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Residual Effect of Herbicides Used in Pastures on Clover Establishment and Productivity

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RESIDUAL EFFECT OF HERBICIDES USED IN PASTURES ON CLOVER ESTABLISHMENT AND PRODUCTIVITY

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS ………………………………………………………….…………….ii

ABSTRACT ………………………………………………………………………..…………...iv

CHAPTER

1 INTRODUCTION ………………………………………………………………..….1
Literature Cited ..……………………………………………………………...……10

2 RESIDUAL EFFECT OF HERBICIDES (PHENOXY, PYRIDINECARBOXYLIC, BENZOIC ACID, AND SULFONYLUREA HERBICIDES) APPLIED FOR SUMMER WEED CONTROL ON ESTABLISHMENT AND GROWTH OF CLOVER ………………………..…………….……………………………………...15
Introduction …………………………………….………………………..………15
Materials and Methods ………………………….…………………………..…19
Results and Discussion …………………………………………….....………21
Literature Cited …………………………………………………………...………….29

3 BALL (TRIFOLIUM NIGRESCENS VIV.), WHITE (TRIFOLIUM REPENS L.), CRIMSON (TRIFOLIUM INCARNATUM L.), AND RED (TRIFOLIUM PRETENSE L.) CLOVER ESTABLISHMENT AND YIELD AS INFLUENCED BY RESIDUAL EFFECT OF FLUROXYPYR PLUS TRICLOPYR AND 2,4-D PLUS PICLORAM ..……………………..………………..……...…...….…......…31
Introduction ……………………………….……………………….…………31
Materials and Methods ………………………..…………………………..…34
Results and Discussion ……………………………………………..…...……36
Literature Cited ……………………….………………………………....………46

4 SUMMARY ………..…………………………………………………………...49

VITA ……………………………………..……………………………………….……..….53

ABSTRACT

Field experiments in 2013 evaluated residual herbicide effects on ball (*Trifolium nigrescens* viv.) and white (*Trifolium repens* L.) clover. For the October planting, averaged across clovers, ground cover for 2,4-D plus aminopyralid and 2,4-D plus picloram averaged 4.4 and was less than for the nontreated (7.0). For the November and March plantings, ground cover for all herbicides was equivalent to the nontreated. Averaged across clover species and planting date, herbicide treatments except 2,4-D plus aminopyralid (4) resulted in ground cover 49/112 days after planting (DAP) equal to the non-treated (5.7). Lowest plant population 4 to 6 wk after Oct/Nov planting was observed for 2,4-D plus aminopyralid (6.3) and 2,4-D plus picloram (7.3). Only 2,4-D plus aminopyralid resulted in yield reduction from the nontreated (29.8%).

Field experiments also evaluated simulated residual effects of fluroxypyr plus triclopyr and 2, 4-D plus picloram on ball (*Trifolium nigrescens* viv.), white (*Trifolium repens* L.), crimson (*Trifolium incarnatum* L.) and red (*Trifolium pretense* L.) clover. For all clovers, when averaged across herbicide rates, plant population 214/217 and ground cover 86/87 DAP was equivalent for fluroxypyr plus triclopyr and the non-treated and greater than 2,4-D plus picloram. Averaged across herbicide rates, clover height was equivalent for fluroxypyr plus triclopyr and the non-treated. 2,4-D plus picloram reduced clover height 67 to 88% from the non-treated. Ground cover 161/196 DAP, when averaged across clovers, for all rates of fluroxypyr plus triclopyr was equivalent to the non-treated. All rates of 2,4-D plus picloram were reduced compared to the non-treated (1.4 to 4.0 vs 7.9). Averaged across clovers, plant height following all rates of fluroxypyr plus triclopyr was equivalent to the non-treated (14.2 to 14.3 vs 15.3 cm) and greater than 2,4-D plus picloram. Compared with the non-treated, 2,4-D plus picloram at 25, 38, and 50% x rates reduced height 58, 76, and 85% respectively. Averaged across clover

species, yield for fluroxypyr plus triclopyr at all rates was equivalent to the non-treated (2624.0 to 2839.7 vs 2811.9 kg/ha). Compared with the non-treated, 2,4-D plus picloram at 25, 38, and 50% x rate reduced yield 65,89, and 99%, respectively.

CHAPTER 1
INTRODUCTION

"Grazing land" is a term used by USDA-Natural Resources Conservation Service (Anonymous 2003) to describe rangeland, pastureland, grazed forestland, native and naturalized pasture, hayland, and grazed cropland. Grazing is the predominant use for grazing lands but they are also used for production of forage plants maintained or manipulated primarily through grazing management. Forage is defined as "edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding" (Allen et al. 2011). Pastureland, often called improved pasture, or tame pasture, is defined as grazing land permanently producing introduced or domesticated native forage species receiving varying degrees of periodic cultural treatment to enhance forage quality and yield (Anonymous 2003). Rangeland encompasses the historic climax vegetation predominantly grasses, grass-like plants, forbs, or shrubs, which includes land re-vegetated naturally or artificially to provide a plant cover that is managed like native vegetation. Range and pasture lands are present in all 50 states of the U.S. Privately owned range and pasture lands comprise over 27% (214 million hectares) of the total acreage of the contiguous 48 states and these lands constitute the largest private land use category, exceeding both forest land (21%) and crop land (18%) (Anonymous 2003).

Ruminant livestock production is a major segment of U.S. agriculture (Rayburn and Washburn 2011). Income from beef cattle and calves, milk products, sheep, and goats totaled about $93,700 million in 2007, compared to $77,200 million from grain crops and $50,300 million from horticultural crops. Beef (*Bos taurus*) production is the major ruminant livestock enterprise on pasturelands in the U.S. Beef cattle production, especially cow/calf and stocker cattle production, leads the livestock industry in Louisiana. Cow/calf production, being the most prevalent production system in Louisiana, is the practice of maintaining and breeding a herd of brood cows and selling their calves as weanlings (Anonymous 2013). This segment of the beef cattle industry requires the greatest use of land. Stocker cattle production, another popular system of beef production in Louisiana, involves grazing weanling or yearling cattle to heavier weights on pastures consisting of nutrient-dense forages. This system is generally implemented during the winter growing season (November to May) when cooler temperatures provide favorable growing conditions for winter forages such as ryegrass, oats and wheat. Gross farm income from beef cattle in Louisiana was $589.6 million in 2013. With value added of $73.7 million, the total value of beef cattle production in Louisiana was $663.3 million in 2013.

Warm season grasses such as bermudagrass (*Cynodan dactylon* L.) and bahiagrass (*Paspalum notatum* Flugge) are the most utilized forage resources in Louisiana and throughout most of the Southeastern U.S. (Han et al. 2012). These warm season grasses are only seasonally productive in the Southern U.S. and forage production is limited within the growing season by low soil nitrogen. Cool-season legumes, particularly clovers, have potential to partially overcome the limitations of warm-season grasses. Complementary forage systems based on warm-season perennial grasses and cool-season annual grasses have proven successful in cattle production in providing supplemental nutrients and decreasing hay requirements during the winter (Gunter et al. 2012). Inter-seeding cool-season legumes into warm-season grass dominant pastures enhances soil nitrogen utilization. Nitrogen fertilizer inputs which represent a large part of the total feed cost in forage-based livestock systems, are a major source of nitrous oxide emissions in the feed production for herbivores and more efficient use of fertilizers is an important tool to mitigate nitrous oxide losses. As the costs of fuel and fertilizer increase, many producers are adapting to the utilization of pasture legumes to decrease nitrogen cost (Han et al. 2012).

Gunter et al. (2012) reported that cattle in a cow/calf operation grazing pastures with clovers produced 4.8 kg of calf body weight per kg of fertilizer nitrogen applied to the pasture compared to 1.0 kg for only grass. Over-seeding with clovers without nitrogen fertilizer resulted in calf body weight gains equal to those for annual ryegrass over-seeded into bermudagrass and annually fertilized with 168 kg/ha N (Gunter et al. 2012). Legumes have the unique ability to obtain aerial nitrogen gas and convert it into organic nitrogen compounds available for use by plants (Han et al. 2010). *Rhizobium* bacteria in nodules along the taproot of legume plant roots fix nitrogen from the environment and release it into the soil upon decomposition (Ball et al. 2002). The recommended *Rhizobia* for ball (*Trifolium nigrescens* viv.), white (*Trifolium repens* L.), crimson (*Trifolium incarnatum* L.) and red (*Trifolium pretense* L.) clover is *R. leguminosarum bv trifolii* (Butler et al. 2010). Legumes can provide 15 to 18 kg N/ha to grasses in a pasture (Cuomo 2000). The nitrogen they produce can be used for their own growth, by associated grasses, or by other plants grown in rotation (Holmes 2010). Over 80% of the N produced by legumes will be returned to pasture through manure and urine (Cuomo 2000).

Several clover species have been proven to be valuable legumes in Louisiana pastures and both annual and perennial clovers are adapted to Louisiana soils (Han et al. 2012). The amount of nitrogen supplied from clover can vary depending on species and evaluations of individual clover species have identified specific characteristics contributing to their success or limitations under various growth conditions. Clovers also contribute differently to total pasture yield throughout the growing season (Han et al. 2010).

White clover, a highly palatable, nutritious forage for all classes of livestock, is native to Europe, and is one of the most widely distributed legumes in the world and is the most important pasture legume in the U.S. (Anonymous 2006). It is a low-growing, perennial clover with prostrate stems and erect leaves that produces most of its growth in the spring through late fall (Twidwell et al. 2013). White clover is best adapted to clay and silt loam soils in cool, moist climates (Anonymous 2006). It can tolerate close grazing and prefers a soil pH of around 6 (Ball et al. 2002). There are two types of white clover grown commercially for agriculture, intermediate types called Dutch white clover and large types called Ladino white clover (Quesenberry 2002). 'Durana' white clover, an intermediate type, is a low-growing, densely spreading, profuse-flowering cultivar that was developed by the University of Georgia for use as a renovation legume for grass pastures in the southeastern U.S. (Bouton et al. 2005). Its persistence and ability to enhance animal gains without the need for nitrogen fertilizer was found to be economically important (Bouton et al. 2005). In contrast to the early-growing clovers such as crimson clover, white clover grows much slower in the spring but increases its yield contribution through the growing season and into August in some situations (Han et al. 2010)

Ball clover is an annual clover that was introduced into the United States from Turkey (Hoveland 1960). It is visually similar to white clover but has long, succulent branching stems growing prostrate to partially upright and the stems may reach 30 inches or more in length in ideal growing conditions. Another key identification feature of ball clover is its hollow stems (Barnes et al. 2007). Ball clover is grown as a winter annual in Texas, Arkansas, Louisiana, Mississppi and Alabama. The seeds of ball clover are very small with more than 60% being hard, which makes it an excellent re-seeder. It produces most of its growth later in the spring compared to other clovers and is a prolific re-seeder even under close grazing (Ball et al. 2002). Ball clover can tolerate loam or clay soils that are wet in the winter but are droughty in the summer and prefers a soil pH of 6.5-8.5 (Barnes et al. 2007). 'AU Don' ball clover, which was developed by Auburn University, has recently been released and will provide higher yields, more uniform growth distributions and more hardiness in comparison to “common” ball clover (Anonymous 2014).

