Effects of a DCPA/Naropamide Herbicide Tank Mix on Germinants of Seven Hardwood Species in Tree Nursery Beds

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Two pre-emergence herbicides-DCPA (Dacthal®) and napropamide (Devrinol®)-were applied as a tank mix of 4.76 kg (10.5 pounds) and .45 kg (1 pound) active ingredient per acre, respectively, to nursery beds of seedlings of 7 different hardwood species-hackberry (Celtis occidentalis L.), *persimmon* (Diospyros virginiana *L.), Russian olive* (Elaeagnus angustifolia *L.), euonymus* (Euonymus bungeanus *Maxim.), American plum* (Prunus americana *Marsh.), sand plum (P* angustifolia *Marsh.), and chokecherry (P* virginiana *L.)-at the time of germination but before seedling emergence. With the exception of American plum, germination counts and observations of seedling growth and condition revealed no damage from these herbicides on these hardwood species. Spring applications of these herbicides as a tank mix have several advantages over separate fall applications (just after sowing), including fewer applications of DCPA and napropamide needed to achieve adequate weed control, reduced loss of herbicide due to leaching and decomposition, reduced time spent spraying, and an increased window for application that achieves adequate control of weeds. Good weed control comparable to that achieved with separate applications of DCPA and napropamide was obtained with the tank mix.* Tree Planters' Notes 44(4): 149-153; 1993.

The development of new post- and pre-emergence selective herbicides for agricultural use has refined the control of weeds in agronomic crops. Many of these selective herbicides can be used in forest tree nurseries. Weed control at the Oklahoma Department of Agriculture's Forest Regeneration Center in Washington, Oklahoma, has been a perpetual battle requiring considerable investments of time and labor.

Pre-emergence herbicides provide selective control of weeds before they germinate and compete with desirable plants for water, nutrients, light, and space. Dacthal® (DCPA or dimethyl tetrachloroterephthalate) and Devrinol® (napropamide or 2-("-naphthoxy)-N,N-diethylpropionamide)) are pre-emergence herbicides commonly used in the control of annual broadleaf and grass weed species throughout the United States (Weed Science Society of America 1989). In forest nurseries, DCPA and napropamide are used extensively in the Northeast and West, but to a much lesser degree in the South (Abrahamson L.P., personal communication).

At Oklahoma's Forest Regeneration Center, a tank mix of DCPA/napropamide was applied soon after sowing to Russian olive *(Elaeagnus angustifolia* L.) in the fall of 1988, and to American plum *(Prunus americana* Marsh.) and sand plum (*P. angustifolia* Marsh.) in the fall of 1989 without phytotoxic damage. The tank mix consisted of DCPA at 4.76 kg (10.5 pounds) of active ingredient (AI) per acre and napropamide at .45 kg (1 pound) AI per acre. Application of these chemicals as a tank mix versus separate application reduces the time needed for spraying. Also the label recommends application of napropamide at a rate of 1.8 kg (4 pounds) AI per acre, but the previous studies detailed above have shown that .45 kg (1 pound) AI per acre is adequate in a tank mix with DCPA. This lower rate would reduce the risk of crop damage by napropamide (a problem in prior studies), and possibly allow another application of napropamide later in the growing season, if necessary, without a build-up of herbicide residue.

Fall-applied herbicides are often leached from the soil by winter and early spring rains, broken down by microorganisms, and/or absorbed by organic matter. However, very few weeds usually emerge during the fall or winter, whether or not pre-emergence herbicide is present. It would be desirable if these herbicides could be applied in the spring just before seedling emergence or just before significant numbers of weeds emerge. Spring application would make more pre-emergence herbicide available when it is needed most so that maximum use is made of the active life (DCPA and napropamide are effective for about 3 months) of the chemical in the soil. Less chemical would be needed for spring applications compared to fall applications, because spring applications would provide weed control for up to 3 months into the growing season whereas fall applications would barely provide weed control beyond spring weed and crop emergence and would require another application to achieve the same degree of weed control. Labor and weather constraints often limit the time when herbicides can be applied, and spring applications would allow more latitude in terms of when and possibly how often they may be applied. In the past, it was believed that fall applications on a fall-sown crop were necessary to avoid phytotoxic damage and provide adequate weed control, but no studies had been conducted to test alternatives to this idea.

