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Controlling roadside noncrop pine in SE Oklahoma using selected glyphosate formulations with and without LI 700 and Milestone VM Plus

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CONTROLLING ROADSIDE NONCROP PINE IN SE OKLAHOMA USING SELECTED GLYPHOSATE FORMULATIONS WITH AND WITHOUT LI 700 AND MILESTONE VM PLUS

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ABSTRACT

Noncrop pine control is a major issue confronting managers of openings along roadsides and in clearcuts.Herbicides containing glyphosate are commonly used for pine control. Traditionally, managers have applied 4 quarts product/acre with inconsistent results. LI 700 is a penetrating non-ionic surfactant that contains lecithin. Selected treatments of Makaze, Accord Concentrate and Accord XRT II, some with and without LI 700 or Milestone VM Plus, were tested for control of loblolly (*Pinus taeda* L) and shortleaf (*P. echinata* Mill) pines in southeastern OK. Herbicides were applied at 15 GPA on 10-Jun-08. Plots were evaluated for control on 14-Jun-09. Three glyphosate formulations at 4 quarts product/acre produced dramatically different results exemplifying the state of operations today. All 6-quart and 8-quart formulations provided ≥89 percent control. Treatments with LI 700 exhibited more control than comparable treatments without LI 700. Adding 4 quarts product/acre of Milestone VM Plus to 4 quarts product/acre of Accord XRT II increased control numerically over Accord XRT II alone. Managers seeking to control unwanted pines while using less product, should consider Makaze (6 quarts product/acre). This treatment required less active ingredient to provide statistically similar pine control as higher rates of glyphosate.

INTRODUCTION

Roadsides, like harvested timberlands, provide openings readily colonized by unwanted pines. Reproductively mature pines can seed openings with an excess of 500,000 sound seeds/acre (Cain and Shelton 2001) resulting in significant wilding pine encroachment that reduces access, elevates fire hazards and increases land management costs (George 1900).

While application volume and method are important factors in pine control (Cain 1988), most research has focused on pine species, herbicide timing and rate, and pine size and density. For example, susceptibility to glyphosate varies by species: slash pine (*Pinus elliottii* Englem) >loblolly pine (*P. taeda* L)>shortleaf pine (*P. echinata* Mill) (Voth 1987, Voth 1989, Yeiser 1999). But even with the species variable addressed, pine control with glyphosate remains inconsistent.

Screening trials have focused on three size classes of pines: seed, seedling and sapling. Yet, inconsistency in control exists within these size classes. For example, Yeiser (1999) controlled germinating seeds in a nursery bed with several herbicide treatments. Follow-up field tests of R6447 (Milestone-azafenidin) provided inadequate pine seed control (Yeiser 2001). In rate trials for seedlings <2 feet tall, herbicide tolerance was sufficient in newly planted loblolly pine receiving a herbaceous release treatment of glyphosate (44oz or 1.374 quarts product/acre) to produce little damage. Released seedlings continued to exhibit enhanced survival and growth with growth gains over checks increasing through age four (Voth 1987, 1989). Cain (1988) applied 1.5 quarts product/acre (Roundup) for pine seedling release and experienced significant damage that varied with the application method. Timing of application did not influence the amount of damage. In a site preparation trial for pine control, small (<6", 500,000 per acre) and large (>1 foot, 800 per acre) natural loblolly pine seedlings were readily controlled with 64oz (2 quarts product/acre) of glyphosate (Razor Pro) in Mississippi and Texas (Ezell and Yeiser 2010). Yeiser (1999) targeted the setting of the first flush (Burkhalter 1996) in an April screening trial of 37 products for control of nursery-grown shortleaf pine seedlings. April control of shortleaf seedlings with Accord Concentrate+Timberland 90 (3, 4, 5 quarts+.25% volume/volume) was inadequate with only 28 percent, 6 percent, and 10 percent mortality, respectively. Other stand-alone treatments of Krenite S (4 quarts product/acre) with 41 percent control and Vanquish (4 quarts product/acre) at 85 percent control appeared more promising than Accord Concentrate. In rate trials of sapling pines, three young pine plantations received a woody release treatment of 1.5 or 2 quarts product/acre of glyphosate (Roundup) applied in September and April or May and both rates reduced crop pine height growth (Minogue and Creighton 1987). In Arkansas and Mississippi, site preparation trials of pines 4-8 feet tall achieved similar and intermediate August control from Vanquish+Accord Concentrate+Timberland

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90 (2+4, 2+3 quarts product/ac+.25% Timberland 90 v/v), as compared to alternative herbicide treatments (Yeiser et al. 1999). These results suggest ≤3 quarts product/acre of glyphosate (Roundup and Razor Pro) may damage pines but are inadequate for reliable pine control.

