, A.P., E.W. Hauser, A.W. White, and J.H. Holladay. 1967. Loss of 2,4-D in washoff from cultivated fallow land. Weeds. 15:133-137.

4. Frank, R. and G.J. Sirons. 1979. Atrazine: its use in corn production and its loss to stream waters in southern Ontario, 1975-1977. Science of the Total Environment. 12(3):223-239.

5. Frank, R., G.J. Sirons, and B.D. Ripley. 1979. Herbicide contamination and decontamination in well waters in Ontario, Canada, 1969-1978. Pesticide Monitoring Jour. 13(3):120-127.

6. Hickman, J.S., M.E. Harward, and M.L. Montgomery. 1983. Herbicides in runoff from agricultural watersheds in a high-winter-rainfall zone. Water Resour. Res. Inst., Oregon State University, Corvallis, OR. WRRI-66.

7. Hinden, E., D.S. May, and G.H. Dunstan. 1964. Collection and analysis of synthetic organic pesticides from surface and ground water. Residue Rev. 7:130-156.

8. Leonard, R.A., G.W. Langdale, and W.G. Fleming. 1979. Herbicide runoff from upland Piedmont watersheds - Data and implications for modeling pesticide transport. Journ. Environ. Qual. 9:37-42.

9. Rhode, W.A., L.E. Asmussen, E.W. Hauser, R.D. Wauchope and H.D. Allison. 1980. Trifluralin movement in runoff from a small agricultural watershed. Jour. Environ. Qual. 9:37-42.

10. Steenhuis, T.S. and M.F. Walter. 1980. Closed form solution for pesticide loss in runoff water. Trans. of ASAE. 23(3):615-620.

11. Wauchope, R.D. and R.A. Leonard. 1980. Maximum pesticide concentrations in agricultural runoff: a semi-empirical prediction formula. Jour. Environ. Qual. 9:665-672.

12. Willis, G.H., R.L. Rogers, and L.M. Southwick. 1975. Loss of diuron, linuron, ferac and trifluralin in surface drainage water. Journ. Environ. Qual. 3:339-402.