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Determining Seasonal Emergence, Growth Characteristics, and Control Programs for Henbit (Lamium amplexicaule L.)

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DETERMINING SEASONAL EMERGENCE, GROWTH CHARACTERISTICS, AND CONTROL PROGRAMS FOR HENBIT (*LAMIUM AMPLEXICAULE L.)*

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
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in

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by
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ABSTRACT

To provide for a weed-free seedbed, Louisiana crop producers typically apply a burndown herbicide four to six wk prior to seeding summer annual crops; however, these treatments often provide inadequate henbit (*Lamium amplexicaule* L.) control. Research was conducted in Louisiana to evaluate henbit emergence from north to south, compare growth of henbit accessions based on emergence date, and control with fall-applied residual herbicides.

For the emergence study during the weeks of Oct 17 to Dec 12 at all locations in all years, soil temperatures at 2.5 cm averaged between 10 and 18.5 C. Henbit at densities of at least 50 m^{-2} emerged each week from approximately Oct 20 through Dec 20, for the three northern most sites which included the Northeast Research Station, a grower's field in Concordia Parish, and the Dean Lee Research and Extension Center.. At all three northern most locations counts in excess of 1000 henbit m^{-2} were observed in November, indicating potential for high henbit density at these locations. Henbit emergence was more sporadic from 2012 through 2015 for the three northern locations, with densities not exceeding 40 henbit m^{-2} at the Dean Lee Research and Extension Center, although large single week increases in the number of henbit did occur between mid-October to mid-December at those locations. Regardless of year, densities at the Ben Hur Research Farm, the southern location, were less overall.

Averaged across emergence date leaf area ratio (LAR) for September and October was 0.012 and 0.010 cm^2 g^{-1}, respectively, and although not significantly different was greater than henbit emerging in November. Specific leaf weight (SLW) for henbit emergence in November was 119.0 g cm^{-2}, greater than September and October populations at 54 and 89 g cm^{-2}, respectively. Additionally, relative growth rate (RGR) for September emerged henbit averaged across harvest intervals was 0.194 g g^{-1} d^{-1}, and greater than for both October and November emerged henbit with 0.121 and 0.092 g g^{-1} d^{-1}, respectively. Results suggest that September emerged henbit could be larger and more difficult to control than November emerged henbit. However, October populations had similar trends and were not different than September emerged henbit, conceding that any competitive advantage September may have over October is slight.

For fall applied residual herbicides study variability in henbit control, across years was observed. Overall, application Nov 1 through Dec 1 provided more consistent henbit control compared with oxyfluorfen applications controlled henbit at least 76% 100 DAT regardless of herbicide date. For flumioxazin and rimsulfuron: thifensulfuron, greater than 70% henbit control 100 DAT was obtained only when applied Nov 1 through Dec 15.

CHAPTER 1
INTRODUCTION

Henbit (*Lamium amplexicaule* L.) is a winter annual weed belonging to the Labiatae family. It is prevalent in more than 50 crops as well as on ditch banks, roads, and field edges (Holm et al. 1997). Henbit is adapted to temperate areas and a wide variety of soils. It is widely naturalized in the United States; however, it is native to Europe and the Mediterranean region (USDA-NRCS 2015).

Taxonomy of Henbit. Characteristics distinctive to henbit include rounded, coarsely toothed, and palmately veined leaves, tubular pink to purplish flowers with a bearded upper and lobed spotted lower lip (Holm et al. 1997). Henbit seedlings have oval, smooth cotyledons. Decumbent square stems occur at the base with branches that root at nodes where ground contact occurs, leaves appear in opposite pairs along the stem (DeFelice 2005; Holm et al. 1997). *Amplexicaule* is derived from the Latin word *amplexicaulis,* meaning “embracing the stem” referring to the upper sessile leaves of henbit that clasp the stem (DeFelice 2005).