Use of an appropriate surfactant is very important. Gnegy (1987) added surfactant to a September woody-release, loblolly pine trial of 1-quart product/acre or 2 quarts product/acre of glyphosate (Roundup) resulting in nearly total year-2 pine mortality. Voth (1989), in a report of large-plot (5-30acres) helicopter trials, applied 5 quarts of Accord+surfactant and concluded that (1) Cide-Kick II was antagonistic to glyphosate activity, (2) glyphosate+Ortho X-77 (1-3.5% test rates) provided excellent hardwood control (95-95%) that was independent of surfactant rate. Loblolly pine control ranged from 95-100 percent as the Ortho X-77 rate increased from 1-3.5% and (3) MON-0818 provided superior control (95 percent) to Cide-Kick II (80 percent). Cobb (1987) reported that the concentration and type of surfactant used with glyphosate in his large-scale operational trials in Alabama and Tennessee affected long-term control of brush species and the speed at which treated brush browns out following application. Thus, be sure to only use a surfactant that is labeled and recommended for your specific application (over-the-top release, site preparation, etc.). Use of glyphosate without the appropriate surfactant will result in reduced herbicide performance on weeds or damage to crop trees. Always read and follow the precautionary statements and applicable use directions on the label of the surfactant product.

The mixed results from trials of different timings, products, surfactants, and rates may be best illustrated in the single study by Cargill et al. (1987). In a roadside shortleaf pine control study in Oklahoma, Cargill et al. (1987) compared June applied Garlon 4+Tordon K (1+1 gallon product/acre in 50 GPA), Tordon 101 Mixture (3 gallons product/acre in 50 GPA), Graslan 40% P at 4 pounds active ingredient/acre against September-applied Krenite S (3 gallons product/acre in 40 GPA), Roundup (1% and 2% solutions) and Rodeo (.75% and 1.5% + X-77 .5% volume/volume). Pine control with Roundup (1%, 2% solutions) was less than 48 percent, with Rodeo (.75%+.5% X-77) 77 percent and with Rodeo (1.5%+.5% X-77) over 96 percent. All of the alternative, non-glyphosate test treatments in this trial also yielded over 96 percent pine control.

In an effort to understand glyphosate activity as related to plant and weather parameters, D'Anieri (1987) related independent variables such as water stress, phenology, and weather variables to the dependent variable, relative crown volume growth. Linear relationships were not strong (D'Anieri 1987), indicating the complex and unobvious parameter relationships. Furthermore, D'Anieri (1987) showed the absorption of glyphosate in sweetgum (*Liquidambar styraciflua* L), loblolly pine and red maple (*Acer rubrum* L) to be similar, but translocation from the leaf was greater for sweetgum>loblolly pine>red maple. This translocation pattern explains the injury patterns often seen in field applications of glyphosate, that is, sweetgum is killed, loblolly pine has terminal dieback, and red maple is suppressed but seldom killed.

Currently, multiple formulations of glyphosate are available for managers to consider. Some products are fully loaded with surfactant while others are not. Fully loaded means the manufacturer does not recommend the addition of more surfactant to the mixture. Furthermore, formulations also vary by concentration and the parent acid from which the formulation acquires its particular properties. In short, this means that all formulations of glyphosate are not the same. Thus, users should not take a given product (glyphosate) rate, and use it across products and expect the same results.

The results reported above are based on studies of different formulations of glyphosate all from the isopropylamine salt. Glyphosate products commonly in use today are:
(1) Accord Concentrate (53.8% glyphosate, containing 5.4lbs per gallon isopropylamine salt)--needs additional surfactant.
(2) Accord XRT II (50.28% glyphosate, containing 5.4lbs per gallon dimethylamine salt)--no additional surfactant recommended.
(3) Accord XRT (53.6% glyphosate, containing 5.4lbs per gallon isopropylamine salt)--fully loaded with surfactant.
(4) Razor Pro (41% glyphosate, containing 4.0lbs per gallon isopropylamine salt)--no additional surfactant recommended
(5) Makaze (41% glyphosate, containing 4.0lbs per gallon isopropylamine salt)--fully loaded with surfactant and contains lecithin.