The present study was conducted to determine if a tank mixture of DCPA/napropamide causes any phytotoxic effects on seven different fall-sown hardwood species when applied in the spring at the time of gerurination, but before seedling emergence.

Materials and Methods

All seven hardwood species in this experiment were sown in early November 1990 in 1.2-m-wide (4-foot-wide) by approximately 198-m-long (650-foot-long) nursery beds. The nursery beds were located on a loam soil with a pH of 6.2. Organic matter content of the soil in these nursery beds at the Forest Regeneration Center was 2%. At the time of the herbicide application in March 1991, most of the hardwood species had begun to germinate. The American plum and sand plum radicals had begun to extend, but the epicotyl had not broken the surface of the ground. Chokecherry *(P. virginiana* L.), euonymus *(Euonymus bungeanus* Maxim.), and hackberry (Celtis *occidentalis* L.) radicals were extending, and for some seedlings the epicotyl had reached the surface of the ground. The persimmon *(Diospyros virginiana* L.) had no radicals extending. Russian olive had radicals extending with many epicotyls above ground.

Five unpaired treatment sample plots were randourly established (measuring 1.83 m (6 feet) long x 1.22 m (4 feet) wide) for each species in the 1990 fall-sown beds. The treatment plots were sprayed with a tank mix of DCPA at 4.76 kg (10.5 pounds) and napropamide at .45 kg (1 pound) active ingredient per acre on March 9, 1991. At the time of application, the weather was sunny, with a temperature of 10 /C (50 /F), and the wind was north at 8 km/hr (5 miles per hour). Each plot was divided in half. Within each half plot (.9 m or 3 feet), half of the drill rows for a given species were chosen at random and marked. These rows were used for destructive germination counts whereas unmarked drill rows were used to assess the condition of the seedlings over time. Each new germinant was gently removed to facilitate counting also eliminated the need for counting each new germinant more than once on future dates of assessment. All plots were mapped. Five control sample plots were established, mapped, and evaluated in the same manner as the treatments but were ran dourly established in relation to the treatment plots and were not sprayed with the herbicide mix.

At varying intervals from March 23 until the final tallies were made, destructive counts were made by gently pulling, examining, and counting the number of newly germinated seedlings within each marked drill row in each half plot. American plum and Russian olive had finished germinating on April 26. Sand plum germinated until April 17. Hackberry, euonymus, and chokecherry germinated through May 1, and persimmon germinated until May 30. All species were examined for any new germination on May 30. Rows not sacrificed for germination counts were used for observations of developmental stages and the general health of the seedlings. Mean germination for both the treatment and control (five samples each) of each species for each date, and for the total cumulative germination were computed, and 95% confidence intervals were developed for each mean. Each sample (depending upon species) was the mean of 12 to 30 subsamples from the drill rows within each plot. A two-tailed t-test for unpaired plots was performed on the treatment and control means for final cumulative germination per .3 m of bed length (i.e., bedfoot) for each species. Significance of the differences between treatment and control means (5 samples for each mean) was assessed using the t-test method of Freese (1967).