Red clover is an erect-growing bunch-type annual plant, having numerous leafy stems arising from a thick crown and a taproot system with many secondary branches (Quesenberry and Blount 2006). Red clover grows best on medium to well-drained soils with a pH range of 6.1 to 6.7 (Taylor et al. 1997). It is a short-lived perennial that is managed as an annual or biennial in Louisiana (Twidwell et al. 2013). Red clover is a high-quality forage legume that can be grazed in late winter and early spring and ‘Southern Belle’, which was bred and developed in north-central Florida, was specifically selected for earlier spring production (Quesenberry and Blount 2006). Southern Belle was released in 2004 and it is one of the only semi-nondormant red clovers currently available to producers in the southeastern U.S. It is also one of the only red clovers known for its reseeding abilities.

Crimson clover was introduced from Europe and is the most important annual clover to U.S. agriculture (Smith 2010). It is grown from as far north as Maine but is primarily grown in the Southeast (Anonymous 2009a). Crimson clover is predominantly used as a winter annual forage legume over-seeded on warm-season perennial grass pastures in the Southeast (Smith 2010). It emerges and grows rapidly in early spring (Han et al. 2010). When evaluated in a bermudagrass pasture, crimson clover yielded 92 kg more dry forage per ha than other, slower-starting clovers between mid-March and late April. While it is not typically a re-seeder in pasture situations, it often grows more vigorously than many other clovers (Anonymous 2009a). Seedlings grow rapidly from the crown forming a rosette. Crimson clover will grow on soils of poorer quality than most other clovers, thriving on both well-drained sandy and clay soils with a preferable pH range of 6.0 to 7.0 (Anonymous 2009a). ‘Dixie’ crimson clover was developed in

Georgia in the early 1950's in response to the need for a cultivar with improved reseeding traits that could also be produced as certified seed (Smith 2010). Historically, common crimson clover produced less than 5% hard seed but 'Dixie' crimson clover has been shown to produce up to 60 to 80% hard seed (Smith 2010).

Any plant can be considered a weed if it has negative effects on people, agriculture, or other societal interests, alters the structure of natural communities, or interferes with the function of ecosystems (Bryson and DeFelice 2009). Weed competition reduces clover stands, seedling growth, and nodulation which hinders early forage production and nitrogen fixation (Grichar et al. 1996). Reduced or complete establishment failures are very costly because they result in lost production, the lack of return on labor and inputs, and the need to invest in replacement forage crops or feed (Butler et al. 2010). Weed management strategies that prevent stand, yield, and quality losses are integral to successful establishment of forage legumes. Specimen labels for pasture herbicides should be read carefully and plant back restrictions should be considered (Butler et al. 2010). Weeds easily become established in the absence of desired, forage species or in areas where the forages are uncompetitive due to poor growth, inadequate plant populations, and overgrazing (Pinkerton and Murdock 1992). Many factors can play a role in weed infestations in a pasture system including: pH, fertilization, poor grazing management, extremes in weather conditions, etc. Addressing these factors in addition to herbicide use can be used to assist in suppression of weeds in pastures. Competition of invasive weeds can quickly decrease the quality and quantity of forage systems by reducing the amount of usable forages and some can also be toxic to animals (Seefeldt et al. 2005). Use of herbicide can be an effective method of weed control but herbicide activity can vary depending on weed species and timing of application (DiTomaso 2000). Warm-season weeds in pasture are most easily controlled with spring or early summer herbicide applications when weeds are actively growing and perennials have not entered the flowering stage (Bradley and Kendig 2004; Green and Martin 1998).

Clovers can be susceptible to herbicides applied in pastures to control broadleaf weeds and there are currently no pasture herbicides available where clover would not be susceptible (Anonymous 2014d). For many producers, the biggest dilemma with chemical control of broadleaf weeds is how and when to apply herbicides without adversely affecting pasture legumes (Johnston 2012). Growth regulating herbicides such as 2,4-D, dicamba, picloram, aminopyralid, fluroxypyr and triclopyr mimic natural plant auxins and are translocated within the xylem and phloem (Cudney 1996). These herbicides disrupt normal plant growth causing twisting of stems and malformed leaves. Auxinic herbicides (growth regulators) such as phenoxy or benzoic acid herbicides are not tolerated by legumes in pastures or rangelands (Sellers and Ferrell 2010).

Other herbicides used for pasture weed control inhibit amino acid synthesis (Cudney 1996). Metsulfuron-methyl, a sulfonylurea herbicide, inhibits the production of essential amino acids blocking protein production and resulting in growth termination and plant death.

Aminopyralid and 2,4-D are active ingredients contained in GrazonNext® (Anonymous 2012), a Dow AgroSciences herbicide labeled for pasture and rangeland use. Aminopyralid is a pyridine carboxylic acid herbicide that is efficacious on a wide spectrum of broadleaf weeds in the Asteraceae, Fabaceae and Solanaceae families through foliar and soil applications (Bukun et al. 2010). Aminopyralid is systemic and is absorbed through the leaves and roots where it is transported to other parts of the plant (Anonymous 2014a). It is a growth regulating herbicide that mimics the action of auxin (indole-3-acetic acid) and binds to auxin receptor proteins that trigger growth responses and development of plant cells. Sensitive plants are unable to regulate the concentration of the growth regulator herbicide and therefore physiological processes are disrupted which leads to plant death (Hartzler 2006). The half-life of aminopyralid in soils ranges from 32 to 533 days with a typical time of 103 days (Anonymous 2014a). It has been shown to reside in soils for at least 215 days after treatment (Ferrell et al. 2006). Forage legumes should not be planted until a soil bioassay has been conducted to determine if aminopyralid residues remaining in the soil will adversely affect the legume establishment (Anonymous 2009b).

Picloram, along with 2,4-D, is an active ingredient in Grazon +D® (Anonymous 2009b) which is a pasture herbicide introduced by Dow Agro Science and has a recommended application rate of 0.38 L/ha formulated product (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha) (Anonymous 2014d). Picloram is another auxin-type, pyridine carboxylic acid herbicide that was introduced in 1963 for the control of broadleaf weeds, including several deep-rooted perennial herbaceous species and woody brush species (Gantz and Laning 1963; Hamaker et al. 1963). The average field half-life of picloram is 90 days, with a range of 20-300 days and dissipation is more rapid under warm, humid conditions (Anonymous 2002). Grazon P+D® may injure or kill legume plants but legumes may be less sensitive to the herbicide after the seed has set and plant growth is mature however seeding of legumes may not be successful if made within one year of application (Anonymous 2009b).

Cimarron Max® (Anonymous 2011) is a Dupont chemical that is labeled for use in pastures to control most broadleaf weeds and bahiagrass (Anonymous 2014d). The active ingredients in Cimarron Max are metsulfuron methyl, dicamba and 2,4-D and the recommended application rate is metsulfuron methyl @ 3.79 g/ha formulated product (Co-pack Part A @ 393 g/ha) plus dicamba plus 2,4-D @ 0.29 L/ha formulate product (Co-pack Part B dicamba @ 210 g/ha plus 2,4-D @ 603 g/ha) (Anonymous 2011). Cimarron Max® should not be applied to broadleaf pasture species such as alfalfa and clover due to their high sensitivity to the herbicide (Anonymous 2011). Metsulfuron has been shown to have soil activity on broadleaf weeds the growing season prior to establishing legumes (Butler et al. 2010).

PastureGard® (Anonymous 2008) is a Dow AgroSciences chemical that controls broadleaf herbaceous and woody plants in pastures. The active ingredients are triclopyr and fluroxypyr and the recommended application rate is 0.38 L/ha formulated product (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha) (Anonymous 2008). PastureGard® should not be used on alfalfa or other desirable forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated but legumes may be replanted 1 month or more after PastureGard® application. The half-life of total fluroxypyr in soils is 1-4 weeks based on lab studies and in field dissipation studies, half-life ranged from 11-38 days (Anonymous 2002). Triclopyr is moderately persistant with an average half-life of 30 days, ranging from 10-46 days depending on soil type, moisture and temperature (Anonymous 2002).

2, 4-D is the most commonly used herbicide for rangeland weed control in the United States (Rice and Stritzke 1989) and is a popular choice because it controls many broadleaf weeds with the lowest chemical cost (Locke 2014). The recommended application rate of 2, 4-D LV4® is 1120 g/ha but it should not be applied to any susceptible broadleaf crop including forage legumes (Anonymous 2014b). White clover has shown some tolerance to 2, 4-D (Payne et al. 2010). The average persistence is generally 1-4 weeks in warm, moist soil and the average half-life is 10 days (Anonymous 2002). 2, 4-D is very effective on many broadleaf weeds but it may also damage non-target species through drift. Because of this issue, non-2,4-D-containing herbicides have become popular options in pastures (Twidwell and Strahan 2009).

Given the benefits of inclusion of clover species and optimum growing conditions in Louisiana, the opportunity exists for their incorporation into pasture programs for cow/calf operations. The success of this endeavor is dependent on the ability of the clover species to tolerate residual herbicide from applications made in summer pasture for weed control. Research was conducted to evaluate the effect of auxinic and sulfonylurea herbicides and for pasture weed control on subsequent establishment and growth of ball, white, crimson, and red clover. This research will address these potential impacts.

