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I am submitting herewith this thesis written by Joseph E. Beeler entitled "Horsenettle (*Solanum carolinense*) control in tall fescue pastures with a 2,4-D amine and picloram package mixture." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Sciences.

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HORSENETTLE (*Solanum carolinense*) CONTROL IN TALL FESCUE PASTURES WITH A 2,4-D AMINE AND PICLORAM PACKAGE MIXTURE

A thesis

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ABSTRACT

Grazon P+D®, a premix combination of 0 .24 kg / L 2,4-D and 0.06 kg / L picloram, has shown promise for horsenettle (*Solanum carolinense*) control. Experiments were conducted in 2001-2002 in Hamilton and 2002-2003 in Monroe County to evaluate Grazon P+D® for horsenettle control and clover (*Trifolium* sp.) tolerance in a tall fescue (*Festuca arundinacea*) pasture. Grazon P+D® treatments included 0.7 Kg acid equivalent (AE) / ha and 1.4 kg AE / ha at three timings in each study: early post (EPost) (10-15cm horsenettle height), mid post (Mpost) (early flower), and late post (LPost) (fruit initiation). In February 2002, separate 3.0 m strips of "Reddy" variety red clover (6.3 kg / ha seeding rate) and "Will" variety ladino white clover (11.2 kg / ha seeding rate) were drilled across all plots. Horsenettle control and density at season's end was determined for both locations. Survival of clover drilled the winter following application was evaluated in the spring and summer of 2002 at Hamilton County. Data were subjected to analysis of variance and means were separated using Fischer's Protected LSD test (P = 0.05). Reduction of ladino white clover existing at the time of application was >95% for all Grazon P+D® treatments. All early and late summer treatments at both locations provided >80% control of horsenettle. Horsenettle density in all treated plots in the experiment at both locations was < 1 stem / $10m^2$, while untreated plots contained >25 stems / $10m^2$. Both late season experiments exhibited a difference in stem density between late season LPost applications and all other applications. EPost and MPost plots contained > 1 stem

/ $10m^2$, while LPost plots contained between 2 and 45 stems / $10m^2$. This difference was due to the short time between the LPost applications and the stem counts. LPost applications eventually exhibited control similar to, or better than other application timings. Horsenettle density was measured in both Hamilton County experiments one year after application on 17 May and 13 June 2002 using the same methods as in 2001. All early and late season treated plots contained from 1 to 25 stems / $10m^2$ as opposed to between 20 and 125 stems / $10m^2$ in the untreated plots. Clover survival was evaluated at both Hamilton County experiments on 17 May 2002. Red and ladino white clover survival was lower in the Grazon P+D® treated plots of both the early and late summer experiments (22 - 50%) than in the controls (73 - 82%). Horsenettle control at both Hamilton County experiments was evaluated on 13 June 2002. All early and late summer experiment Grazon P+D® treatments controlled horsenettle between 45 and 75% with no control difference between treatments.

Grazon P+D® reduced horsenettle growth immediately after application and provided suppression of horsenettle the following year; however, treated plots showed reduced survival of clover drilled the winter following application. This reduced survival can be attributed to the herbicide. All applications of the herbicide controlled horsenettle equally well the year of application. Horsenettle control one year after application was less in EPost applications than in MPost or LPost applications in the late summer study. All other applications controlled horsenettle equally well one year after application regardless of timing or rate. An

application of Grazon P+D® (0.7 Kg AE / ha) at either the flower or fruiting stage will provide excellent control the year of application and reduce horsenettle infestation one year after application. It will, however, reduce survival of clover drilled the winter following application.

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CHAPTER I

INTRODUCTION

Farm industries associated with pasture and hay production play a significant role in Tennessee's Agriculture. According to the Tennessee Agricultural Statistics Service (2002), beef cattle production accounted for 19% of the state's total agricultural cash receipts in 2001, or 41 million dollars. This was nearly double that of the next closest industry. The dairy industry, which is dependent upon hay and pasture, accounted for 10% of the state's total agricultural cash receipts in 2001, or 22 million dollars. Hay production accounted for an additional 4 million dollars in 2001. As of 2001, over 2 million head of beef cattle and calves were being raised on 45,000 operations spread across Tennessee (Tennessee Agricultural Statistics Service, 2001). Over the last decade, the price paid for Tennessee beef cattle has not increased. The average price received by Tennessee farmers for all beef cattle was 65.0 cents per pound in 2001. This is basically unchanged from the 65.4 cents per pound received in 1991. Beef cattle prices fell to a low of 40.7 cents per pound in 1996. The low profitability of the beef cattle market necessitates producers to minimize expenses in their operations.