Results

There was considerable overlap in the 95% confideuce intervals for treatment and control means for number of new germinants for all species on any date of assessment and for total germination (table 1). Overall, for total cumulative germination, only the control and treatment means for sand plum showed a significant difference, with the herbicide mix treatment having higher germination than the control for sand plum. It appears that this herbicide mix, when applied in a tank mix at the given rate, will not adversely affect germinating seedlings of chokecherry, euonymus, American plum, sand plum, hackberry, Russian olive, or persimmon. Observations of the seedlings' health and growth indicated no differences between plots treated with DCPA/napropamide and the control. Later, during the middle of the 1991 growing season, it was noticed that the stems of American

Table 1-Mean number of seedling germinants per .3 m of bed length (bed foot) for treatments and controls of fall-sown hardwood species after spring pregermination treatment with an herbicide tank mix

		Dates of assessment (1991)						
Species	Treatment	3/23	4/6	4/17	4/26	5/1	5/30	total no. germinants
chokecherry	C	2 ± 4	1 ± 3	1 ± 2	0 ± 1	0 ± 1	0	5 ± 6
	T	3± 4	2 ± 3	1 ± 2	0 ± 2	0 ± 2	0	6 ± 7
euonymus	C	4 ± 6	2 ± 4	0 ± 1	0 ± 0	0 ± 0	0	6 ± 5
	T	5± 8	1 ± 3	0 ± 1	0 ± 0	0 ± 0	0	6 ± 9
American plum	C	1 ± 2	20 ± 17	6 ± 6	0 ± 1	0	0	27 ± 16
	T	1 ± 2	16 ± 8	5 ± 6	1 ± 5	0	0	23 ± 7
sand plum	C	22 ± 28	20 ± 21	4 ± 17	0	0	0	45 ± 12*
	T	27± 26	27 ± 26	3 ± 9	0	0	0	56 ± 16*
hackberry	C	0 ± 2	30 ± 11	7 ± 10	0 ± 1	0 ± 0	0	38 ± 6
	T	0 ± 1	22 ± 19	6 ± 8	0± 1	0 ± 1	0	29 ± 22
Russian olive	C	24 ± 26	3 ± 6	0 ± 1	0 ± 1	0	0	27 ± 38
	T	31 ± 26	4 ± 11	0± 1	0± 1	0	0	35 ± 40
persimmon	C	0 ± 0	0 ± 1	3 ± 10	12 ± 40	13 ± 38	25 ± 77	53 ± 198
	T	0 ± 0	0 ± 0	0 ± 0	7± 21	13± 27	31± 73	54 ± 162

The herbicide mixture is DCPA (Dachtal®) at 4.76 kg (10.5 pounds) AI per acre and napropamide (Devrinol®) at .45 kg (1 pound) AI per acre. C = control, T = treatment. 95 % confidence intervals are computed as the mean ± standard deviation x $t_{.05}$

*Treatment and control values for total no. of sand plum germinants were statistically significant using a two-tailed *t*-test at "= .05

the roots appeared to be unaffected (Weatherford, G., personal communication).

Discussion

Seedlings tend to be most sensitive to herbicides like DCPA and napropamide during or just after ger-urination. They cause root stubbing, malformation, and restricted growth. Usually there is no foliar activity. In studies by Abrahamson (1987 and 1988), both DCPA and napropamide were separately applied to euonymus and Russian olive just after seeds were sown (post-seeding) and at 4 to 5 weeks after seedling emergence (post-germination). There were no phytotoxic effects to the seedlings. In other studies by Abrahamson (1988), DCPA applied post-germination was shown to have some phytotoxic effects on American plum, chokecherry, and hackberry. However, napropamide applied post-germination to hackberry caused no noticeable phytotoxic effect. The effect of these pre-emergence herbicides on seedlings at different times greatly depends upon the species and the particular chemical applied. Of the species examined in the present study, Abrahamson (1988) has only investigated the effects of DCPA and napropamide separately upon euonymus and Russian olive post-seeding, but not in a tank mix or applied close to when seedlings germinate as in this study.

Although not formally examined in this study, use of a DCPA/napropamide tank mix at the rate used in this study has historically provided good weed control of many grasses and broadleaved weeds at the Forest Regeneration Center, and good weed control was napropamide were mixed in this study and in previous studies to replace the tank mix of bifenox (Modown®) and napropamide formerly used. Modown is no longer manufactured, and DCPA will help control weeds not controlled by napropamide and vice versa (table 2). In addition to the further species controlled by each chemical in the mix, it is possible that a synergistic effect of the mix may control even more weeds than those listed.