Leci-Tech/LI 700--Lecithin occurs naturally in the cell membrane of all cellular organisms. It is a surfactant that contains phospholipids with a natural affinity for water and oil (Shurtleff and Aoyagi 2011). Lecithin can be totally metabolized by humans, so it is well tolerated by humans and non-toxic when ingested (Shurtleff and Aoyagi 2011). Leci-Tech/LI 700 contains lecithin and is a non-ionic penetrating surfactant, which reduces off-target spray drift, and reduces spray water pH (Loveland Products Inc. 2011). It enhances drift management (improves droplet size) and improves droplet deposition (less bounce), adhesion, spreading and penetration.

Milestone VM Plus is a herbicide by Dow AgroSciences containing the active ingredients, aminopyralid and triclopyr (Dow AgroSciences 2010). It is labeled for control of herbaceous broadleaf weeds and woody plants in rangeland, permanent grass pastures, Conservation Reserve Program (CRP), forests, and on non-cropland areas including industrial sites, rights-of-way, (such as roadsides, etc), fencerows, non-irrigation ditch banks, natural areas and grazed areas in and around these sites. Use within sites listed above may include applications to seasonably dry wetlands and around standing water on sites such as deltas

and riparian areas. Milestone VM Plus is labeled for pine control.

PROBLEM

Research results from surfactant, rate, product concentration, and timing trials for pine control with glyphosate from the isopropylamine salt are mixed and sometimes conflicting. More confusion will likely occur with the more recent introduction into the market of Accord XRT II and Makaze. An appropriate pine-control treatment will likely not result from an intuitive, linear approach to biological processes using current technology. New adjuvants that: (1) improve the penetration of glyphosate into needles and (2) facilitate glyphosate movement to binding sites in cells are needed. A desirable outcome from future research would be increased pine control with decreased levels of active ingredient.

OBJECTIVE

The objective of this study was to compare selected glyphosate treatments with and without the addition of LI 700 or Milestone VM Plus for the control of unwanted, noncrop pines.

METHODS

The study site was near Broken Bow, OK. Unwanted, noncrop loblolly and shortleaf pines 3-feet to 8-feet tall on roadsides and ditches received a herbicide treatment for control. Test treatments (quarts product/acre) were: (1) Razor Pro-10, (2) Accord XRT II+LI 700-8+1/2%, (3) Accord XRT II-8, (4) Makaze-8, (5) Accord Concentrate+LI 700-6+1/2%, (6) Accord XRT II+LI 700- 6+1/2%, (7) Accord XRT II-6, (8) Makaze-6, (9) Accord Concenrate+LI 700-4.5+1/2%, (10) Accord XRT II+LI 700-4+1/2%, (11) Accord XRT II-4, (12) Accord XRT II+Milestone VM Plus+LI 700-4+4+1/2%, (13) Accord XT II+Milestone VM Plus-4+4, (14) Accord Concentrate+LI 700-3+1/2%, (15) Makaze-4, and (16) a untreated check. These test treatments represent the glyphosate issues before managers today. That is, formulations of glyphosate originate from different salts, come in different concentrations, and are packaged with and without surfactant and other adjuvants such as lecithin.

Treatment plots were 30-feet x 120-feet. The evaluation plot was 10-feet x 100-feet and internal to the treatment plot leaving 10-feet on each end as buffer. Pines more than 8-feet tall were cut and removed from plots. Thirty pines within each plot were systematically and randomly selected for evaluation and tagged for measurement.

Pre-treatment pine total height was recorded 4-Jun-08, herbicide was applied June 10, 2008. All herbicide treatments were applied at 15 gallons/acre using a CO_2 backpack aerial simulator with a single, KLC-9 nozzle. Total pine heights were recorded again, 14-Jun-09 (one year after treatment).

percent control was computed as: ((initial height - evaluation day height)/initial height) x 100. This means that trees taller at the end of the study (check) than when the study initiated have a negative value. Control, the purpose of the study, has a positive value (herbicide treatments). Percent data were transformed with an arcsine square root transformation. Real values are reported here.

Treatments were assigned to plots in a randomized complete block design with block being different locations along the timber access road. Pine height and density (trees/acre) averaged: block 1=4.5-feet, mean=4,356 (range=2,178-7,296) trees/ac, block 2=4.8-feet, average=3,049 (range=1,220-4,574) trees/acre and block 3=5.2-feet, mean=3,477 (range=1,684-5,227) trees/acre.