Successful weed management is essential for producing quality livestock forage and hay (Rhodes and Breeden, 2000). Horsenettle has recently become a more prevalent problem weed in Tennessee pastures (Breeden and Rhodes, 2001).

Its ability to reproduce from an extensive rhizomous root system makes it nearly impossible to control by mowing, the most common weed control practice in pasture situations (Illnicki et al. 1962). In addition to crop competition, chemical control seems to hold the most promise for continual control of this perennial weed.

A package mixture of 0.06 kg / L picloram (4-amino-3,5,6-trichloropicolinic acid, triisopropanolamine salt) and 0 .24 kg / L 2,4-D amine (2,4-dichlorophenoxyacetic acid, triisopropanolamine salt) (Dow AgroScience, Grazon P+D® label) has shown particular promise for horsenettle control (Breeden and Rhodes, 2001). The current trade name for this product is Grazon P+D® .

CHAPTER II

LITERATURE REVIEW

HORSENETTLE NATURAL HISTORY

Horsenettle (*Solanum carolinense*) is a perennial plant in the Solanaceae family. It is native to the United States (Gunn and Gaffney, 1974) and is found throughout the Eastern U.S. to Southern Ontario and in the Western U.S. from Arizona and Idaho to California and Oregon (Ilnicki et al, 1962). It is one of the ten most common pasture weeds in the southern United States, although it also found frequently in cultivated fields (Bradbury and Aldrich, 1956). It has also become a troublesome weed in no-till corn (*Xea mays*) production (Worsham 1982; Prostko et al 1994; Banks et al. 1977). In pastures, it is a drought-resistant competitor (Bradbury and Aldrich, 1957) that can reduce the yield and quality of forages (Smith and Calvert, 1980; Banks and Santelmann, 1978; Gorrell et al. 1981; Hackett et al. 1987). Both the foliage and fruit are toxic when eaten by livestock (Kingsbury, 1964; Kates et al. 1974). Poisoning occurs usually when an animal ingests > 0.1% of its body weight in foliage or berries (Case, 1954; Case, 1955). Mature plants are covered in spines that can injure the mouths of livestock, thus potentially reducing weight gain (Ilnicki et al, 1962). Horsenettle thrives in well-drained, sandy or gravelly soil, but will grow in any soil that will maintain other plants (Banks and Santelmann, 1978; Bradbury and Aldrich, 1957; Ahrens, 1978).

Horsenettle grows as an erect branching plant 20 to 100 cm in height. The leaves are oblong to ovate, simple, alternate, unevenly lobed with deeply cut margins, and 5 to 13 cm in length. Horsenettle shoots measured in Mississippi produced an average canopy 51 cm tall and 64 cm wide (Carlisle et al. 1980).

The flower is star shaped, five lobed, varies in color from violet to white, and is approximately 2 cm in diameter. The plant flowers and produces berries by July and will continue until frost (Illnicki et al. 1962, Nichols et al. 1991). One study indicated that the annual flowering and fruiting cycle for horsenettle is not consistent between years (Nichols et al. 1991). The berry is orange to yellow and succulent at maturity. It is smooth and round with a tomato-like appearance, and is 1 to 2 cm in diameter (Ilnicki et al, 1962). The seeds are approximately 2mm wide and 5mm thick (Gunn and Gaffney, 1974). Horsenettle has an extensive root system (Bradbury and Aldrich, 1956; Gorrell et al. 1981). The main taproot can penetrate as deep as 3 m. Laterally branching roots can reach as far as 3 m from the taproot (Illnicki et al. 1962).

Horsenettle propagates by seed, creeping roots, and root fragments (Illnicki et al. 1962). A single plant may produce over 100 berries, each containing 40 to 170 seeds (Gorrell et al. 1981; Bradbury and Aldrich, 1956). One study found that root segments as small as 5 mm in length and 2 mm in diameter can produce new plants from as deep as 20 cm in the soil (Smith and Calvert, 1980). Another study recorded 63% regeneration from sections 10 mm in length, but no regeneration from 5 mm sections (Wehtje et al. 1987). Root

sections have shown little tolerance to freezing (Wehtje et al. 1987). Seedling plants may produce 31 times more root length than shoot growth (Illnicki et al. 1962). One study recorded a three-fold increase in total starch and non-structural carbohydrates in plants between June and September (Nichols et al. 1991). Though the shoot dies after frost, the plant produces new plants the following spring from both the taproot and the lateral roots.