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CHAPTER 2
RESIDUAL EFFECT OF HERBICIDES (PHENOXY, PYRIDINECARBOXYLIC, BENZOIC ACID, AND SULFONYLUREA HERBICIDES) APPLIED FOR SUMMER WEED CONTROL ON ESTABLISHMENT AND GROWTH OF CLOVER

Introduction

Warm-season perennial grasses and cool-season annual grasses grown in complementary forage systems have proven successful in cattle production in providing supplemental nutrients and decreasing hay requirements during the winter (Gunter et al. 2012). Inter-seeding cool-season legumes into warm-season grass dominant pastures enhances soil nitrogen utilization. Nitrogen fertilizer inputs which represent a large part of the total feed cost in forage-based livestock systems, are a major source of nitrous oxide emissions in the feed production for herbivores and more efficient use of fertilizers is an important tool to mitigate nitrous oxide losses (Gunter et al. 2012). As the costs of fuel and fertilizer increase, many producers are adapting to the utilization of pasture legumes to increase nitrogen levels (Han et al. 2012).

Gunter in 2012 reported that cattle in a cow/calf operation grazing pastures with clovers produced 4.8 kg of calf body weight per kg of fertilizer nitrogen applied to the pasture compared to 1.0 kg for only grass. Over-seeding with clovers without nitrogen fertilizer resulted in calf body weight gains equal to those for annual ryegrass over-seeded into bermudagrass and annually fertilized with 168 kg/ha N.

White clover (*Trifolium repens* L.), is a highly palatable, nutritious forage for all classes of livestock, is a native species of Europe, is one of the most widely distributed legumes in the world and is the most important pasture legume in the U.S. (Anonymous 2006). It is a low-growing, perennial clover with prostrate stems and erect leaves that produces most of its growth in the spring through late fall (Twidwell et al. 2013).White clover is best adapted to clay and silt soils in cool, moist climates (Anonymous 2006). It can tolerate close grazing and prefers a soil pH of around 6 (Ball et al. 2002). Its persistence and ability to enhance animal gains without the need for nitrogen fertilizer was found to be economically important (Bouton et al. 2005). In contrast to the early-growing clovers, white clover grows much slower in the spring but increases its yield contribution through the growing season and into August in some situations (Han et al. 2010).

Ball clover (*Trifolium nigrescens* viv.) is an annual clover that was introduced into the United States from Turkey. It is visually similar to white clover but it has long, succulent branching stems growing prostrate to partially upright and the stems may reach 30 inches or more in length in ideal growing conditions (Hoveland 1960). Ball clover is grown as a winter annual in Texas, Arkansas, Louisiana, Mississppi and Alabama. It produces most of its growth later in the spring compared to other clovers and is a prolific re-seeder even under close grazing (Ball et al 2002). Ball can tolerate loam or clay soils that are wet in the winter but are droughty in the summer and prefers a soil pH of 6.5-8.5 (Barnes et al. 2007).

For many producers, the biggest dilemma with chemical control of broadleaf weeds is how and when to apply herbicides without adverse effects on pasture legumes (Johnston 2012). Growth regulating herbicides such as 2,4-D, dicamba, picloram, aminopyralid, fluroxypyr and triclopyr, which are effective in controlling pasture weeds, mimic natural plant auxins and translocate throughout plants via the xylem and phloem causing abnormal growth and disruption of the conductive tissues of plants which produces physical symptoms such as twisting and malformed leaves and stems (Cudney 1996). Auxinic herbicides (growth regulators) such as phenoxy or benzoic acid herbicides are not tolerated by legumes in pastures or rangelands (Sellers and Ferrell 2010). Unfortunately, clovers are highly susceptible to herbicide injury from any chemical labeled for use on broadleaf weeds, therefore there are currently no pasture herbicides available that are recommended for use in temporary broadleaf pastures including clovers (Anonymous 2014c).

Aminopyralid, one of the active ingredients of GrazonNext® (Anonymous 2014c) along with 2,4-D, is a Dow AgroSciences chemical which is labeled for pasture and rangeland with a recommended application rate of 0.38 L/ha formulated product (aminopyralid @ 93 g ae/ha + 2,4-D @ 748 g ae/ha). The half-life of aminopyralid in soils ranges from 32 to 533 days with a typical time of 103 days (Anonymous 2014a). It has been shown to reside in soils for at least 215 days after treatment (Ferrell et al. 2006). Forage legumes should not be planted until a soil bioassay has been conducted to determine if aminopyralid residues remaining in the soil will adversely affect the legume establishment (Anonymous 2012).

Picloram, along with 2,4-D, is an active ingredient in Grazon P+D® (Anonymous 2014c) which is a pasture herbicide introduced by Dow AgroSciences and has a recommended application rate of 0.38 L/ha formulated product (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha). The average field half-life of Picloram is 90 days, with a range of 20-300 days and dissipation is more rapid under warm, humid conditions (Anonymous 2002). Grazon +D® may injure or kill legume plants but legumes may be less sensitive to the herbicide after the seed has set and plant growth is mature however seeding of legumes may not be successful if made within one year of application (Anonymous 2009).

Cimarron Max® (Anonymous 2014c) is a Dupont chemical that is labeled for use in pastures to control most broadleaf weeds and bahiagrass. The active chemicals in Cimarron Max are metsulfuron methyl, dicamba and 2,4-D and the recommended application rate is metsulfuron methyl @ 3.79 g/ha formulated product (Co-pack Part A @ 393 g/ha) plus dicamba plus 2,4-D @ 0.29 L/ha formulated product (Co-pack Part B dicamba @ 210 g/ha plus 2,4-D @ 603 g/ha)

(Anonymous 2011). Metsulfuron has been shown to have soil activity on broadleaf weeds the growing season prior to establishing legumes (Butler et al. 2010).

PastureGard® (Anonymous 2008) is a Dow AgroSciences chemical that controls broadleaf herbaceous and woody plants in pastures. The active ingredients are triclopyr and fluroxypyr and the recommended application rate is 0.38 L/ha formulated product (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha). PastureGard® should not be used on alfalfa or other desirable forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated but legumes may be replanted 1 month or more after PastureGard® application (Anonymous 2008). In lab studies of the aerobic soil metabolism of fluroxypyr, the half-life of total fluroxypyr in soils is 1-4 weeks and in field dissipation studies the half-lives for North American sites range from 11-38 days for total fluroxypyr (Anonymous 2002). Triclopyr is moderately persistant with an average half-life of 30 days, ranging from 10-46 days depending on soil type, moisture and temperature.

The recommended application rate of 2, 4-D is 1120 g/ha but it should not be applied to any susceptible broadleaf crop including forage legumes (Anonymous 2014b). White clover has shown some tolerance to 2, 4-D (Payne et al. 2010). The average persistence of phytotoxicity is generally 1-4 weeks in warm, moist soil and the average half-life is 10 days.

Limited information is available on the impact of residual amounts of these commonly used pasture herbicides on the growth and establishment of both ball and white clover in Louisiana. The objective of this research is aimed at documenting potential negative effects following use of these herbicides for summer pasture weed control.

Materials and Methods

Field experiments were initiated in 2013 at the Northeast Research Station near St. Joseph, LA and the Macon Ridge Research Station near Winnsboro, LA to evaluate residual pasture herbicide effects on establishment and growth of ball (*Trifolium nigrescens* viv.) and white (*Trifolium repens* L.) clover. Soils were a Gigger silt loam (fine-silty, mixed, active thermic Typic Fragiudalfs) with a pH of 4.9 at Winnsboro and a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with a pH of 7 at St. Joseph. Sites were tilled by disking and generally weed-free prior to herbicide application. To simulate pasture weed control practices, GrazonNext® (aminopyralid @ 93 g ae/ha plus 2,4-D @ 748 g ae/ha), Grazon P+D® (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha), Pasturegard® (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha), Cimarron Max® (metsulfuron methyl @ 393 g/ha plus dicamba @ 210 g/ha plus 2,4-D @ 603 g/ha) and 2,4-DLV4® (2,4-D @ 1120 g/ha) were applied at full recommended rates on July 2, 2013 at Winnsboro and July 1, 2013 at St. Joseph. A non-treated control was included for comparison. Applications were made with a tractor mounted compressed air spraying at 140 L/ha at 193 kPa. Sites were maintained weed free at both locations with glyphosate @ 1120 g/ha and glufosinate @ 593 g/ha as needed until time of planting to measure residual effects of herbicides. ‘AU Don’ ball clover and ‘Durana’ white clover were planted on October 14, 2013, November 20, 2013 and March 5, 2014 at Winnsboro and October 15, 2013, November 21, 2013 and March 7, 2014 at St. Joseph. The experimental design utilized was a randomized complete block with a factorial arrangement of herbicide treatments (4), clover species (2), and planting dates (3) replicated four times. Planted plot area was 1.5 m wide by 4.6 m long. October and November plantings were accomplished using a small-plot drill, cone-type planter with a drill spacing of 7 rows approximately 20 cm apart. Planting depth was targeted at 1 to 1.5 cm. The March planting was accomplished with a one row manual, push-planter due to excess moisture hindering tractor use. Plant counts were recorded at St. Joseph on November 11, 2013 (30 DAP in October) and December 19, 2013 (30 DAP in November) and on November 5, 2013 (30 DAP in October) and December 20, 2013 (30 DAP in November) at Winnsboro. Plant counts were accomplished by counting all clover plants within 91 cm of row within each plot. Plots were treated with sethoxydim @ 315 g/ha on November 5, 2013 and clethodim @ 175 g/ha on January 24, 2014 at Winnsboro and St. Joseph, respectively, to control grasses. In addition, plots at Winnsboro were treated with 2, 4-DB at 245 g/ha on January 30, 2014 to control broadleaf weeds. Visual ratings of percent clover present within each plot were made at Winnsboro on November 18, 2013 (35 DAP in October), December 17, 2013 (65 DAP in October), January 9, 2014 (50 DAP in November), February 19, 2014 (92 DAP in November), May 2, 2014 (68 DAP in March) and June 24, 2014 (112 DAP in March) and at St. Joseph on November 21, 2013 (37 DAP in October), December 12, 2013 (59 DAP in October), January 10, 2014 (50 DAP in November), January 30, 2014 (71 DAP in November), May 20, 2014 (74 DAP in March) and June 9, 2014 (95 DAP in March). Ratings were based on a scale of 0 = no clover present and 10 = complete coverage of clover throughout the plot. A m^2 quadrant was used to calculate a percentage of plants present within each of twenty 41 cm^2 squares inside the quadrant as quantitative emergence data for the March planting date at Winnsboro on May 20 (75 DAP) and June 24, 2014 (109 DAP) and at St. Joseph on May 20 (73 DAP) and June 9, 2014 (94 DAP). Harvest of October and November plantings was accomplished at Winnsboro on May 6, 2014 (175-215 DAP) from an area 46 cm wide and 2 m long using a push mower with a bag attachment and St. Joseph on May 19^{th} 2014 (180-210 DAP). A harvest of March planted clovers at Winnsboro was accomplished on June 24, 2014

(114 DAP) and on June 9, 2014 (95 DAP) at St. Joseph by cutting 61 cm of row with hand clippers. A whole plot weight was recorded for each sample collected followed by collection of a sub-sample for percent moisture and dry weight determination. The sub-sample was weighed and dried at approximately 57 degrees Celsius for 72 hours. A dry weight of the sample was then recorded for dry matter and yield calculation.