Henbit produces cleistogamous (closed), pseudocleistogamous (both open and closed), and clasmogamous (open) flower types. These various flower types are dependent on vegetative development of the plant (Lord 1979; 1980) and are produced due to phenotypic plasticity that allows henbit to overcome and reproduce in unfavorable sites and conditions. Stojanova et al. (2016) observed that henbit flowers were predominately clasmogamous early-season to reduce inbreeding and shifted to cleistogamous later in the growing season when presence of pollinators were limited in Northern and Southern France.

The fruit of henbit occur in groups at the base of the calyx tube and separate at maturity. The nutlet-like seeds are 1.8 to 2.3 mm long, obviate oblong and grayish-brown with a surface slightly shiny and white spotted (DeFelice 2005; Holm et al. 1997). Henbit can produce 200 to 2,000 seed per plant (Allan 1979; Holm et al. 1997). Hill et al. (2014) collected 800 to 40,000 seed m^{-2} at densities of 10 to 65 plants m^{-2}, respectively. Roberts and Boddrell (1983) found that 52 to 70% of henbit seed germination occur within the first 18 months after dispersal. Henbit seed are conditionally dormant at maturity, which infers that dormancy can be broken by after-ripening in dry state storage in the presence of light or gibberellins, and exposure to alternating warm/cold temperatures after imbibing water (Kucera et al. 2005). Others have shown that henbit seed subjected to light for a 14 hour photoperiod or complete darkness germinated at alternating temperatures of 15/6 C and 20/10 C (Baskin and Baskin 1981; Baskin and Baskin 1984; Baskin et al. 1986). Seed produced in autumn months germinated the following year at high percentages when exposed to light and high temperatures during the preceding summer (Baskin and Baskin 1981). Conversely, low winter temperatures can cause seed produced in autumn and non-dormant seeds to become dormant showing an ecological consequence to temperature fluctuations (Baskin and Baskin 1984). Blackshaw et al. (2002) reported henbit emergence at soil temperatures 5 to 25 C, with greatest emergence 15 to 20 C. Emergence declined as soil water content decreased.

Intraspecific Variation among Plant Species. Timing or date of a plant species emergence is important in determining the growth, performance, and survival of the plant (Miller 1987). Furthermore, understanding weed growth rates are important for development of management strategies, as poor weed control can result from improper timing of herbicide applications (Horak and Loughlin 2002). Ross and Harper (1972) found that final cocksfoot (*Dactylis glomerata* L.)

size was greater following early emergence compared to later emergence due to a longer growth period and competitive advantage, regardless of the final plant density. Similarly, when seeded in late-May, June, or July in North Carolina, May sown Carolina geranium (*Geranium carolinianum* L.) developed more leaves, reached rosette stage, flowered earlier, and had higher fecundity (Roach 1986).

Differences among a weed species biology pertaining to germination and rates of growth have been documented. Alcocer-Ruthling et al. (1992a) observed that sulfonylurea-susceptible prickly lettuce (*Lactuca serriola* L.) gained 31% more aboveground biomass 52% faster than the resistant biotype. However, sulfonylurea-resistant prickly lettuce germinated faster than the susceptible biotype, but no differences were found in their fecundity or seed viability (Alcocer-Ruthling et al. 1992b). Cumulative germination of chlorsulfuron-resistant and -susceptible kochia [*Kochia scoparia* (L.) Schrad.] biotypes were similar at 28 C; however, the resistant biotype germinated faster than the susceptible at 8 and 18 C (Thompson et al. 1994a). Additionally, no differences in seed production and plant growth or competitiveness was observed with both biotypes producing 12,000 seed per plant with a relative competiveness of 0.75 and 0.85 for the resistant and susceptible biotypes, respectively (Thompson et al. 1994b).

Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.] accessions differed in height, node formation, branching, flower and fruiting habits which contributed to adaptability in changing environments (Cardina and Brecke 1989). Klingaman and Oliver (1996) found that entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray) accessions from southern latitudes remained vegetative longer which lead to increased biomass compared to northern accessions. Similarly, differences in vine length, leaf size and shape, and days to flower initiation was observed among pitted morningglory (*Ipomoea lacunosa* L.) accessions collected from different geographic locations (Stephenson et al. 2006). Although the previously discussed research compared plant accessions from different regions and not singular plant communities, their findings highlights a plants ability to adapt when subjected to variables inherent to a local environment.