Data were analyzed using PROC GLM and means separated according to Duncan's New Multiple Range test (SAS Publishing 2008). Three analyses were performed. One analysis was conducted on all treatments in the study. For the second analysis, glyphosates were grouped according to similar amounts of active ingredient. These groups are: 2.0-2.5, 3.0-3.3 and 4.0 quarts product/ac. Percent control was averaged for these groups with mean active ingredient becoming 1.6, 2.2, 3.1, and 4.0 quarts glyphosate/ac. A third analysis was performed on pairs of treatments, each with a level of glyphosate with and without LI 700.

RESULTS

COMPARISONS BASED ON PRODUCT VOLUME

When all treatments were compared, herbicides reduced pine height from 37 percent to 99 percent while check pines increased in height almost 60 percent (Table 1). The high rate of Razor Pros (10 quarts) provided intermediate control of pines. Results indicated 12 treatments with and without LI 700 provided statistically similar and best pine control ranging from 76 percent to 99 percent. Glyphosate rates ranged from a low of 4 quarts product/acre to a high of 8 quarts product/acre with higher rates providing more control than lower rates. All treatments containing LI 700 provided more numeric control than the comparable treatment without LI 700.

When we examine control based on product volume, the 4 and 4.5 quarts product/acre treatments containing only glyphosate, Accord Concentrate+LI 700, Accord XRT II+LI 700, Accord XRT II and Makaze, provided 60 percent, 89 percent, 81 percent and 37 percent pine control, respectively. This is widest range and the most variable control of the four glyphosate-groups (Table 1). Accord Concentrate (4.5 quarts/acre product) and Makaze (4 quarts/acre product) provided some of the lowest pine

control. The dimethylamine salt in Accord Concentrate II (4 quarts product/acre with and without LI 700) produced 81 percent and 89 percent control, respectively, and increased pine control over the other 4 and 4.5 quarts product/acre treatments. Adding Milestone VM Plus to 4 quarts product/acre glyphosate also numerically increased pine control over the addition of LI 700.

COMPARISONS BASED ON LEVEL OF GLYPHOSATE

The comparison of glyphosate rates and treatments with and without LI 700 is more appropriate when separated into groups based on the amount of active ingredient, glyphosate, and the presence and absence of LI 700 (Table 1). Glyphosate groups averaged 94.2 percent, 92.3 percent, 80.3 percent and 39.4 percent pine control for 4.0, 3.1, 2.2 and 1.6 quarts glyphosate/ac, respectively. Significantly less control resulted from 1.6 quarts glyphosate/acre than other treatments with all other treatments being statistically similar. No differences were detected among treatments within each of the four glyphosate-groups.

DISCUSSION

The high rate of Razor Pro (10 quarts product/acre) is a research treatment (exceeds the maximum labeled rate) (Table 1) and is neither recommended nor available for forest operations. Like that of other high rates of Razor Pro (12, 14 quarts/acre) tested and not reported here, all provided intermediate control with lower glyphosate rates achieving higher control. These results suggest: 10-14 quarts product/acre of glyphosate may exceed the biological limit of pine, screening trials are currently testing near the biological limit, and a new technology is needed that facilitates glyphosate cuticle penetration and cellular movement to binding sites for glyphosate inhibition of amino acids.

Managers prefer a low rate that provides comparable control as a high rate. But, glyphosates vary in concentration, thus a quart of one product may contain more or less glyphosate than a quart of a competitor's product. Therefore, it is important for managers to compare glyphosate formulations based on the amount of active ingredient and not the volume of the container. For example, 4 quarts of Makaze and 3 quarts of Accord Concentrated contain 1.64 and 1.61 quarts of glyphosate, respectively. This illustrates the differences in glyphosate based on a comparison of volume and active ingredient. This is important because, as the rate of glyphosate increases, pine control increases, that is, 39.4 percent, 80.3 percent, 91.6 percent, and 96.7 percent, pine control resulted from 1.6, 2.2, 3.1, and 4 quarts/acre of glyphosate, respectively. Based on concentration, Makaze (8 quarts product/acre), Accord Concentrate (6 quarts product/acre), and Accord XRT II (6 quarts product/acre), have approximately the same amount of glyphosate and provided comparable pine control. Likewise, Makaze (6 quarts product/acre), Accord Concentrate (4.5 quarts product/acre), and Accord XRT II (4 quarts product/acre) have similar amounts of glyphosate and provided similar pine control with the exception of Accord Concentrate (4.5 quarts product/acre) that provided less control than comparable glyphosate treatments. The average pine control for 2.2, 3.1, and 4 quarts glyphosate/acre were similar. However, years of experience have demonstrated the inconsistent performance of 2.2 quarts of glyphosate, thus favoring the selection of 3.1 quarts (commonly 6 quarts of product for many formulations). The next level higher than 2.2 quarts is 3.1 quarts glyphosate/acre with Makaze 6 quarts product/acre being the best glyphosate (numeric) performer of the 2.2 group. This is an opportunity for users of 6 quarts product/acre to achieve the same control as the users of 8 quarts product/acre but with less active ingredient.