HORSENETTLE CONTROL

The combination of multiple means of propagation and large deep-rooted tubers makes horsenettle a difficult weed to control. Its ability to produce new shoots from small root segments makes cultivation not only an ineffective control option, but actually detrimental by disseminating the plants through sectioning the roots and dragging the cuttings to other areas in the field (Bradbury and Aldrich, 1959; Neville, 1950; Illnicki et al. 1962). One study showed that mowing at a height of 7 cm on 5 to 8 day intervals reduced tuber starch levels initially. However, these plants eventually formed a rosette appearance that allowed them to survive mowing and accumulate sufficient starch to survive into the following year (Illnicki et al. 1962).

Another possible cultural control option for horsenettle is to use crop competition. Frank (1990) found that snapbeans (*Phaseolus vulgaris*) grown at 15 cm spacing reduced horsenettle shoot numbers by 16 and 45% more in the first and second years respectively than did snapbeans grown in 60 cm row spacing. A

review of the literature discovered no other research in the area of crop competition for controlling horsenettle.

CONTROL OF HORSENETTLE USING HERBICIDES

A number of studies have focused on horsenettle control with herbicides (Albert, 1960; Banks et al. 1977; Dale and Edwards, 1979; Gorrell et al. 1981; Palmer and Miears, 1975; Prostko et al. 1994; Whitwell et al. 1980; Smith and Calvert, 1980; Wehtje et al. 1987). Early research dealt mainly with the usefulness of the phenoxy and benzoic acid compounds (Bradbury and Aldrich, 1956; Smith and Calvert, 1980). Albert (1960) reported that 2,4-D [(2,4-Dichlorophenoxy)acetic acid] in three applications over a four-year period would reduce horsenettle, but not eradicate it. Dale and Edwards (1979) reported 62% and 72% control of horsenettle in bermudagrass pastures utilizing dicamba [3,6-dichloror-2-methoxybenzoic acid] at 0.56 and 1.12 kg / ha respectively. They were only able to achieve 25% control with dicamba plus 2,4-D at 0.28 and 0.84 kg / ha respectively. Pagano (1974) achieved 60% and 80% growth inhibition and fruit suppression utilizing 2,4-DB [4-(2,4-Dichlorophenoxy) butanoic acid] at 0.42 and 0.84 kg / ha respectively when applied during sprouting and pre-bloom stages of growth. Banks et al. (1977) reported that 2,4-DB applied alone or with linuron [3-(3,4-dichlororphenyl)-1-methoxy- 1-methylurea] to peanuts *(Arachis hypogaea)* at the cracking stage reduced the number of horsenettle plants that fruited. This study also found that dicamba at 3.3 and 6.7 kg / ha incorporated into the soil provided good horsenettle control. Gorrell (1981) found that dicamba

at 0.6 and 1.1 kg / ha reduced stem populations 74% and 82%, respectively, after 3 years of 2 annual foliar applications.

A number of herbicides other than the phenoxies and benzoic acids have also been evaluated for controlling horsenettle. Pagano (1974) demonstrated that terbacil [3-tert-butyl-5-chloro-6-methyluracil] applied at 2.2kg / ha provided horsenettle shoot control in both cultivated fields and orchards. Prostko et al. (1994) studied the efficacy of a number of the sulfonylurea herbicides for controlling horsenettle in field corn. They found neither nicosulfuron (2-[[[[4,6-dimethoxy-2-pyrimidinyl) amino]carbonyl]amino] sulfonyl]-N,N-dimethyl-3-pyridinecarboxamide) or primisulfuron (methyl2-[[[[[4,6-bis(difluoromethoxy)-2-pyrimidinyl]amino] carbonyl]amino]sulfonyl]benzoate) alone or in combination with dicamba to be more effective than dicamba alone. Gorrell et al. (1981) found that three annual applications of triclopyr [(3,5,6,-trichloro-2-pyridinyl)oxy-acetic acid] at 3.4 kg / ha reduced shoots 82% to 92%.