Measurement of Plant Growth Dynamics. Plant growth analysis utilizes parameters to determine growth and development of plant systems in a controlled, semi-natural, or natural condition (Hunt 2003), which can elucidate competitive ability of a species. Growth in the context of an individual plant means irreversible change over time; in size (however measured), habit or form, and occasionally in number (Hunt 2003). Radosevich et al. (1997) stated that total dry matter production and leaf area are basic processes of vegetative growth. Therefore, growth measurements such as dry weights of a plant and leaf area recorded over time can show the relative size, productivity, and photosynthetic capability of the plant.

Leaf area ratio (LAR) is the most important variable for whole plant growth and a unit measure of plant leafiness, thereby measuring photosynthetic capacity of a plant (Radosevich et al. 1997). It is a product of two parameters, specific leaf area (SLA) and leaf mass ratio (LMR), which are leaf area per unit leaf mass and fraction of total plant mass allocated to leaves, respectively (Lambers et al. 2008). Another important variable of whole plant growth is net assimilation rate, which is the measure of total dry matter net gain per unit of leaf area (James and Drenovsky 2007; Lambers et al. 2008; Poorter and Remkes 1990). It determines photosynthetic efficiency by reflecting the ratio of carbon gain during photosynthesis and carbon loss through respiration (Forbes and Watson 1992; Poorter and Bergkotte 1992). Multiple factors such as architecture of leaves affect NAR, which influences interception of light and how photoassimilates are utilized by the plant. Additionally transportation, storage, and the chemical makeup of these photoassimilates can also affect NAR (Kriedemann et al. 1999).

Relative growth rate (RGR) is the increase of the total dry weight of a plant over a unit of time. It is considered the central parameter in plant growth analysis which is determined by differences in physiology, morphology, and partitioning assimilates to biomass, and utilizes LAR and NAR for its calculation (Kriedemann et al. 1999). Furthermore, favorable environments for plant growth typically leads to higher RGR. Additionally, specific leaf area (SLA), a component in the calculation of LAR, has been found to strongly correlate to RGR (Poorter and Remkes 1990). Specific leaf area measures the amount of leaf area per unit of dry matter (Kvet et al. 1971), thus is related to leaf thickness. Also, it is a measure of photosynthetic capacity; however, the prevailing view states that SLA reflects plant utilization of resources in rich or poor environments (Wilson et al. 1999). Specific leaf weight (SLW) is the reciprocal of SLA and is a predictive index of previous light environment and net photosynthetic potential (Barden 1977; Pearce et al 1969). This parameter assesses the functioning of total plant leaf area or total canopy by taking into account light, nitrogen status, and other stressors (Field and Mooney 1986). Stem-to-leaf ratio is a ratio of stem to leaf dry matter, which describes plant allocation of resources. A plant’s capacity to acquire resources and compete with adjacent plants can be observed with dry matter partitioning coefficients (Radosevich et al. 1997). Partitioning illustrates the flow of assimilates from source (leaves) to sink (meristematic tissue and fruit structures) components within a plant, dictated by developmental lifecycle needs (Singh et al. 2008). The source sink relationship with SLR is dependent on NAR carbon allocations and photosynthetic capacity inferred by LAR. Therefore, it is related inherently to RGR due to growth and maturation of a plant as lifecycle dictates movement of assimilates (Kriedemann et al. 1999).