Adding LI 700 to glyphosate mixtures consistently increased numerical pine control for comparisons with the fully loaded Accord XRT II (4, 6, 8 quarts/acre). Selecting 4 quarts product as the base level, then adding Milestone VM Plus (4 quarts product/acre) to Accord XRT II (4 quarts product/acre) numerically increased control from 80.8 percent to 93.0 percent and introduced 0.65-quart aminopyralid/acre and 0.09 quarts triclopyr/acre into the environment. Adding LI 700 to the Accord XRT II+Milestone VM Plus mixture further increased control to 94.8 percent. Alternatively, selecting 6 quarts product/acre of Makaze, increased control to 92 percent and introduced an additional 0.5-quart glyphosate/acre into the environment. Thus, to achieve more control with the addition of Milestone VM Plus to the base 4-quart product/acre rate requires the use of more active ingredients than selecting Makaze (6 quarts product/acre). Selecting Makaze (6 quarts product/acre) rather than Accord XRT II+Milestone VM Plus may reduce pine control by 3 percent. It appears that Milestone VM Plus substitutes for Accord XRT II for pine control at a 2-quart product/acre to 1quart product/acre replacement level.

CONCLUSIONS

When selecting a formulation of glyphosate for pine control, managers should select an application rate based on the amount of active ingredient (glyphosate) and not the quarts of product. Although not statistically significant, the addition of LI 700 surfactant improved the performance of Accord XRT II at all test rates. Managers should consider 6 quarts product/acre of Makaze for pine control. This product and rate achieved pine control comparable to higher rates while introducing fewer active ingredients into the environment than Accord XRT II+Milestone VM Plus.

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Table 1—Herbicides, application rates, amount of active ingredient and percent control of noncrop pine along a timber access road in southeastern Oklahoma. Product was applied 10-Jun-08 and control determined 14-Jun-09. Duncan's New Multiple Range Tests (DNMRT) was used to separate means for all treatments, groups of treatments selected for comparable amounts of glyphosate, and treatments with and without LI 700

Herbicide	Product Rate/ac (qts.+%)	Glypho-sate (qts a.i.)	percent Control	All Treat-ments[1]	Glypho-sate Groups	With vs Without LI 700
Razor Pro	10	4.1	75.8	ab		
Accord XRT II+LI 700	8+1/2	4.0	99.0	a	a[1,2]	a[1,3]
Accord XRT II	8	4.0	94.3	a	a	a
Makaze	8	3.3	89.2	a	b[1,2]	
Accord Concenentrate+LI 700	6+1/2	3.2	90.9	a	b	
Accord XRT II+LI 700	6+1/2	3.0	95.2	a	b	b[1,3]
Accord XRT II	6	3.0	90.9	a	b	b
Makaze	6	2.5	92.1	a	c[1,2]	
Accord Concentrate+LI 700	4.5+1/2	2.4	59.6	bc	d	
Accord XRT II+LI 700	4+1/2	2.0	88.6	a	c	c[1,3]
Accord XRT II	4	2.0	80.8	ab	c	c
Accord XRT II+Milestone VM Plus+LI 700	4+4+1/2	2.0	94.8	a	c	d[1,3]
Accord XRT II+Milestone VM Plus	4+4	2.0	93.0	a	c	d
Accord Concentrate+LI 700	3+1/2	1.6	41.7	c	e[1,2]	
Makaze	4	1.6	37.1	c	e	
Check	---	0	-59.0	d		

[1] Means within a column sharing the same letter are not significantly different (DNMRT, a=0.05).
[2] a=1st of 4 DNMRT; b=2nd of 4 DNMRT; c and d=3rd of 4 DNMRT; e=4th of 4 DNMRT.
[3] Each pair of letters represents a different DNMRT.