Glyphosate [N-(phosphonomethyl) glycine] has been studied for its use in controlling horsenettle with mixed results. Pagano (1974) reported that glyphosate applied pre-bloom to horsenettle at 4.5 kg / ha slightly reduced starch levels in root tubers, while applications at other times had no effect. Whitwell et al. (1980) reported that plants treated while blooming were more rapidly killed than those treated at the pre-bloom stage. Dale and Edward (1979) obtained 54% control of horsenettle with glyphosate applied at 1.12 kg / ha with a rope wick

while simultaneously injuring bermudagrass (*Cynodon dactylon*) 18%. Kirby and Santelmann (1974) demonstrated that glyphosate applied between 2.2 and 4.5 kg / ha resulted in 90 to 100% reduction of horsenettle, especially when applied at the pre-bloom stage. Glyphosate applied at 1.1, 2.2, and 3.4 kg / ha provided greater than 60% control the following spring if applied before leaf yellowing. Applications made after the beginning of plant senescense provided less control (Whaley and Vangessel, 2002 a; 2002 b). Kendig and Talbert (1986) found that hexazinone [3-cyclohexl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione] applied early at 1.1 and 2.2 kg / ha followed by two post emergent applications of glyphosate between 2.8 and 5.6 kg / ha provided between 79 and 95% control in one season in blueberries (*Vaccinium spp.*).

Picloram has provided excellent horsenettle control. Palmer and Miears (1975) achieved horsenettle control utilizing picloram at both the pre-bloom and early berry stage at rates of 0.28, 0 .56, and 0.84 kg / ha in bermudagrass pastures. This control lasted into the next spring. Gorrell et al (1981) applied picloram alone and in combination with 2,4-D in three Kentucky bluegrass (*Poa pretensis*) pastures over a three-year period in southwestern Virginia and reported that picloram at 0.6 and 1.1 kg / ha reduced horsenettle roots 1 year after the first annual applications. No shoots emerged within 18 months after three annual applications. There was no difference between picloram applied alone and in a mixture with 2,4-D at 1.1 kg / ha. Smith and Calvert (1980) found that picloram

pellets (2.4 and 3.6 kg / ha) to effectively control horsenettle. They also found that application of any chemical with liquid N as the diluent resulted in desiccation of the foliage and reduced translocation. Gorrell et al. (1988) achieved control of both the shoot and the roots of horsenettle plants treated with 1.12 kg / ha of picloram in a greenhouse study. A concern of using picloram is that it is highly phytotoxic to tobacco (*Nicotianna tobacum*), a crop frequently raised in close proximity to pasture fields in certain areas of the southern U.S. (Sheets and Harrell, 1986; Breeden and Rhodes, 2001).

PICLORAM

Picloram is in the picolinic acid chemical family. It has an auxin type mode of action (Chang and Foy, 1983). It was first discovered in 1960 and reported in 1963 (Ahrens, 1994). It is manufactured as an acid ($C_6H_3Cl_3N_2O_2$), isoctyl ester ($C_{14}H_{19}Cl_3N_2O_2$), potassium salt ($CH_2Cl_3KN_2O_2$), and triisopropanolamine salt ($C_{15}H_{24}Cl_3N_3O_5$) (Ahrens, 1994). Grazon P+D® is composed of the triisopropanolamine form of picloram (Dow AgroSciences, Grazon P+D® label). Typical symptoms of picloram injury include epinasty, swelling of the stem - particularly at the nodes, leaf cupping, and leaf curling. Susceptible plants usually die within 3 - 5 weeks (Ahrens, 1994).

Picloram is quickly incorporated into the roots and foliage of plants. Ninety-seven percent of foliar applied picloram was absorbed in sunflowers (*Helianthus annuus*) and rapeseed within 24h of application (Ahrens, 1994). It is then transported through the simplastic pathway to growth points where it

accumulates (Radosevich and Bayer, 1979). Picloram can also be translocated through the apoplastic system (O'Donovan and Vanden Born, 1981). With the ability to translocate through the xylem and little adsorption to soil organic matter or clay, picloram can be used effectively as a soil applied herbicide, though it is most frequently applied as a foliar herbicide. Picloram is very persistent in susceptible plants. Gorrell and others (1988) detected no picloram metabolites in horsenettle 16 d after treatment and very little biotransformation of the parent material. The picloram tended to accumulate in the roots of horsenettle. Picloram has a photolysis half-life in water of 2.6 d (Ahrens, 1994). It is degraded relatively slowly by soil microbes. It has an average field half-life of 90 d (Wauchope et al. 1992) though it may range from 20 to 300 d depending upon environmental conditions. Leaching is probable in some situations, especially in sandy soils which are low in organic matter.

2,4-D

2,4-D is in the phenoxyacetic acid chemical family. Its weed control qualities were first reported in 1943 (Ahrens, 1994). It has an auxin type mode of action. Typical symptoms of 2,4-D injury include epinasty, leaf cupping, and leaf curling. Chlorosis at the growing points follows and precedes death. Susceptible plants usually die within 3 - 5 weeks (Ahrens, 1994). 2,4-D is manufactured as an acid ($C_8H_6Cl_2O_3$), butoxyethyl ester ($C_{14}H_{18}Cl_2O_4$), dimethylamine salt ($C_{10}H_{13}Cl_2NO_3$), and isoctyl ester ($C_{16}H_{22}Cl_2O_3$) (Ahrens, 1994).