Others used various growth parameters to investigate growth characteristics of Palmer amaranth (*Amaranthus palmeri* S. Wats.) (Bond and Oliver 2006), ragweed parthenium (*Parthenium hysterophorus* L.) (Pandey et al. 2003), and spurred anoda [*Anoda cristata* (L.) Schllecht.] (VanGessel et al. 1998). Palmer amaranth accessions that originated from southern and eastern regions of the U.S. had greater LAR, which could indicate greater photosynthetic capacity (Bond and Oliver 2006). In addition, they observed an increase in SLR as plants grew indicating the allocation of resources for leaf growth shifting to greater stem or reproductive structures growth later in the growing season. However, Bond and Oliver (2006) observed greater NAR in accessions from the western U.S., whose leaves were smaller, which may be an adaption to balance photosynthesis with lower total leaf area. Ragweed parthenium growth during summer and winter months was compared by Pandey et al. (2003). Lower NAR and RGR was observed when ragweed parthenium grew during the winter months. These plants had lower total biomass and flower and seed number due to a decrease in net photosynthetic rate caused by low air temperatures. This is supported by Williams (1946), who stated that NAR is decreased when environmental conditions reduce net photosynthetic rate. Also, plants depend upon optimum photosynthetic area for a proper rate of growth, but slow photosynthetic rate reduces new leaf development, thus hampering growth (Beale et al. 1996). Similar to the findings of Bond and Oliver (2006) with Palmer amaranth, spurred anoda accessions originating from warmer climates produced higher LAR (VanGessel et al. 1998), indicating a competitive advantage for these populations. They also observed that spurred anoda is a day sensitive plant, thus Colorado accessions, who typically grow in lower light environments, had lower LAR and

SLA, indicating greater carbon allocation to stems than leaves. Furthermore, SLR increased during the growing season, indicating an allocation of resources to leaves early then a shift in resource allocation to stems and reproductive structures later in the season (VanGessel et al. 1998), which is similar to that for Palmer amaranth (Bond and Oliver 2006).

Control of Winter Annual Weeds. If not controlled, winter weed vegetation following multiple month's growth can reach heights up to 1 m (Stougaard et al. 1984). Targeting winter weeds when small with fall-applied herbicides provide greater control than spring applications (Hasty et al. 2004). Multiple studies have shown increased weed control following herbicides applied to weeds 5 cm or less (Baldwin et al. 1991; Baldwin and Frans 1972; Barrentine 1989; DeFelice et al 1989; Harrison et al 1989; Oliver 1989), which gives credence to targeting winter annual weeds early in their life cycle for management.

Herbicide applications in the fall provide excellent control of winter weeds (Young and Krausz 2001). Fall-applied residual herbicides such as atrazine, rimsulfuron plus thifensulfuron, and simazine controlled mouseear chickweed [*Cerastium fontanum* ssp. *vulgare* (Hartman) Greuter & Burdet] and henbit 93% prior to planting a spring annual crop (Krausz et al. 2003) Henbit control was 94% at soybean planting after application of residual herbicides in the fall (Monnig and Bradley 2007). Fall applications of residual herbicides suppressed glyphosate-resistant (GR) horseweed [*Conyza Canadensis* (L.) *Cronq.*] greater than 86% 190 days after application; however, spring moisture and increased temperatures increased degradation of fall-applied residual herbicides warranting a spring herbicide application (Owen et al. 2009). Additionally, they found that cotton yields were greater following programs that included fall-applied residual herbicides compared to dicamba applied alone in the spring. Monning and Bradley (2007) found that if 2,4-D co-applied with chlorimuron plus sulfentrazone or chlorimuron plus tribenuron was delayed until 7 days before planting, control of annual fleabane (*Erigeron annuus* (L.) Pers.), corn speedwell (*Veronica arvensis* L.), field pennycress (*Thlaspi arvense* L), henbit, and shepherd's-purse (*Capsella bursa-pastoris* (L.) Medik.) ranged from 37 to 75% at planting; however, if these same herbicide treatments were applied in the fall, control was greater than 95%.