In the present study, the 95% confidence intervals overlapped considerably for the treatment and control means for germination for each species on each date of assessment and overall. Large confidence intervals probably indicated a lack of precision in the experiment and the need for more subsamples to account for the environmental variation and reveal any further significant differences if they existed. However, 95% confidence intervals do not indicate the significance of differences between means as *t*-tests do, and it is possible for 95% confidence intervals to overlap considerably between two means and for two-tailed *t*-tests to show the difference between those means to be significant at "= .05 (Patton, D., personal communication). Nevertheless, it is interesting that the sand plum treated with the mixture had significantly higher over all germination than the control because napropamide has been shown to have beneficial plant growth regulating effects on other plants (Weed Science Society of American 1989). A study comparing the effect of higher differing rates of the mixture on sand plum would be interesting to ascertain if this pre-emergence mix does indeed enhance germination. This study should also be repeated with American plum to deter-

Table *2-Weed control by DCPA and napropamide*

Common name	Scientific name
Controlled by DCPA but not by napropamide	
burning nettle	*Urtica wrens* L.
copperleaf	*Acalypha* spp.
deadnettle	*Lamium* spp.
dodder	*Cuscuta* spp.
[European] field pansy	*Viola arvensis* Murray
Florida purslane	*Richardia scabra* L.
groundcherry	*Physalis* spp.
knotweed	*Polygonum* spp.
lovegrass	*Eragrostis* spp.
nightshade	*Solanum* spp.
spurge	*Euphorbia spp.*
Controlled by napropamide but not by DCPA	
brome	*Bromus* spp.
cheatgrass	*B. secalinus* L.
	B. tectorum L.
ripgut brome	*B. rigida* Roth
[wooly] cupgrass	*Eriochola villosa* (Thunb.) Kunth
fall panicum	*Panicum dichotomiflorum* Michaux
filaree	*Erodium spp.*
[common] groundsel	*Senecio vulgaris* L.
knotweed	*Polygonum* spp.
little mallow	*Malva parviflora* L.
mallow	several genera have plants called mallow: *Malva, Malvella, Urena, Abutilon,* Althaea, *Abelmoschus, and Hibiscus*
panicum (panicgrass)	*Panicum* spp.
pinapple weed	*Matricaria matricarioides* (Less.) Porter
prickly lettuce	*Lactuca serriola* L.
soft chess	*Bromus hordeaceus* L.
sowthistle	*Sonchus* spp.
sprangletop	*Leptochloa* spp.
ryegrass	*Lolium* spp.
ragweed	*Ambrosia* spp.
wild barley	*Hordeum* spp.
wild oats	*Avena* spp.
Controlled by both chemicals	
annual bluegrass	*Poa annua* L.
barnyard grass	*Echinochloa crus-galli* (L.) P Beauv. var. *crus-galli*
carpetweed	*Mollugo verticillata* L.
chickweed	*Stellaria* spp. or *Cerastium* spp.
crabgrass	*Digitaria* spp.
foxtail	*Setaria* spp. or *Alopecurus* spp.
goosegrass	*Eleusine indica* (L.) Gaertner
Johnson grass (fom seed)	*Sorghum halepense* (L.) Pers.
lamb's-quarters	*Chenopodium album* L.
pigweed	*Amaranthus* spp.
purslane	*Portulaca* spp.
sandbur	*Cenchrus* spp.
witchgrass	*Panicum capillare* L.

ture, and if so at what rate(s), or if it is due to an interaction of the herbicides with another environmental factors) (e.g., fertilizer). A study examining the phytotoxicity and weed control of separate applications of DCPA and napropamide upon these species versus a tank mix would also be helpful in understanding the results of this study. Despite the limitations of this research, the application of DCPA/ napropamide as a pre-emergence tank mix at the time of germination shows promise for weed control in nursery beds of all species tested in this study.