The ester forms of 2,4-D penetrate foliage more quickly than other forms. In general, 4 h without rainfall after application is needed for adequate absorption. 2,4-D is translocated throughout the plant primarily through the simplastic pathway and accumulates at growing points. 2,4-D generally tanslocates slower in grass species than in broadleaf species (Ahrens, 1994). Metabolism is fairly slow in most plants. At least 63% of 2,4-D was unmetabolized after 72 h in the leaves of bladder compion (*Silene vulgaris*) and lentils (*Lens culinaris*) (Wall and Morrison. 1991). Species susceptibility varies as does metabolism rates (Davis and Linscott, 1986).

The average field half-life of 2,4-D is 10 d (Wauchope et al. 1992). It does not readily photodegrade, but is degraded by soil microbes in warm, moist soils. 2,4-D is very volatile, although low salt formulations are available (Ahrens, 1994).

CHAPTER III

HORSENETTLE (*Solanum carolinense*) CONTROL IN TALL FESCUE PASTURES WITH A 2,4-D AMINE AND PICLORAM PACKAGE MIXTURE

INTRODUCTION

Farm industries associated with pastures and hay production play a significant role in Tennessee's Agriculture. According to the Tennessee Agricultural Statistics Service (2002), beef cattle production accounted for 19% of the state's total agricultural cash receipts in 2001, or 41 million dollars. This was nearly double that of the next closest industry. The dairy industry, which is dependent upon hay and pasture, accounted for 10% of the state's total agricultural cash receipts in 2001, or 22 million dollars. Hay production accounted for an additional 4 million dollars in 2001. As of 2001, over 2 million head of beef cattle and calves were being raised on 45,000 operations spread across Tennessee (Tennessee Agricultural Statistics Service, 2001). Over the last decade, the price paid for Tennessee beef cattle has not increased. The average price received by Tennessee farmers for all beef cattle was 65.0 cents per pound in 2001. This is basically unchanged from the 65.4 cents per pound received in 1991. Beef cattle prices fell to a low 40.7 cents per pound in 1996 (Tennessee Agricultural Statistics Service, 2001). The low profitability of the beef cattle market necessitates producers to minimize expenses in their operations.

Successful weed management is essential for producing quality livestock forage and hay (Rhodes and Breeden, 2000). Horsenettle has recently become a more prevalent problem weed in Tennessee pastures (Breeden and Rhodes, 2001). Its ability to reproduce from an extensive tuberous root system makes it nearly impossible to control by mowing, the most common weed control practice in pasture situations (Illnicki et al. 1962). In addition to crop competition, chemical control seems to hold the most promise for continual control of this perennial weed.

A package mixture of 0.06 kg / L picloram and 0.24 kg / L 2,4-D amine (Dow AgroScience, Grazon P+D® label) has shown particular promise for horsenettle control (Breeden and Rhodes, 2001). The current trade name for this product is Grazon P+D® .

MATERIALS AND METHODS

Two studies were conducted beginning in the summer of 2001 and lasting through the spring of 2002 at a pasture field site located in Hamilton County, TN. These studies were then repeated at a field site in Monroe County, TN beginning in the summer of 2002. These locations were chosen for their uniform, naturally-occurring, horsenettle infestations. The objectives of these studies were as follows:

1. To determine the efficacy of a 2,4-D amine and picloram package mixture as reflected by application dosage (2) and application timing (6) in the

control of horsenettle in the season of application and the following season.

2. To determine the effects of each of the application timing / rate combinations on the survival of red and ladino white clovers seeded the winter following applications.

A randomized complete block design with 4 replications was used with blocking based on field parameters. The field sites were divided into two studies in which the same research was conducted beginning at different times within the same year. The first study (early summer) at each location was mowed at a height of 8 cm in early June (after tall fescue seed head production) 1 week before the first treatments were applied. The early summer study at both locations was then fenced with electric ribbon to exclude cattle. The second study (late summer) at each location remained in normal grazing or mowing rotation until late July, at which time it was also mowed and fenced. This also took place one week prior to applying the first of the late summer treatments. The research protocol conducted at both the Hamilton and Monroe County locations was identical for both early and late summer studies. Early and late summer studies were conducted in order to correctly represent the two most common times of herbicide application in pasture production systems.