Oftentimes winter annual weeds are controlled with herbicide applications in the spring. Additionally, others have stated that fall-applied herbicides can effectively control winter annual weeds prior to planting a soybean crop, but an additional herbicide application in the spring may be needed for total control (Monnig and Bradley 2007; Hasty et al. 2004). However, fall-applied chlorimuron plus metribuzin or sulfentrazone with or without glyphosate plus 2,4-D provided 99% control of purple deadnettle (*Lamium purpureum* L.), another *Lamium* species like henbit, at soybean planting compared to 48% control following glyphosate plus 2,4-D applied 30 d preplant (Hasty et al. 2004), indicating an advantage with fall-applied herbicides versus spring-only applications for this species. Similarly, following a fall-applied residual herbicide, spring applications of dicamba alone or co-applied with diuron, flumioxazin, or fomesafen provided 86% control of GR horseweed 21 days after application, but, when these spring herbicide treatments did not follow a fall-applied herbicide, GR horseweed control was 70% (Owen et al. 2009).

Fall herbicide applications could improve herbicide efficacy and reduce spring workloads for producers by reducing spring herbicide applications prior to planting (Hasty et al. 2004; Krausz et al. 2003). Bruce et al. (2000) found soil temperatures are greater in the spring due to reduced vegetative cover following fall herbicide applications. Furthermore, winter annual weeds compete for nutrients and water resources during establishment of a summer crop

(Bernards and Sandell 2011). Others have documented that *Lamium* species can serve as host for overwintering pests such as soybean cyst nematode (*Heterodera glycines*), which can reduce soybean yield (Creech et al. 2007; Venkatesh et al. 2000; Werle et al. 2013). Therefore, the presence of henbit when seeding a summer annual crop may interfere with crop planting, growth, and development via direct competition or harboring of other pests.

Webster (2013) stated that henbit is the fifth and sixth most troublesome weed in Louisiana cotton and soybean, respectively. The troublesome nature of henbit in Louisiana crops may be due to the difficulty in control following spring herbicide applications prior to seeding a summer annual crop (D. O. Stephenson, IV, personal communication). Considering the poor control of henbit in Louisiana reported by crop producers with spring-applied herbicides, development of herbicide programs for henbit management are needed. Additionally, little information is available investigating emergence pattern and growth characteristics of henbit, which would be useful in planning weed control programs. Although others have determined the effect of temperature and soil moisture on henbit emergence (Roberts and Boddrell 1983; Baskin and Baskin 1981, 1984; Baskin et al. 1986; Blackshaw et al. 2002), their research was conducted in fields at northern latitudes. It has not been determined if the findings of Blackshaw et al. (2002) are applicable to the fall, winter, and spring environments in Louisiana. Therefore, this research investigates emergence patterns, comparative growth of henbit accessions based on emergence date, and the effect of application date of residual herbicides for henbit control.

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CHAPTER 2

DETERMINATION OF HENBIT (*Lamium Amplexicaule L.*) EMERGENCE PATTERNS IN LOUISIANA

Introduction

Henbit (*Lamium amplexicaule* L.) is a winter annual weed belonging to the Labiatae family. Henbit is widely naturalized in the United States (USDA-NRCS 2015) and adapted to a wide variety of soils (Holm et al. 1997). Dependent on vegetative development of the plant, henbit produces cleistogamous (closed), pseudocleistogamous (both open and closed), and clasmogamous (open) flower types (Lord 1979; 1980). Henbit flowers were observed to be predominately clasmogamous early-season reducing inbreeding and shifted later in the growing season to cleistogamous when presence of pollinators were limited in Northern and Southern France (Stojanova et al. 2016).

Henbit fruit are nutlet-like, 1.8 to 2.3 mm long, obviate oblong, and are grayish-brown, slightly shiny and white spotted (DeFelice 2005; Holm et al. 1997). Approximately 52 to 70% henbit seed germination occurred within the first 18 months after dispersal as observed by Roberts and Boddrell (1983). This winter annual weed can produce 200 to 2,000 seed per plant (Allan 1979; Holm et al. 1997). Furthermore, Hill et al. (2014) collected 800 to 40,000 seed m^{-2} at densities of 10 to 65 plants m^{-2}, respectively. The seeds of henbit have physiological dormancy that can be broken by after-ripening in dry state storage, or by dormancy releasing treatments such as light, gibberellins, and warm/cold alternating exposures after imbibing water once mature (Kucera et al. 2005).