Statistical analysis was conducted with Proc Mixed of SAS version 9.2 (SAS Institute, 2004). Fixed effects for the models included clover species, herbicide treatment, and planting date main effects and all possible interactions. Random effects for the models included location, block, and plot. Dependent variables were plant population, percent ground cover within rows per plot, and yield. Tukey's tests were used to compare means at the 0.05 level of significance.

Results and Discussion

Statistical analysis indicated a significant herbicide by planting date interaction with respect to clover ground cover. For the October planting, averaged across clovers, ground cover 35 or 37 DAP depending on locations where 2,4-D alone or in combination with dicamba plus metsulfuron and where fluroxypry plus triclopyr were applied was equivalent to the nontreated (average of 5.9 vs. 7.0 with 0= no clover present and 10 = 100 percent ground cover per row) (Table 2.1). Ground cover for 2,4-D plus aminopyralid and 2,4-D plus picloram averaged 4.4 and was less than for the nontreated. For both the November and March planting dates, ground cover 50 DAP in November and 68 or 74 DAP in March for all herbicide treatments were equivalent to nontreated and averaged 2.9 for the November planting and 8.4 for the March planting. Clover ground cover for the herbicide treatments was equal when clover was planted in October and March following applications of 2,4-D alone but for the other herbicide treatments, ground cover was lower for the October planting.

Table 2.1. Ground cover of clover as influenced by herbicide treatments applied to bare ground in July and planted in October, November, and March.[1]

		Ground cover [2]		
	Rate	Planting date		
Herbicide treatment	g ae/ha	October 14/15	November 20/21	March 5/7
2,4-D	1120	6.4 abcd[3]	2.5 g	7.7 ab
2,4-D + dicamba + metsulfuron methyl	603 + 210 + 393	5.3 cde	2.9 fg	8.0 ab
2.4-D + aminopyralid	748 + 93	4.0 efg	2.5 g	7.7 ab
2,4-D + picloram	560 +152	4.9 def	2.1 g	7.9 ab
fluroxypyr + triclopyr	140 + 420	5.9 bcde	2.8 g	8.3 a
None	0	7.0 abc	2.4 g	8.4 a

[1]Herbicides applied July 2, 2013 in Winnsboro and July 1, 2013 in St. Joseph. Clover planted October 14, November 20, 2013 and March 5, 2014 in Winnsboro and October 15, November 21, 2013 and March 7, 2014 in St. Joseph. Data averaged for ball and white clover.

[2]Ground cover ratings made 35 days after planting (DAP) in October at Winnsboro and 37 DAP at St. Joseph; 50 DAP in November at Winnsboro and St. Joseph; and 68 DAP in March at Winnsboro and 74 DAP at St. Joseph. Ratings based on 0-10 scale with 0 = no clover present and 10 = 100% ground cover within row.

[3]Means within and across columns followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey’s test.

For all herbicide treatments ground cover for the November planting was lower compared with the October and March plantings. The decrease in clover stand for the November planting could be a result of adverse weather conditions such as below average temperatures (Appendix A) and excessive rainfall (Appendix B).

A clover species main effect was significant for ground cover and plant population. Averaged across herbicide treatments and planting dates, ground cover 35 to 74 DAP depending on location and planting date was 16% greater for white clover compared with ball clover (Table 2.2).

Table 2.2. Ground cover and plant population of ball and white clover as influenced by herbicide treatments applied to bare ground and planted in October, November, and March.[1]

	Ground cover		Plant population[4]
Clover	35/74 DAP[2]	49/112 DAP[3]	4 to 6 wk after planting
Ball	5.0 b[5]	4.8 b	8.8 b
White	5.8 a	5.5 a	11.2 a

[1]Herbicide treatments included 2,4-D at 1120 g ae/ha, 2,4-D + dicamba + metsulfuron at 603 + 210 + 393 g ae/ha, 2,4-D + aminopyralid at 748 + 93 g ae/ha, 2,4-D + picloram at 560 +152 g ae/ha, and fluroxypyr + triclopyr at 140 + 420 g ae/ha. Clover planted October 14, November 20, 2013 and March 5, 2014 in Winnsboro and October 15, November 21, 2013 and March 7, 2014 in St. Joseph. Data averaged across herbicide treatments and clover planting dates.
[2]Ground cover ratings made 35 days after planting (DAP) in October at Winnsboro and 37 DAP at St. Joseph; 50 DAP in November at Winnsboro and St. Joseph; and 68 DAP in March at Winnsboro and 74 DAP at St. Joseph. Ratings based on 0-10 scale with 0 = no clover stand and 10 = complete stand establishment. Ground cover 1 and ground cover 2 ratings made 1-3 months after planting and were based on a 0-10 scale with 0 = no clover present and 10 = 100% ground cover.
[3]Ground cover ratings made 65 days after planting (DAP) in October at Winnsboro and 49 DAP at St. Joseph; 92 DAP in November at Winnsboro and 71 DAP at St. Joseph; and 112 DAP in March at Winnsboro and 95 DAP at St. Joseph. Ratings based on 0-10 scale with 0 = no clover present and 10 = 100% ground cover within row.
[4]Plant population data collected December 20, 2013 at Winnsboro and December 19, 2013 at St. Joseph and represent average number of plants in three random 30.48 cm row sections per plot for the October and November plantings.
[5]Means within each column followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Averaged across herbicide and planting dates, plant population in December 4 to 6 wk after the October and November plantings for white clover was 1.3 times that for ball clover. White clover grows much slower in the spring but increases its yield contribution through the growing season and into August in some situations (Han 2010). Ball clover produces most of its growth later in the spring compared to other clovers and is a prolific re-seeder even under close grazing (Ball et al. 2002).

A significant herbicide main effect was noted for ground cover, plant population, and clover yield. Averaged across clover species and planting date, ground cover 49 to 112 DAP depending on location and planting date for all herbicide treatments with the exception of 2,4-D + aminopyralid was equal to the non-treated (5.7) (Table 2.3). Plant population rating in December 4 to 6 wk after the October and November plantings where 2,4-D (11.5), 2,4-D plus dicamba plus metsulfuron (11.7), or fluroxypyr plus triclopyr (11.7) were applied was equivalent to the non-treated (12.8). Lowest plant population at this evaluation interval was observed for 2,4-D plus aminopyralid (6.3) and 2,4-D plus picloram (7.3). Plant population in May 1 to 2 mo after the March planting for all herbicide treatments was equivalent to the non-treated. Plant population, however, for 2,4-D plus aminopyralid was less than for 2,4-D plus dicamba plus metsulfuron and for fluroxypyr plus triclopyr (77.5 vs. 98.4 and 97.2, respectively). For the herbicide treatments, average clover yield was reduced for only 2,4-D plus aminopyralid (30% yield reduction).

Ground cover 49 to 112 DAP depending on location and planting date was 14.5% greater for white clover compared with ball clover.

Table 2.3. Ground cover, plant population, and yield of clover as influenced by herbicide treatments applied to bare ground and planted in October, November, and March.[1]

Herbicide treatment	Rate	Ground cover	Plant population	Plant population	Yield[5]
	g ae/ha	49/112 DAP[2]	May 20, 2014[3]	December 19/20, 2013[4]	(% reduction)
2,4-D	1120	5.6 ab	93.8 ab	11.5 ab	19.1 a
2,4-D + dicamba + metsulfuron methyl	603 + 210 + 393	5.5 ab	98.4 a	11.7 ab	15.8 a
2,4-D + aminopyralid	748 + 93	4.0 c	77.5 b	6.3 c	-29.8 b
2,4-D + picloram	560 +152	4.6 bc	87.2 ab	7.3 bc	-17.1 ab
fluroxypyr + triclopyr	140 + 420	5.8 a	97.2 a	11.7 ab	17.5 a
None	0	5.7 ab	95.3 ab	12.8 a	.

[1]Herbicides applied July 2, 2013 in Winnsboro and July 1, 2013 in St. Joseph. Clover planted October 14, November 20, 2013 and March 5, 2014 in Winnsboro and October 15, November 21, 2013 and March 7, 2014 in St. Joseph. Data averaged across planting dates and ball and white clover.

[2]Ground cover ratings made 65 days after planting (DAP) in October at Winnsboro and 49 DAP at St. Joseph; 92 DAP in November at Winnsboro and 71 DAP at St. Joseph; and 112 DAP in March at Winnsboro and 95 DAP at St. Joseph. Ratings based on 0-10 scale with 0 = no clover present and 10 = 100% ground cover within row.

[3]Plant population represents percentage of twenty 41 cm^2 squares of row containing clover plants.

[4]Plant population represents average number of plants in three random 30.48 cm row sections per plot.

[5] Yield data expressed as percent difference compared to the non-treated. Forage was harvested May 6, 2014 at Winnsboro and May 19, 2014 at St. Joseph for October and November planting dates and June 24, 2014 at Winnsboro and June 9, 2014 at St. Joseph for the March planting date.

[6]Means within columns followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Planting date main effect was significant for ground cover and plant population. Averaged across clover species and herbicides, ground cover 49 to 112 DAP depending on location and planting date was greatest for the March planting (8.0) and least for the November planting (2.3) (Table 2.4). Plant population in December was 1.7 times greater for the October planting compared with the November planting. A significant interaction between clover species and planting date was observed for plant population. Averaged across herbicide treatments, plant population 30 days after the October and November plantings was equivalent for ball and white clover for the October planting (16.3 and 12.1) but for the November planting, population was 1.8 times greater for white clover (Table 2.5). For ball clover, plant population was greater for the October planting. In June plant population was equivalent for ball and white clover planted in October (90.8 vs 97.3%) and March (89.7 vs 96.6%) but for the November planting was 1.7 times greater for white clover than for ball clover. For ball clover plant population in June was lower for the November planting. Plant population of white clover was equivalent for the three planting dates.