Although both 2,4-D and picloram alone have shown some success in controlling horsenettle (Albert, 1960; Dale and Edwards, 1979; Palmer and

Miears, 1979; Gorell et al. 1981), the combination of the two herbicides seems most promising (Palmer and Miears, 1975; Gorrell et al. 1981). This is due not only to efficacy of the combination, but also the reduced cost to producers. With these factors in mind only a 2,4-D and picloram package treatment was chosen for use in this research. The number of applications was also limited due to the limited stands of uniform horsenettle available for research. Treatment variables included the dosage of 2,4-D and picloram packaged mixture and the application timing. The packaged mix was applied at 0.7 kg AE / ha (0.14 kg AE picloram / ha and 0.56 kg AE 2,4-D ha) and at 1.4 kg AE / ha (0.28 kg AE picloram / ha and 1.1 kg AE 2,4-D / ha). Application timings in each study included an EPost (vegetation height of 13 - 15 cm), MPost (vegetation height of 15 - 25 cm or at early flowering), and LPost (at first fruit production). Two non-treated weedy check treatment plots were included. All treatments and the untreated controls were replicated 4 times for a total of 32 plots in each study. All herbicide applications were made using compressed CO_2 and a hand-held six nozzle boom equipped with 8001 flat fan nozzles at a rate of 94 L of spray solution per ha, a pressure of 280 kilopascals, and a speed of 4.8 km / hr. Plot size was 4.6 m x 9.2 m with a treated area of 3.5 m x 9.2 m so as to allow for untreated check strips on both sides of the treated area of each plot. This allowed for better assessments of the herbicide effects.

In the early summer study at Hamilton County in 2001, EPost treatments were made on 12 June. MPost treatments were made on 25 June, and LPost

treatments were made on 30 July. In the late summer study at Hamilton County, EPost treatments were made on 30 July. MPost treatments were made on 10 August, and LPost treatments were made on 7 September. In the early summer study at Monroe County, EPost treatments were made on 13 June. MPost treatments were made on 25 June, and LPost treatments were made on 1 August. In the late summer study at Monroe County, EPost treatments were made on 1 August. MPost treatments were made on 21 August, and LPost treatments were made on 11 September.

Data were collected multiple times from 14 to 90 d after application, depending on application timing. Data collected included the following:

1. Horsenettle control was visually assessed. This assessment was recorded as the percentage of total horsenettle control, with 0 = no control and 100 = complete control.
2. Horsenettle density was determined in both the early and late studies 3 to 4 weeks after the final late summer application and again the following spring. The number of horsenettle shoots within a 1.2 m x 4.6 m section within each plot was counted. The section to be counted consisted of the center 1.2 m of the plot's width and the first 4.6 m of its length.

Each study at both locations was mowed to a height of 10 cm and raked in February of the year following application in order to best represent typical grazing management of a pasture. Separate 3.5 m strips of red clover and ladino

white clover were then drilled across each plot with 3.5 m left as an untreated check. Ladino white clover (Will variety) was drilled at a rate of 6.7 kg / ha, and the red clover (Reddy variety) was drilled at a rate of 11.2 kg / ha. Clover was drilled on 22 February 2002 at Hamilton County and on 5 March 2003 at Monroe County. Fencing remained on all studies to protect germinating clover from cattle. Data were collected from both studies in the spring of 2002 (Hamilton Co.) or 2003 (Monroe Co.). Data collected included the following:

1. Survival of both red and ladino white clover drilled the previous winter was visually evaluated in each plot and then recorded from 0 to 100%. Clover survival was visually evaluated in both studies at Hamilton County on 20 May 2002 (the year following applications).
2. Horsenettle control: Evaluations of horsenettle control were conducted at Hamilton County on 20 May and 13 June 2002. Spring 2003 evaluations at the Monroe County site have not been conducted as of date.

After the final evaluation, the early and late studies were terminated. All data were analyzed utilizing analysis of variance and means were separated using Fisher's protected LSD at P=0.05 significance level (SAS, 1996). Data is presented by location.