Timing or date of a plant species emergence is important in determining the growth, performance, and survival of plants (Miller 1987). Henbit emergence is strongly affected by soil temperature (Baskin and Baskin 1981; Baskin and Baskin 1984). Fully ripened seed had greater than 95% germination when temperatures were within a range of 15/6 to 30/15 C. Additionally, an upper threshold was indicated, with no germination of henbit seeds occurring at 35/20 C, and lower numbers occurring at 5 to 10 C. Germination of autumn produced seed occurred at high percentages the following year in the presence of light when exposed to high temperatures during the preceding summer (Baskin and Baskin 1981). Conversely, low winter temperatures can cause seed produced in autumn and non-dormant seeds to become dormant showing an ecological consequence to temperature fluctuations (Baskin and Baskin 1984).

The presence of henbit when seeding a summer annual crop may interfere with the crops planting, growth, and development. Cocksfoot (*Dactylis glomerata* L.) final size was greater following early emergence compared to later emergence due to a competitive advantage of longer growth period, regardless of the final plant density (Ross and Harper 1972). Similarly, Carolina geranium (*Geranium carolinianum* L.) sown in late-May, June, or July in North Carolina, developed more leaves, reached rosette stage, flowered earlier, and had higher fecundity when planted in May (Roach 1986).

Understanding weed emergence and growth rate is important for development of management strategies, as poor weed control can result from improper timing of herbicide applications (Horak and Loughlin 2002). Research was conducted to evaluate seasonal henbit emergence in Louisiana as a means to assist in the development of herbicide control strategies for crop producers.

Materials and Methods

A study to evaluate henbit seasonal emergence was conducted in 2011/2012, 2012/2013, 2013/2014, and 2014/2015 at the Northeast Research Station in St. Joseph, and a producer farm in Concordia Parish near Jonesville, Dean Lee Research and Extension Center near Alexandria and Louisiana State University Agricultural Center Ben Hur Research Farm in Baton Rouge, from north to south. Six, 1 m^{-2} plots were established in mid-September of each year at each location in areas where corn, cotton, or soybean were produced the preceding summer. Crop management practices prior to implementation of each experiment was not considered a factor in the study. Total number of emerged henbit were counted weekly from mid-September through late-March. A weather station (WatchDog 100 Weather Station, Spectrum Technologies, 360 Thayer Ct., Aurora, IL 60504) was placed at each location each year to record air temperature, soil temperature at a 2.5 cm depth, rainfall, and solar radiation on an hourly basis for the duration of each experiment to determine if environmental variables could predict henbit emergence. Additionally, soil degree-day (SDD) was calculated on a weekly basis using the following formula:

$$\text{Weekly SDD} = T_{mean} - T_{base}$$

Where T_{mean} is the mean soil temperature recorded over the weekly interval and T_{base} equals 0 C. Base temperature of 0 C has been commonly used for winter annual weeds (Ball et al. 2004; Bullied et al. 2003). After each count, paraquat at 0.56 kg ai ha^{-1} plus a nonionic surfactant at 0.25% v/v was applied to remove all henbit and other vegetation to enable evaluation of newly emerged henbit the following week.

Data were subjected to multivariate analysis using PROC IM followed by PROC REG in SAS (release 9.4, SAS Institute, 100 SAS Campus Drive, Cary, NC 27513) that utilized the R-square and Mallows' C_p selection methods and PROC DTREE in SAS to develop a decision tree. Both statistical methods were used to determine if the environmental variables and/or SDD could predict weekly henbit emergence. Factors included in all analyses were weekly henbit emergence data and all environmental variables measured.