According to the 2,4-D plus aminopyralid label, “forage legumes should not be planted until a soil bioassay has been conducted to determine if aminopyralid residues remaining in the soil will adversely affect the legume establishment” (Anonymous 2012). The 2,4-D plus picloram label states that “Grazon P+D® may injure or kill legume plants but legumes may be less sensitive to the herbicide after the seed has set and plant growth is mature however seeding of legumes may not be successful if made within one year of application” (Anonymous 2009).

Results from the current research indicate that based on negative impacts on growth and/or yield of ball or white clover, label restrictions with regard to these herbicides and clover planting is well founded for conditions presented in this research in Louisiana.

Table 2.4. Ground cover and plant population of clover as influenced as influenced by herbicide treatments applied to bare ground and planted in October, November, and March.[1]

Planting date	Ground cover 49/112 DAP[2]	Plant population December 19/20[3]
October	5.2 b[4]	12.8 b
November	2.3 c	7.7 a
March	8.0 a	--

[1]Herbicides treatments to include 2,4-D at 1120 g ae/ha, 2,4-D + dicamba + metsulfuron at 603 + 210 + 393 g ae/ha, 2,4-D + aminopyralid at 748 + 93 g ae/ha, 2,4-D + picloram at 560 +152 g ae/ha, and fluroxypyr + triclopyr at 140 + 420 g ae/ha were applied July 2, 2013 in Winnsboro and July 1, 2013 in St. Joseph. Clover planted October 14, November 20, 2013 and March 5, 2014 in Winnsboro and October 15, November 21, 2013 and March 7, 2014 in St. Joseph. Data averaged across herbicide treatments and ball and white clover.

[2]Ground cover ratings made 65 days after planting (DAP) in October at Winnsboro and 49 DAP at St. Joseph; 92 DAP in November at Winnsboro and 71 DAP at St. Joseph; and 112 DAP in March at Winnsboro and 95 DAP at St. Joseph. Ratings based on 0-10 scale with 0 = no clover present and 10 = 100% ground cover.

[3]Plant population collected December 20, 2013 at Winnsboro and December 19, 2013 at St. Joseph and represent average number of plants in three random 30.48 cm row sections per plot.

[4]Means within each column followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Table 2.5. Plant population and yield of ball and white clover as influenced by herbicide treatments applied to bare ground and planted in October, November, and March.[1]

	Plant population 30 DAP[2]		Plant population June 9/24, 2014[3]	
Planting date	Ball clover	White clover	Ball clover	White clover
October	16.3 b[4]	12.1 bc	90.8 a	97.3 a
November	11.8 c	21.4 a	53.1 b	87.9 a
March	.	.	89.7 a	96.6 a

[1]Herbicide treatments including 2,4-D at 1120 g ae/ha, 2,4-D + dicamba + metsulfuron at 603 + 210 + 393 g ae/ha, 2,4-D + aminopyralid at 748 + 93 g ae/ha, 2,4-D + picloram at 560 +152 g ae/ha, and fluroxypyr + triclopyr at 140 + 420 g ae/ha were applied July 2, 2013 in Winnsboro and July 1, 2013 in St. Joseph. Clover planted October 14, November 20, 2013 and March 5, 2014 in Winnsboro and October 15, November 21, 2013 and March 7, 2014 in St. Joseph. Data averaged across herbicide treatments.

[2]Plant population data collected November 5, 2013 at Winnsboro and November 11, 2013 at St. Joseph and represent average number of plants in three random 30.48 cm row sections per plot.

[3]Plant population data collected June 24, 2014 at Winnsboro and June 9, 2014 at St. Joseph and represents percentage of twenty 41 cm^2 squares of row containing clover plants.

[4]Means for ball and white clover for each parameter followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Results also indicate that under conditions experienced, 2,4-D, 2,4-D plus metsulfuron plus dicamba, and fluroxypyr plus triclopyr can be successfully utilized for summer pasture weed control in a warm season grass/clover complimentary forage system without negative effects on growth and subsequent yield of ball and white clover in Louisiana.

Appendix A. Rainfall data for Winnsboro and St. Joseph July 2013 - June 2014.

	Winnsboro	St. Joseph
Month	-----------------cm---------------	
July	11.05	19.38
August	3.96	2.03
September	7.52	15.65
October	12.47	4.55
November	14.68	22.4
December	8.76	9.8
January	5.49	12.12
February	10.08	10.13
March	15.75	19.99
April	18.67	17.25
May	22.63	17.91
June	9.58	13.54
Total	140.64	164.75

Appendix B. Average daily temperatures for Winnsboro and St. Joseph July 2013 – June 2014

	Winnsboro	St. Joseph
Month	-----------------celsius---------------	
July	27.11	25.33
August	27.96	25.59
September	26.79	23.29
October	19.85	18.68
November	11.53	13.01
December	8.42	8.59
January	5.42	6.52
February	8.20	9.18
March	11.92	11.24
April	17.88	17.22
May	22.23	21.51
June	26.69	24.79
Total	17.83	17.07

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CHAPTER 3
BALL (TRIFOLIUM NIGRESCENS VIV.), WHITE (TRIFOLIUM REPENS L.), CRIMSON (TRIFOLIUM INCARNATUM L.), AND RED (TRIFOLIUM PRETENSE L.) CLOVER ESTABLISHMENT AND YIELD AS INFLUENCED BY RESIDUAL EFFECT OF FLUROXYPYR PLUS TRICLOPYR AND 2,4-D PLUS PICLORAM

Introduction

The most utilized forage resources in Louisiana and throughout most of the Southeastern United States include warm season grasses such as Bermudagrass (*Cynodan dactylon* L.) and Bahiagrass (*Paspalum notatum* Flugge) (Han et al. 2012). These warm season grasses are only seasonally productive in the Southern United States and forage production is limited within the growing season by low soil nitrogen. Cool-season legumes, particularly clovers, have potential to partially overcome these limitations of warm-season grasses (Han et al. 2012). Inter-seeding cool-season legumes into warm-season grass dominant pastures enhances soil nitrogen utilization (Gunter et al. 2012). As the costs of fuel and fertilizer increase, many producers are adapting to the utilization of pasture legumes to increase nitrogen levels (Han et al. 2012).

Several clover species have been proven to be valuable legumes in Louisiana pastures and both annual and perennial clovers are adapted to various Louisiana soils. The amount of nitrogen supplied from clover can vary depending on clover species and evaluations of individual clover species have identified specific characteristics contributing to their success or limitations under various growth conditions (Han et al. 2012). Clovers also contribute differently to total pasture yield throughout the growing season (Han et al. 2010).

White clover (*Trifolium repens* L.) is a highly palatable, nutritious forage for all classes of livestock, is a native species of Europe, is one of the most widely distributed legumes in the world, and is the most important pasture legume in the U.S. (Anonymous 2006). It is a low-growing, perennial clover with prostrate stems and erect leaves that produces most of its growth in the spring through late fall (Twidwell et al. 2013). White clover is best adapted to clay and silt soils in cool, moist climates (Anonymous 2006). It can tolerate close grazing and prefers a soil pH of around 6 (Ball et al. 2002). In contrast to the early-growing clovers such as crimson clover, white clover grows much slower in the spring but increases its yield contribution through the growing season and into August in some situations. (Han et al. 2010)

Ball Clover (*Trifolium nigrescens* viv.) is an annual clover that was introduced into the United States from Turkey (Hoveland 1960). It is visually similar to White Clover but it has long, succulent branching stems growing prostrate to partially upright and the stems may reach 30 inches or more in length in ideal growing conditions (Hoveland 1960). Ball clover is grown as a winter annual in Texas, Arkansas, Louisiana, Mississppi and Alabama. It produces most of its growth later in the spring compared to other clovers and is a prolific re-seeder even under close grazing. (Ball et al. 2002). Ball can tolerate loam or clay soils that are wet in the winter but are droughty in the summer and prefers a soil pH of 6.5-8.5. (Barnes et al. 2007).

Red Clover (*Trifolium pratense* L.) is an erect-growing bunch-type plant with no rhizomes or stolons, having numerous leafy stems arising from a thick crown and it has a taproot system with many secondary branches (Quesenberry and Blount 2006) Red clover grows best on medium to well-drained soils with a pH range of 6.1 to 6.7 (Taylor et al. 1997). It is a short-lived perennial that is managed as an annual or biennial in Louisiana (Twidwell et al. 2013). Red clover is a high-quality forage legume that can be grazed in late winter and early spring and 'Southern Belle', which was bred and developed in north-central Florida, was specifically selected for earlier spring production (Quesenberry and Blount 2006).

Crimson Clover (*Trifolium incarnatum* L.) was introduced from Europe and is the most important annual clover to U.S. agriculture (Smith 2010). It is grown from as far north as Maine but is primarily grown in the Southeast (Anonymous 2009a). Crimson clover is predominantly used as a winter annual forage legume over-seeded on warm-season perennial grass pastures in the Southeast (Smith 2010). It emerges and grows rapidly in early spring (Han et al. 2010). While it is not typically a re-seeder in pasture situations, it often grows more vigorously than many other clovers (Anonymous 2009a). Crimson clover will grow on soils of poorer quality than most other clovers, thriving on both well-drained sandy and clay soils with a preferable pH range of 6.0 to 7.0.

Clovers are highly susceptible to herbicide injury from any chemical labeled for use on broadleaf weeds therefore there are currently no pasture herbicides available that are recommended for use in temporary broadleaf pastures including clovers (Anonymous 2014). For many producers, the biggest dilemma with chemical control of broadleaf weeds is how and when to apply herbicides without adverse effects on pasture legumes (Johnston 2012). Growth regulating herbicides such as 2,4-D, dicamba, picloram, aminopyralid, fluroxypyr and triclopyr mimic natural plant auxins and translocate throughout plants via the xylem and phloem causing abnormal growth and disruption of the conductive tissues of plants which produces physical symptoms such as twisting and malformed leaves and stems (Cudney 1996). Auxinic herbicides (growth regulators) such as Phenoxy or Benzoic Acid herbicides are not tolerated by legumes in pastures or rangelands (Seller and Ferrell 2010).