RESULTS AND DISCUSSION

HORSENETTLE CONTROL

All herbicide treatments provided >75% horsenettle control at both locations regardless of application rate or timing (tables 3-1 to 3- 4). LPost applications applied in the late summer study provided less control than all other late summer treatments at season's end. However, the late season evaluations were taken two weeks after the late post applications. This did not allow the LPost applications enough time to manifest activity provided by earlier treatments. Residual horsenettle control was evaluated at the Hamilton county location in May and June of the year following application. In the May evaluation, all early summer treatments provided similar residual horsenettle control of > 75% (table 3-1). In the late summer applications evaluated the following May, the EPost treatments provided less control (< 60%) than did the MPost and LPost applications (> 80%) (table 3-2). The reduced control of these treatments in relation to all other late summer treatments could be due to extremely dry conditions at the time of application that may have increased herbicide volatilization and reduced the amount of herbicide absorbed by the plants. The plants had also been mowed 2 week prior to the Epost application leaving less foliage to intercept the herbicide. Horsenettle control decreased (< 70%) for all treatments in both studies when evaluated again in June (tables 3-1 & 3- 2). Again, EPost applications in the late summer study provided less control than did MPost and Lpost applications (< 45%) the year following application.

Table 3-1. Horsenettle control and stem density after 2,4-D + picloram early season treatments - 2001.[a]

Treatment Date	Rate	Horsenettle control			Horsenettle density	
		9/26/01	5/20/02	6/13/02	9/26/01	5/20/02
	Kg AE/ha	----------%----------			-----stems/ 10 m^2-----	
6/12/01	0.7	92b	83ab	57a	5b	4b
6/12/01	1.4	99a	92ab	63a	1b	1b
6/25/01	0.7	99a	78b	61a	0b	4b
6/25/01	1.4	99a	90ab	58a	0b	2b
7/30/01	0.7	98a	95a	67a	3b	2b
7/30/01	1.4	99a	83ab	57a	0b	9b
untreated		0c	0c	0c	71a	35a
LSD		5	14	24	26	20

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

Table 3-2. Horsenettle control and stem density after 2,4-D + picloram late season treatments - 2001.[a]

Treatment Date	Rate	Horsenettle control			Horsenettle density	
		9/26/01	5/20/02	6/13/02	9/26/01	5/20/02
	kg AE/ha	----------%----------			-----stems/ 10 m^2-----	
7/30/01	0.7	99a	56b	41b	0c	24b
7/30/01	1.4	99a	58b	36b	0c	16bc
8/10/01	0.7	99a	85a	55ab	0c	14bc
8/10/01	1.4	99a	86a	47ab	1c	11bc
9/7/01	0.7	87b	88a	65a	24abc	5c
9/7/01	1.4	82b	92a	63a	43ab	4c
untreated		0c	0c	0c	59a	73a
LSD		7	15	21	37	16

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

Table 3-3. Horsenettle control and stem density after 2,4-D + picloram early season treatments - 2002.[a]

		Horsenettle control	Horsenettle density
Treatment Date	Rate	10/2/02	10/2/02
		%	stems/ 10 m^2
6/13/02	0.7 kg AE / ha	99a	0b
6/13/02	1.4 kg AE / ha	98a	0b
6/25/02	0.7 kg AE / ha	98a	0b
6/25/02	1.4 kg AE / ha	99a	4b
8/1/02	0.7 kg AE / ha	99a	0b
8/1/02	1.4 kg AE / ha	99a	0b
untreated		0b	47a
LSD		2	24

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

Table 3-4. Horsenettle control and stem density after 2,4-D + picloram late season treatments - 2002.[a]

Treatment Date	Rate	Horsenettle control	Horsenettle density
		10/2/02	10/2/02
		%	stems/ 10 m^2
8/1/02	0.7 kg AE / ha	99a	0b
8/1/02	1.4 kg AE / ha	99a	0b
8/21/02	0.7 kg AE / ha	98a	1b
8/21/02	1.4 kg AE / ha	99a	0b
9/11/02	0.7 kg AE / ha	81b	14b
9/11/02	1.4 kg AE / ha	79b	3b
untreated		0c	69a
LSD		14	47

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

May evaluations were conducted before the majority of the horsenettle plants had emerged for the season. June evaluations were made after the majority of the plants had emerged and thus demonstrated less control.