The results of this 1-year study must be accepted with caution because the treatments have not been repeated over time or under different temperature, mositure, wind, soil texture or other environmental conditions (Owston and Abrahamson 1984). Nevertheless, the results are encouraging, and the experiment will be repeated at the Forest Regeneration Center. Further studies could include such measurements as height, stem caliper and/or root weight to help detect possible phytotoxic effects. Also, the phytotoxic safety limit of this herbicide mixture could be determined by applying higher (2 or 4 x) doses for a species (Owston and Abrahamson 1984).

In this study, the DCPA component of the mix was applied near the label's maximum recommended level of active ingredient per acre while the napropamide part was applied at much less than the recommended rate. Neither chemical's label prohibits nor gives recommendations for mixing these chemicals. In the past, this tank mix has been applied as a part of ongoing research conducted by Dr. Larry Abrahamson of the State University of New York at Syracuse in cooperation with the Oklahoma Department of Agriculture's Forest Regeneration Center. The present study was conducted with Dr. Abrahamson's advice and consent, and all applicators were licensed by the Oklahoma Department of Agriculture with demonstration and research category pesticide applicator licenses.

Fermenta Plant Company advises application of Dacthal® W-75 separately (not as a tank mix) to nursery stock at the rate of 14 to 16 pounds (6.3 to 7.2 kg) in 50 to 100 gallons (190 to 380 1) of water per acre (.4 ha). This would be 10.5 to 12 pounds (4.7 to 5.4 kg) of active ingredient per acre. Weed control at this rate should last 3 months or more. For DCPA (dimethyl tetrachloroterephthalate), the active ingredient of Dacthal, the average half life is 60 to 100 days in most soil types, with no leaching. This chemical is absorbed by organic matter, and microorganisms are the primary factor in the disappearance of the chemical. No loss occurs from photodecomposition and/or volatilization. DCPA is not absorbed by foliage or translocated in the plant (Weed Science Society of America 1989).

For Devrinol® 50-WP, the Stauffer Chemical Company recommends separate surface application to fruit and nut crops at the rate of 8 pounds (3.6 kg) per broadcast acre (.4 ha). This would be 4 pounds (1.8 kg) of the active ingredient, napropamide, per acre for Devrinol. Napropamide has a half life of 8 to 12 weeks in loam soils when incorporated at 70 to 90 /F (21 to 32 /C). This chemical is quite resistant to leaching and is slowly broken down by microorganisms; very little is lost to volatilization from the soil surface. Also, napropamide is only absorbed somewhat by foliage but is rapidly taken up by roots, trapslocated, and metabolized (Weed Science Society of America 1989). Fortunately both DCPA and napropamide are fairly stable, nonreactive, and nonflamma ble chemicals that carry only d caution label. Given the characteristics Of the active ingredients of Dacthal® and Devrinol®, their label recommendations, and the site arid weather conditions of the study area, one would expect that other southern nurseries might also have success using these chemicals at rates similar to those used in this study.

Conclusions

Preliminary results indicate that an application of DCPA (Dacthal)/napropamide (Devrinol) as a tank mix at 4.76 kg (10.5 pounds) and .45 kg (1 pound) of active ingredient per acre, respectively, just before seed ger-urination will not damage young seedling germinants of sand plum, chokecherry, euonymus, hackberry, persimmon, or Russian olive, but will provide good weed control for these species. With the exception of American plum, this application had no adverse effect upon the number of seedling germinants or the growth of the seedlings over time. The germination of sand plum appears to be enhanced by this herbicide application.

Further studies of these herbicides on these and other hardwood species should be conducted and the phytotoxicity of this herbicide mixture determined for each species. The results, if positive, would indicate that the DCPA/napropamide mixture could be applied in the spring just before seedling emergence of a fall sown hardwood crop at the Forest Regeneration Center. However, other nurseries must do their own studies to determine the safety and effectiveness of these chemicals on each species they grow. Differing soil and weather conditions often alter the weed control and phytotoxicity of these chemicals, and the phytotoxicity of these chemicals appear to be species specific.

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