Picloram, along with 2,4-D, is an active ingredient in Grazon P+D® which is a pasture herbicide introduced by Dow Agro Science and has a recommended application rate of 0.38 L/ha formulated product (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha) (Anonymous 2014). The average field half-life of Picloram is 90 days, with a range of 20-300 days and dissipation is more rapid under warm, humid conditions (Anonymous 2002). Grazon P+D® may injure or kill legume plants but legumes may be less sensitive to the herbicide after the seed has set and plant growth is mature however seeding of legumes may not be successful if made within one year of application (Anonymous 2009b).

PastureGard® is a Dow AgroSciences chemical that controls broadleaf herbaceous and woody plants in pastures (Anonymous 2008). The active ingredients are triclopyr and fluroxypyr and the recommended application rate is 0.38 L/ha formulated product (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha). PastureGard® should not be used on alfalfa or other desirable forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated but legumes may be replanted 1 month or more after PastureGard® application (Anonymous 2008). In lab studies of the aerobic soil metabolism of fluroxypyr, the half-life of total fluroxypyr in soils is 1-4 weeks and in field dissipation studies the half-lives for North American sites range from 11-38 days for total fluroxypyr (Anonymous 2002). Triclopyr is moderately persistant with an average half-life of 30 days, ranging from 10-46 days depending on soil type, moisture and temperature.

Limited information is available on the impact of residual effects of pasture herbicides on the growth and establishment of ball, white, crimson, and red clover in Louisiana. The objective of this research is aimed at documenting potential negative effects following use of these herbicides for summer pasture weed control.

Materials and Methods

Field experiments were initiated in 2013 at the Northeast Research Station near St. Joseph, LA and the Macon Ridge Research Station near Winnsboro, LA to evaluate simulated residual effects of herbicides Pasturegard® (fluroxypyr and triclopyr) and Grazon P+D® (2, 4-D and picloram) on establishment and growth of ball 'AU Don', white 'Durana', crimson 'Dixie' and red ‘Southern Belle’ clover. Clovers were planted and sprayed on October 14, 2013 at Winnsboro and on October 15, 2013 at St. Joseph at 0, 25, 38, and 50% of the recommended rate of Pasturegard® (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha) and Grazon P+D® (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha). Soils were a Gigger silt loam (fine-silty, mixed, active thermic Typic Fragiudalfs) with a pH of 4.9 at Winnsboro and a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with a pH of 7 at St. Joseph. Sites were tilled by disking and generally weed-free prior to herbicide application. Herbicides were applied with a tractor mounted compressed air spraying at 140 L/Ha^{-1} at 193 kPa. The experimental design utilized was a randomized complete block with a factorial arrangement of clover species, herbicides, and rates replicated four times. Planted plot area was 1.5 m wide by 4.6 m long. Clover was planted using a small-plot, drill, cone-type planter with a drill spacing of 7 rows approximately 20 cm apart. Planting depth was targeted at 1 to 1.5 cm. Clovers emerged on October 21, 2014. Plant counts were recorded at St. Joseph on November 11, 2013 (17 DAP) and October 30, 2013 (27 DAP) at Winnsboro. Plant counts involved counting all clover plants within 91 cm of row within each plot. An additional plant count was accomplished at Winnsboro on March 24, 2014 (161 DAP) and on April 4, 2014 (171 DAP) at St. Joseph. Plots were treated with sethoxydim @ 315 g/ha on November 5, 2013 and clethodim @ 175 g/ha on January 24, 2014 at Winnsboro and St. Joseph, respectively, to control grasses. In addition, plots at Winnsboro were treated with 2,4-DB at 245 g/ha on January 30, 2014 to control broadleaf weeds. Visual ratings of percent clover present were recorded at Winnsboro on November 19, 2013 (36 DAP), December 17, 2013 (64 DAP), January 8, 2014 (86 DAP), February 19, 2014 (128 DAP), and March 24, 2014 (161 DAP) and on November 21, 2013 (37 DAP), December 19, 2013 (65 DAP), January 10, 2014 (87 DAP), February 17, 2014 (125

DAP), and April 30, 2014 (196 DAP) at St. Joseph. Ratings were based on a scale of 0 = no clover present and 10 = complete coverage of clover throughout the rows within the plot. A m^2 quadrant was used to calculate a percentage of plants present within each of twenty 41 cm^2 squares inside the quadrant as another quantitative measurement on May 16, 2014 (214 DAP) at Winnsboro and May 20, 2014 (217 DAP) at St. Joseph. Plots were harvested on May 6, 2014 (204 DAP) at Winnsboro and May 19, 2014 (216 DAP) at St. Joseph by cutting an area 46 cm wide and 2 m long using a push mower with a bag attachment. A whole plot weight was recorded for each sample followed by collection of a sub-sample was collected for dry weight determination. The sub-sample was weighed and dried at approximately 57° Celsius for 72 hours. A dry weight of the sample was then recorded for dry matter and yield determination. Heights were also recorded using a rising plate meter on April 16, 2014 (184 DAP) at Winnsboro and April 30, 2014 (196 DAP) at St. Joseph.

Statistical analysis was conducted with Proc Mixed of SAS version 9.2 (SAS Institute, 2004). Fixed effects for the models included clover species, herbicides, and rate main effects and all interactions. Random effects for the models included location, block, and plot. Dependent variables were number of clovers present, percent clover present per plot, and yield. Tukey’s tests were used to compare means at the 0.05 level of significance.

Results and Discussion

Data analysis indicated a significant clover species main effect for plant population and ground cover. Averaged across herbicide treatments and rates, plant population 17/27 DAP depending on location was equivalent for ball, red, and white clover (Table 3.1). Plant population for crimson clover averaged 43% less compared with ball, red, and white. Ground cover 128/125 DAP depending on location was greatest for crimson clover (5.5) and lowest for ball (3.3). At 161/196 DAP, when averaged across herbicide treatments and rates, ground cover rating was greatest for crimson (6.5) and lowest for ball (4.8) and red clover (5.0). Plant population 214/217 DAP was equivalent for white (73 %) and crimson clover (65 %) and greater than ball clover (54 %); plant population was equivalent for ball and red clover (62 %). Han et al. (2010) reported that crimson clover emerges and grows rapidly in early spring. While it is not typically a re-seeder in pasture situations, it often grows more vigorously than many other clovers (Anonymous 2009a).

Table 3.1. Plant population and ground cover for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

	Plant population	Late season ground cover		Plant population
Clover	17/27 DAP[2]	128/125 DAP[3]	161/196 DAP[4]	214/217 DAP[5]
Ball	15.8 a[6]	3.3 c	4.8 c	54 c
Crimson	9.4 b	5.5 a	6.5 a	65 ab
Red	15.1 a	4.1 bc	5.0 c	62 bc
White	18.0 a	4.5 b	5.7 b	73 a

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged across herbicide treatments and rates.
[2]Plant population determined 17 days after planting (DAP) at Winnsboro and 27 DAP at St. Joseph. Plant population represents average number of plants in three 30.48 cm row sections per plot.
[3]Ground cover visually determined 128 DAP at Winnsboro and 125 DAP at St. Joseph on a scale 0=no clover present and 10 = 100% ground cover within row.
[4]Ground cover visually determined 161 DAP at Winnsboro and 196 DAP at St. Joseph on a scale 0=no clover present and 10 = 100% ground cover within row.
[5]Plant population determined 214 DAP at Winnsboro and 217 DAP at St. Joseph. Plant population represents percentage of twenty 41 cm^2 squares of row containing clover plants.
[6]Means within each column followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey’s test.

A significant interaction of clover species and herbicide treatment was observed for plant population and clover height. For all clovers, when averaged across herbicide rates, plant population 161/171 DAP depending on location was equivalent for fluroxypyr plus triclopyr and the non-treated and greater than for 2,4-D plus picloram (Table 3.2). For 2,4-D plus picloram plant population was greatest for white clover. For fluroxypyr plus triclopyr plant population was equal for crimson and red and greater than for ball and white.

When averaged across herbicide rates, height of ball, crimson, red, and white clover was reduced when 2,4-D plus picloram was applied but was equivalent to the non-treated for fluoxypyr plus triclopyr. equivalent when fluroxypyr + triclopyr. Where fluroxypyr plus triclopyr was applied plant height was greatest for crimson clover (17.6 cm). For 2,4-D plus picloram height was equivalent to white (4.2) but greater than for ball and red. Averaged across herbicide rates, ground cover 36/37 DAP for ball clover for both herbicides was less compared with the non-treated (1.5 and 3.1 vs 5.1) and was less for 2,4-D plus picloram (1.5) compared with fluroxypyr plus triclopyr (3.1) (Table 3.3). For crimson, red, and white clover, ground cover 36/37 DAP was less for 2,4-D plus picloram compared with fluroxypyr plus triclopyr but ground cover for fluroxypyr plus triclopyr was equal to the non-treated. Comparing herbicides, ground cover following 2,4-D plus picloram was greater for crimson compared with the other clovers. For fluroxypyr plus triclopyr ground cover was greatest for crimson and red and lowest for ball. When herbicide was not applied ground cover was lowest for ball clover. Ground cover 64/65 DAP was equivalent where fluroxypyr + triclopy was applied and the non-treated for all clovers with the exception of ball which was decreased by fluroxypyr plus triclopyr (4.2 vs 6.1). When 2,4-D plus picloram was applied, ground cover 64/65 DAP was significantly decreased for all clovers when compared to the non-treated, but crimson treated with 2,4-D plus picloram was equivalent to ball treated with fluroxypry plus triclopy (3.3 vs 4.2).

Table 3.2. Plant population and plant height for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

	--------Plant population 161/171 DAP[2]-------				-------------Plant height 184/196[3]--------------			
Herbicide treatment	Ball	Crimson	Red	White	Ball	Crimson	Red	White
2,4-D + picloram	0.64 c	2.4 c	1.0 c	2.4 de	1.8 e	7.0 d	3.5 e	4.2 de
fluroxypyr + triclopyr	6.7 b	12.3 a	10.1 ab	5.3 c	14.2 c	17.6 ab	12.9 c	12.5 c
none	10.1 ab	12.9 a	11.8 a	6.4 abc	15.1 bc	19.3 a	14.0 c	13.0 c

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged for 0, 25, 38, and 50% of recommended use rate of 2,4-D + picloram at 560 + 152 g ae/ha and of fluroxypyr + triclopyr at 140 + 420 g ae/A.