Results and Discussions

Statistical analyses of environmental variables and SDD were unable to predict henbit emergence (data not shown; Appendix 2.1; 2.2). The analyses did indicate that a prior week's emergence can predict the following week's emergence, but that would be an ineffective tool for crop producers to predict emergence for implementation of management strategies. Therefore, data will be used to document henbit emergence at each location in Louisiana. Based on data from all locations henbit emerged from September through March (Figure 2.1). Additionally, for the majority of the sampling dates at all locations henbit emergence was no more than 200 plants m^{-2}. At the Northeast Research Station, at least 50 henbit m^{-2} were observed between 24-Oct and 12-Dec in 2011/2012, 2012/2013, and 2013/2014 with 25 and 39 henbit m^{-2} observed the weeks of 24-Nov and 5-Dec, respectively, in 2014/2015 (Figure 2.2). Similarly, at least 50 henbit m^{-2} emerged in Concordia Parish between the weeks of 10-Oct and 19-Dec in 2011/2012, 2012/2013, and 2014/2015 (Figure 2.3). Emergence of 400 henbit m^{-2} was observed the weeks of 14-Nov in 2011/2012 and 28-Nov 2012/2013, indicating the potential for high henbit density at this location. In 2011/2012, at least 50 henbit m^{-2} were counted each week beginning 24-Oct through 26-Dec at the Dean Lee Research and Extension Center, and henbit densities of greater than 200 m^{-2} were observed for 6 consecutive weeks (Figure 2.4).