HORSENETTLE STEM DENSITY

Horsenettle stem density was measured for all treatments at season's end at both research locations. All early summer treatments at both locations contained < 6 horsenettle plants / 10 m^2 while all untreated plots contained > 45 plants / 10 m^2 (tables 3-1 & 3-3). All EPost and MPost applications in the late summer study at both locations contained fewer horsenettle plants (< 1 plant / 10 m^2) than did the untreated plots (> 45 plants / 10 m^2)(tables 3-2 & 3-4). LPost

applications in the late summer study at Hamilton County contained > 20 plants / 10 m^2 (table 3-2). However, these plants were in the process of senescing. Once again, the lack of control at the time of measurement was due more to the short time interval between application and measurement than a lack of efficacy. LPost applications in late summer at Monroe County contained < 15 plants / 10 m^2, which was fewer than in the untreated plots (> 45 plants / 10 m^2) (table 3-4). Horsenettle density was measured at Hamilton County in May of the year following application. All early summer treatments contained fewer plants (< 10 plants / 10 m^2) than did the untreated plots (> 40 plants / 10 m^2)(table 3-1). All late summer treatments contained fewer plants (< 25 plants / 10 m^2) than did the untreated plots (> 70 plants / 10 m^2)(table 3-2). LPost applications in the late summer study were more efficacious than EPost applications at controlling horsenettle regrowth. No differences existed in control of regrowth between either MPost or LPost applications (Table 3-2).

CONTROL AND STEM DENSITY SUMMARY

This combination of herbicides provides excellent control in the season of application regardless of timing or rate. Control is reduced by the next summer, but still the number of plants is decreased when compared to areas left untreated. Horsenettle shoots were reduced significantly 1 year after application by all treatments. No treatment completely eradicated horsenettle 1 year after treatment.

These results are similar to those of Gorrell et al.(1981), who found that picloram at 0.6 kg AE / ha or 1.1 kg AE / ha in combination with 2,4-D at 1.1 kg

AE / ha reduced horsenettle shoots one year after application but did not completely control them. They did not find that the addition of 2,4-D improved efficacy over that of picloram alone. The rate of picloram used by Gorrell et al. however was twice that of the highest rates used in this research. The addition 2,4-D may be unimportant when using higher rates of picloram, but may increase overall efficacy when combined with lower rates of picloram such as those used in this research. The use of 2,4-D may also broaden the weed control spectrum of the application. Considering the possibility for soil leaching of picloram and its high phytotoxicity to many crops, the use of lower rates of picloram supplemented with 2,4-D is preferable to using a higher rate of picloram alone.

Palmer and Miears (1975) achieved horsenettle control one year after application utilizing picloram alone at 0.28 kg ai / ha, a rate equivalent to the highest rate applied in this research. Their research indicates that the addition of 2,4-D is not nessecary at this rate of picloram. However, neither the reported research nor that of Gorrell et al.(1981) was able to achieve complete control of horsenettle one year after application at this rate of picloram even with the addition of 2,4-D.

CLOVER SURVIVAL

Survival of drilled red and ladino white clover was visually evaluated at Hamilton County in May of 2002, the year following applications. Both species had < 50% survival in the treated plots of the early summer study as compared to > 75% survival in the untreated plots (table 3-5). In the late summer study, all

treated plots had < 50% survival of red clover as compared to 80% survival in the untreated plots (table 3-6). Ladino white clover survival was <50% in treated plots of the late summer study. Untreated plots exhibited greater than 60% Ladino white clover survival (table3-6). EPost and MPost applications of 0.7 kg AE / ha had a similar effect on the survival of drilled Ladino white clover as did the untreated plots in the late summer study, as did Epost applications of 1.4 kg AE / ha (< 55 %) (table3-6). Clover drilled the winter following application of this herbicide mixture will exhibit reduced survival. Reductions of 50% or more can be expected.

Table 3-5. Clover survival in 2002 after 2,4-D + picloram early season treatments in 2001.[a]

		Clover survival	
		Red	Ladino White
Treatment Date	Rate	5/20/02	5/20/02
		----------%----------	
6/12/01	0.7 kg AE / ha	32b	36bc
6/12/01	1.4 kg AE / ha	37b	37bc
5/25/01	0.7 kg AE / ha	40b	46b
6/25/01	1.4 kg AE / ha	30b	28bc
7/30/01	0.7 kg AE / ha	23b	33bc
7/30/01	1.4 kg AE / ha	28b	22c
untreated		79a	78a
LSD		23	22

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

Table 3-6. Clover survival in 2002 after 2,4-D + picloram late season treatments in 2001.[a]

		Clover survival	
		Red	Ladino White
Treatment Date	Rate	5/20/02	5/20/02
		----------%----------	
7/30/01	0.7 kg AE / ha	46b	50ab
7/30/01	1.4 kg AE / ha	32b	38abc
8/10/01	0.7 kg AE / ha	50ab	41abc
8/10/01	1.4 kg AE / ha	22b	21c
9/7/01	0.7 kg AE / ha	37b	23bc
9/7/01	1.4 kg AE / ha	31b	21c
untreated		80a	63a
LSD		31	26

[a] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at P=0.05.

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