[2]Plant population determined 161 DAP at Winnsboro and 171 DAP at St. Joseph represents average number of plants in three 30.48 cm row sections per plot.

[3]Plant height determined 184 days after planting (DAP) at Winnsboro and 196 DAP at St. Joseph.

[4]Means for each parameter followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Table 3.3. Ground cover for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

Herbicide treatment	--------Ground cover 36/37 DAP²-----				------Ground cover 64/65 DAP[3] ------				--------Ground cover 86/87 DAP[4] --------			
	Ball	Crimson	Red	White	Ball	Crimson	Red	White	Ball	Crimson	Red	White
2,4-D + picloram	1.5 e[5]	5.1 c	2.5 de	2.4 de	1.3 e	3.3 d	1.4 e	2.0 e	1.0 f	2.0 ef	1.1 f	1.4 f
fluroxypyr + triclopyr	3.1 d	7.3 ab	6.3 bc	5.3 c	4.2 d	7.5 ab	6.1 bc	5.9 c	3.3 de	7.0 ab	5.5 c	5.1 c
none	5.1 c	8.1 a	7.1 ab	6.4 abc	6.1 bc	8.1 a	6.6 abc	6.3 bc	4.1 cd	7.6 a	5.7 bc	4.7 cd

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged for 0, 25, 38, and 50% of recommended use rate of 2,4-D + picloram at 560 + 152 g ae/ha and of fluroxypyr + triclopyr at 140 + 420 g ae/A.

[2]Ground cover visually determined 36 DAP at Winnsboro and 37 DAP at St. Joseph on a scale 0=no clover present and 10 = 100% ground cover within row.

[3]Ground cover visually determined 64 DAP at Winnsboro and 65 DAP at St. Joseph on a scale 0=no clover present and 10 = 100% ground cover within row.

[4]Ground cover visually determined 86 DAP at Winnsboro and 87 DAP at St. Joseph on a scale 0=no clover present and 10 = 100% ground cover within row.

[5]Means for each parameter followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Ball, red, and white clover were all equivalent when treated with 2,4-D plus picloram (1.3 to 2.0). Ground cover 86/87 DAP for all clovers was equivalent for fluroxypyr plus triclopyr and the non-treated and greater than for 2,4-D plus picloram. Greatest ground cover was noted for crimson clover when herbicide was not applied (7.6).

Herbicide rate by herbicide interaction was noted with respect to ground cover, plant population, clover height, and yield. Averaged across clover species, fluroxypyr plus triclopyr at 50% of the recommended application rate was the only herbicide treatment where ground cover 36/37 DAP was equivalent to the non-treated (5.6 vs 6.7) (Table 3.4). Ground cover at this evaluation interval was equivalent for fluroxypyr plus triclopyr at 25, 38, and 50% x rates (5.2 to 5.6). In contrast, for 2,4-D plus picloram, ground cover 36/37 DAP was equivalent at rates of 25 and 38% x, but was greater for 25% compared with 50% x rate (4.0 vs 1.8). Ground cover 161/196 DAP, when averaged across clovers, for all rates of fluroxypyr plus triclopyr was equivalent when compared to the non-treated. Ground cover at this evaluation interval indicated 2,4-D plus picloram was equivalent for 38 and 50% x rates (2.1 and 1.4) but was greater for 25% x rate (4.0).

All rates of 2,4-D plus picloram were significantly reduced when compared to the non-treated (1.4 to 4.0 vs 7.9). Plant population 214/217 DAP was equivalent for the non-treated (93%) and for fluroxypyr plus triclopyr at all rates (87 to 92%) and was greater than for 2,4-D plus picloram. Plant population for 2,4-D plus picloram was equivalent for rates of 38 and 50%x (20 and 15%) and less than for 25% x (50%).

Table 3.4. Ground cover and plant population for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

	Ground cover 36/37 DAP[2]			Ground cover 161/196[3]			Plant population 214/217 DAP[4]		
	----------Percent of use rate---------			---------Percent of use rate--------			--------Percent of use rate-------		
Herbicide treatment	25	38	50	25	38	50	25	38	50
2,4-D + picloram	4.0 c[5]	2.8 cd	1.8 d	4.0 b	2.1 c	1.4 c	49.8 b	20.2 c	15.2 c
fluroxypyr + triclopyr	5.6 ab	5.6 b	5.2 b	7.9 a	7.5 a	7.3 a	92.0 a	89.2 a	87.0 a
none	6.7 a	--	--	7.9 a	--	--	92.7 a	--	--

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged for 0, 25, 38, and 50% of recommended use rate of 2,4-D + picloram at 560 + 152 g ae/ha and of fluroxypyr + triclopyr at 140 + 420 g ae/A.

[2]Ground cover visually determined 36 DAP at Winnsboro and 37 DAP at St. Joseph on a scale 0=no clover establishment and 10= complete stand establishment within row.

[3]Ground cover visually determined 161 DAP at Winnsboro and 196 DAP at St. Joseph on a scale 0=no clover establishment and 10= complete stand establishment within row.

[4]Plant population determined 214 DAP at Winnsboro and 217 DAP at St. Joseph. Plant population represents percentage of twenty 41 cm^2 containing clover plants.

[5]Means for each parameter followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Averaged across clovers, plant height 184/196 DAP following all rates of fluroxypyr plus triclopyr was equivalent to the non-treated (14.2 to 14.3 vs 15.3 cm) (Table 3.5). Plant height for all rates of 2,4-D plus picloram was less compared with rates of fluroxypyr plus triclopyr. For 2,4-D plus picloram, height was greater for 25% x rate compared with 38 and 50% x (2.3 and 3.7 vs 6.4 cm). Compared with the non-treated, 2,4-D plus picloram at 25, 38, and 50% x rates reduced height 58, 76, and 85% respectively. Averaged across clover species, yield for fluroxypyr plus triclopyr at all rates was equivalent to the non-treated (2624 to 2840 vs 2812 kg/ha). For 2,4-D plus picloram, clover yield was equivalent for rates of 38 and 50% x (322 and 15 kg/ha), and for both rates yield was less than for 25% x (973). Compared with the non-treated, 2,4-D plus picloram at 25, 38, and 50% x rate reduced yield compared with the non-treated 65,89, and 99%, respectively.

Table 3.5. Height and yield for ball, crimson, red, and white clover as influenced by herbicide treatments applied at reduced rates.[1]

	Height 184/196 DAP[2]			Yield 184/196 DAP[2]		
	--------Percent of use rate-------			---------Percent of use rate---------		
Herbicide treatment	25	38	50	25	38	50
2,4-D + picloram	6.4 b[3]	3.7 c	2.3 c	973 b	322 c	15 c
fluroxypyr + triclopyr	14.5 a	14.2 a	14.3 a	2840 a	2624 a	2695 a
None	15.3 a	--	--	2812 a	--	--

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged for clovers.
[2]Plant height (cm) and yield (kg/ha) determined 184 days after planting (DAP) at Winnsboro and 196 DAP at St. Joseph.
[3]Means for each parameter followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Herbicide rate main effect was significant for plant population 161/171 DAP and ground cover 64/65, 86/87, and 128/125 DAP. Averaged across clover species and herbicide and compared to the non-treated, plant population 161/171 DAP was reduced from 44% (25% x rate) to 59% (50% x rate) less (Table 3.6). Ground cover 64/65 DAP was reduced by all rates compared to the nontreated. Ground cover 86/87 DAP was reduced for all herbicide rates and was equivalent for rates of 25 and 38% x (3.8 vs 3.2) and for 38 and 50% x (3.2 vs 2.9). Averaged across herbicide treatments and clover species, ground cover 128/125 DAP was reduced equally for rates of 25, 38, and 50% x when compared with the non-treated (3.7 to 4.5 vs 6.4). A herbicide rate by clover species interaction was observed with respect to clover yield.

Table 3.6. Plant population and ground cover for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

Percent of herbicide use rate	Plant population 161/171 DAP[2]	Ground Cover 64/65 DAP[3]	Ground Cover 86/87 DAP[4]	Ground Cover 128/125 DAP[5]
0	11.8 a[6]	6.8 a	5.5 a	6.4 a
25	6.7 b	4.5 b	3.8 b	4.5 b
38	6.4 bc	3.8 c	3.2 bc	3.8 b
50	4.8 c	3.6 c	2.9 c	3.7 b

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged for herbicide treatments and for ball, crimson, red and white clovers.

[2]Plant population determined 171 days after planting (DAP) at Winnsboro and 161 DAP at St. Joseph. Means represent average number of clover plants per 30.5 cm row sections per plot.

[3]Ground cover visually determined 64 DAP at Winnsboro and 65 DAP at St. Joseph on a scale 0=no clover establishment and 10= complete stand establishment within row.

[4]Ground cover visually determined 86 DAP at Winnsboro and 87 DAP at St. Joseph on a scale 0=no clover establishment and 10= complete stand establishment within row.

[5]Ground cover visually determined 128 DAP at Winnsboro and 125 DAP at St. Joseph on a scale 0=no clover establishment and 10= complete stand establishment within row.

[6]Means within each column followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

Averaged across herbicide, all herbicide rates decreased yield for ball and red clover vs. non-treated (Table 3.7). For crimson clover, yield for the 25 and 38% x rate were equivalent to the non-treated while yield was reduced 49.9% for the 50% x rate. For white clover, yield for the 25% x rate was equivalent to the non-treated, however, yield was reduced 51.7% and 49.5%, respectively for the 38 and 50% x rates. For the 25% x rate, yield was 1295.2 kg/ha for ball clover, which was equal to yield for red clover (1679 kg/ha), but lower than that for crimson (2300.8 kg/ha) and white (2351.3 kg/ha). For the 38% x rate, yield was 1090.9 kg/ha for ball clover, which was equal to yield observed for red (1246.9 kg/ha) and white (1335.6 kg/ha), and less than that for crimson clover (2221.1 kg/ha).

Table 3.7. Yield for ball, crimson, red, and white clover as influenced by herbicide treatments applied at planting at reduced rates.[1]

	Yield[2]			
	Percent of use rate			
Clover	0	25	38	50
Ball	2816 a[3]	1295 a	1091 e	1259 e
Crimson	3068 a	2301 abc	2221 a-d	1535 b-e
Red	2600 a	1679 b-e	1247 e	1230 e
White	2763 a	2352 ab	1336 de	1362 cde

[1]Herbicide treatments applied at 0, 25, 38, and 50% of the use rates for 2,4-D + picloram at 560 + 152 g ae/ha and fluroxypyr + triclopyr at 140 + 420 g ae/A . Clover was planted and herbicides were sprayed on October 13, 2013 in Winnsboro and October 15, 2013 in St. Joseph. Data averaged across herbicide treatments.
[2]Yield (kg/ha) determined 184 days after planting (DAP) at Winnsboro and 196 DAP at St. Joseph.
[3]Means within columns and rows followed by the same letter are not significantly different at $p \leq 0.05$ using Tukey's test.

The label for fluroxypyr plus triclopyr states that "PastureGard® should not be used on alfalfa or other desirable forbs, especially legumes such as clover, unless injury or loss of such plants can be tolerated but legumes may be replanted 1 month or more after PastureGard®

application" (Anonymous 2008). The GrazonP+D® label states that the material "may injure or kill legume plants but legumes may be less sensitive to the herbicide after the seed has set and plant growth is mature however seeding of legumes may not be successful if made within one year of application" (Anonymous 2009b). Our results indicate that when the label is followed, clover species evaluated can be seeded into pasture in the fall in Louisiana following summer application of fluroxypyr plus triclopyr under conditions presented within this research with minimal to no negative effects on growth and no impact on yield. In lab studies of the aerobic soil metabolism of fluroxypyr, the half-life of total fluroxypyr in soils is 1-4 wk and in field dissipation studies the half-life for North American sites range from 11-38 d for total fluroxypyr (Anonymous 2002). Triclopyr is moderately persistent with an average half-life of 30 d, ranging from 10-46 d depending on soil type, moisture, and temperature (Anonymous 2002). Even at the upper end of the persistence range, the herbicide would go through approximately 3 half-lives if applied on July 1 and clovers were seeded in October. In this research, clovers evaluated were able to tolerate fluroxypyr plus triclopyr at a 50% x rate immediately after planting with no negative impact on yield. As pre-cautioned on the 2,4-D plus picloram label, based on our findings this herbicide is not a viable option for summer weed management in a warm season grass/cool season clover complimentary forage system in Louisiana due to potential for negative impact on growth and yield of clover species evaluated.

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CHAPTER 4
SUMMARY

Field experiments were initiated in 2013 at the Northeast Research Station near St. Joseph, LA and the Macon Ridge Research Station near Winnsboro, LA to evaluate residual pasture herbicide effects on establishment and growth of ball (*Trifolium nigrescens* viv.) and white (*Trifolium repens* L.) clover. To simulate pasture weed control practices, GrazonNext® (aminopyralid @ 93 g ae/ha plus 2,4-D @ 748 g ae/ha), Grazon P+D® (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha), Pasturegard® (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha), Cimarron Max® (metsulfuron methyl @ 393 g/ha plus dicamba @ 210 g/ha plus 2,4-D @ 603 g/ha) and 2,4-DLV4® (2,4-D @ 1120 g/ha) were applied at full recommended rates on July 2, 2013 at Winnsboro and July 1, 2013 at St. Joseph. 'AU Don' ball clover and 'Durana' white clover were planted on October 14, 2013, November 20, 2013 and March 5, 2014 at Winnsboro and October 15, 2013, November 21, 2013 and March 7, 2014 at St. Joseph.

For the October planting, averaged across clovers, ground cover where was applied 2,4-D alone and in combination with dicamba and metsulfuron and fluroxypry plus triclopyr were equivalent to the nontreated. Ground cover for 2,4-D plus aminopyralid and 2,4-D plus picloram was less than for the nontreated. For both the November and March planting dates, ground cover for all herbicide treatments were equivalent to nontreated. Averaged across clover species and planting date, all herbicide treatments with the exception of 2,4-D plus aminopyralid resulted ground cover 49/112 DAP equal to the non-treated. Plant population 4 to 6 wk after the October and November plantings where 2,4-D, 2,4-D plus dicamba plus metsulfuron, or fluroxypyr plus triclopyr were applied was equivalent to the non-treated. Lowest plant population at this evaluation interval was observed for 2,4-D plus aminopyralid and 2,4-D plus picloram. Averaged across clover species and planting dates, plant population 1 to 2 mo after the March planting was equivalent for all herbicide treatments compared with the non-treated. However, plant population at this interval for 2,4-D plus aminopyralid was less than for 2,4-D plus dicamba plus metsulfuron and for fluroxypyr plus triclopyr. 2,4-D plus aminopyralid resulted in a significant yield reduction from the nontreated, the only treatment to do so. Results from the current research indicate that based on negative impacts on growth and/or yield of ball or white clover, label restrictions with regard to 2,4-D plus aminopyralid and 2,4-D plus picloram and clover planting is well founded for conditions presented in this research in Louisiana. Results also indicate that under conditions experienced, 2,4-D, 2,4-D plus metsulfuron plus dicamba and fluroxypyr plus triclopyr can be successfully utilized for summer pasture weed control in a warm season grass/clover complimentary forage system without negative effects on growth and subsequent yield of ball and white clover in Louisiana.

Field experiments were also initiated in 2013 at the Northeast Research Station near St. Joseph, LA and the Macon Ridge Research Station near Winnsboro, LA to evaluate simulated residual effects of herbicides Pasturegard® (fluroxypyr and triclopyr) and Grazon +D® (2, 4-D and picloram) on establishment and growth of Ball 'AU Don', White 'Durana', Crimson 'Dixie' and Red 'Southern Belle' clover. Clovers were planted and sprayed on October 14, 2013 at Winnsboro and on October 15, 2013 at St. Joseph at 0, 25, 38 and 50% of the recommended rate of Pasturegard® (fluroxypyr @ 140 g ae/ha plus triclopyr @ 420 g ae/ha) and Grazon +D® (2,4-D @ 560 g ae/ha plus picloram @ 152 g ae/ha).

For all clovers, when averaged across herbicide rates, plant population 214/217 DAP was equivalent for fluroxypyr plus triclopyr and the non-treated and greater than for 2,4-D plus picloram. Where floroxypyr plus triclopyr was applied, plant population 214/217 DAP was greater for crimson and red clover compared with ball clover, which was equivalent to white clover. When averaged across herbicide rates, height of ball, crimson, red, and white clover was equivalent when fluroxypyr plus triclopyr was applied compared with the non-treated. Height where fluroxypyr plus triclopyr was applied was greatest for crimson clover. Where 2,4-D plus picloram was applied, height was reduced significantly for ball, crimson, red, and white clover compared with the non-treated. For ball clover, ground cover 36/37 DAP for both herbicides was less compared with the non-treated and was less for 2,4-D plus picloram compared with fluroxypyr plus triclopyr. Ground cover 64/65 DAP was equivalent where fluroxypyr plus triclopy was applied and the non-treated with the exception of ball which was decreased by fluroxypyr plus triclopyr. When 2,4-D plus picloram was applied, ground cover 64/65 DAP was significantly decreased for all clovers when compared to the non-treated. Averaged across herbicide rates for all clovers, ground cover 86/87 DAP was equivalent for fluroxypyr plus triclopyr and the non-treated and greater than for 2,4-D plus picloram. For all clover/herbicide treatment, ground cover 86/87 DAP was less compared with the non-treated crimson clover with the exception of crimson treated with fluroxypyr plus triclopyr. Averaged across clover species, fluroxypyr plus triclopyr at 50% of the recommended application rate was the only herbicide treatment where ground cover 36/37 DAP was equivalent to the non-treated. Ground cover at this evaluation interval was equivalent for fluroxypyr plus triclopyr at 25, 38, and 50% x rates. In contrast, for 2,4-D plus picloram, ground cover 36/37 DAP was equivalent at rates of 25 and 38% x, but was greater for 25% compared with 50% x rate. Ground cover 161/196 DAP, when averaged across clovers for all rates of fluroxypyr plus triclopyr, was equivalent when compared to the non-treated. All rates of 2,4-D plus picloram were significantly reduced at this interval when compared to the non-treated. Plant population 214/217 DAP was equivalent for the non-treated (92.7%) and for fluroxypyr plus triclopyr at all rates and was greater than for 2,4-D plus picloram. Averaged across clovers, plant height 184/196 DAP following all rates of fluroxypyr plus triclopyr was equivalent to the non-treated. Plant height for all rates of 2,4-D plus picloram was less compared with rates of fluroxypyr plus triclopyr. Compared with the non-treated, 2,4-D plus picloram at 25, 38, and 50% x rates reduced height. Averaged across clover species, yield for fluroxypyr plus triclopyr at all rates was equivalent to the non-treated. Compared with the non-treated 2,4-D plus picloram at 25, 38, and 50% x rate reduced yield. Our results indicate that when the label is followed, clover species evaluated can be seeded into pasture in the fall in Louisiana following summer application of fluroxypyr plus triclopyr under conditions presented within this research with minimal to no negative effects on growth and no impact on yield. In this research, clovers evaluated were able to tolerate fluroxypyr plus triclopyr at a 50% x rate immediately after planting with no negative impact on yield. As pre-cautioned on the 2,4-D plus picloram label, based on our findings this herbicide is not a viable option for summer weed management in a warm season grass/cool season clover complimentary forage system in Louisiana due to potential for negative impact on growth and yield of clover species evaluated.

VITA

Suzanne grew up on a farm on the Tensas/Madison Parish line in northeast Louisiana where her family farmed cattle and row-crops and maintained hunting and fishing lands. From an early age, Suzanne learned the importance of agriculture and embraced it as a way of life. Her passion for animals and interest in livestock management lead her to pursue a bachelor's degree in Animal Science at Mississippi State University. While there, Suzanne learned many aspects of animal agriculture including pasture and forage production and maintenance. Soon after graduation, she accepted a Research Associate position at the LSU AgCenter's Northeast Research Station. She currently works at the Macon Ridge Research Station as a Research Associate in the Forage and Pasture, Soil Science, and Biofuels research programs. While working for the AgCenter, Suzanne was provided the opportunity to further her education in the LSU School of Plant, Environmental, and Soil Sciences where she is currently a candidate for a Master of Science degree.