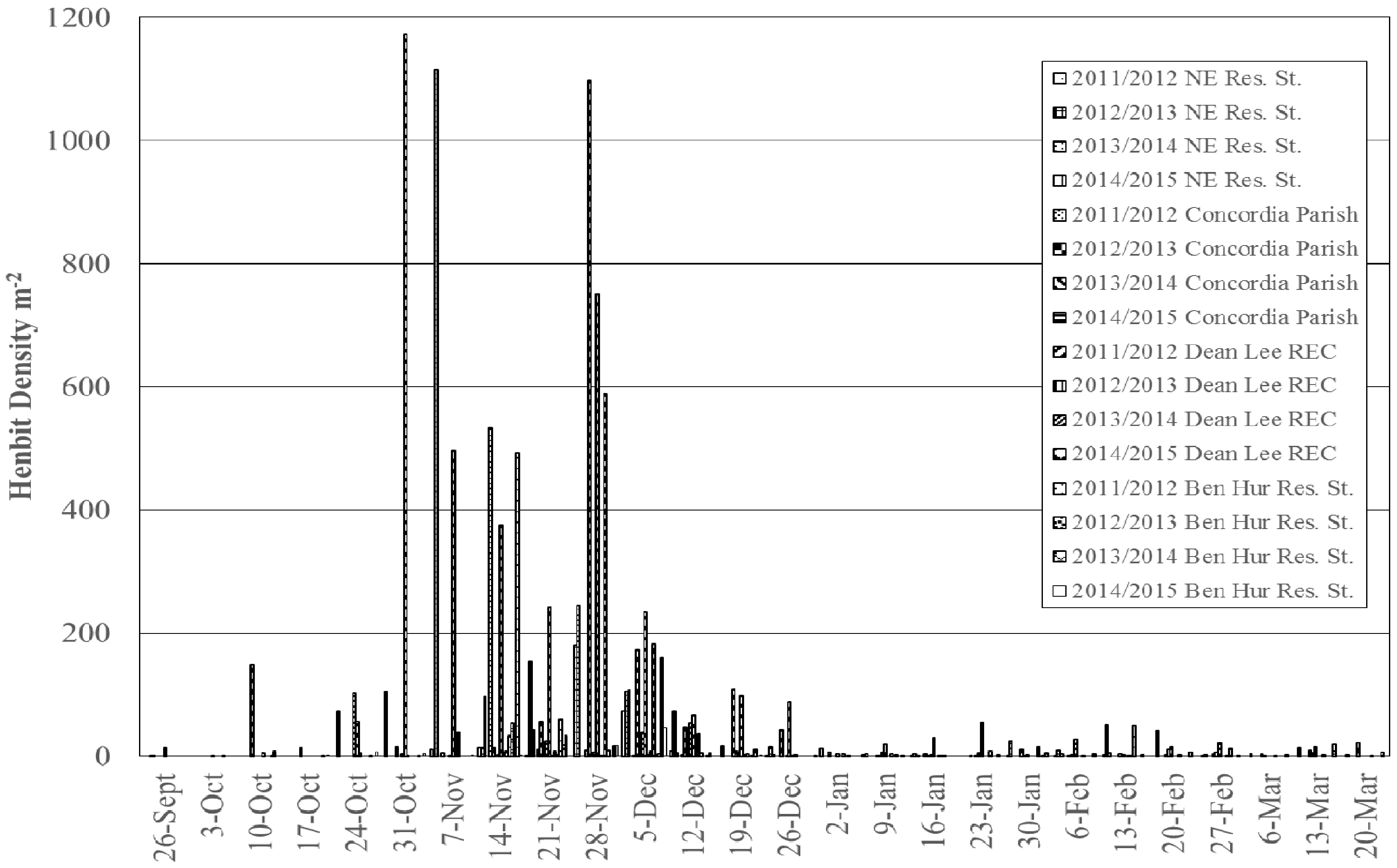

Figure 2.1. Henbit density m^{-2} at the Northeast Research Station in St. Joseph, a producer field in Concordia Parish near Jonesville, Dean Lee Research and Extension Center near Alexandria, and the Ben Hur Research Farm in Baton Rouge determined weekly from 26-Sept. through 20-Mar. in 2011/2012, 2012/2013, 2013/2014, and 2014/2015.

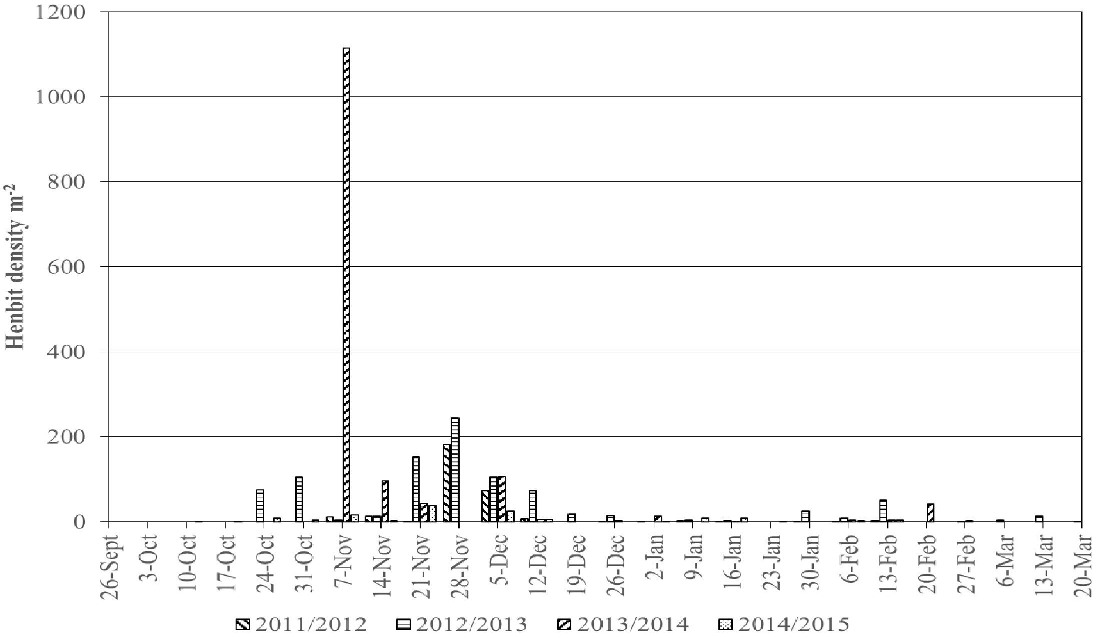

Figure 2.2. Henbit density m^{-2} at the Northeast Research Station in St. Joseph counted weekly from 26-Sept. through 20-Mar. in 2011/2012, 2012/2013, 2013/2014, and 2014/2015.

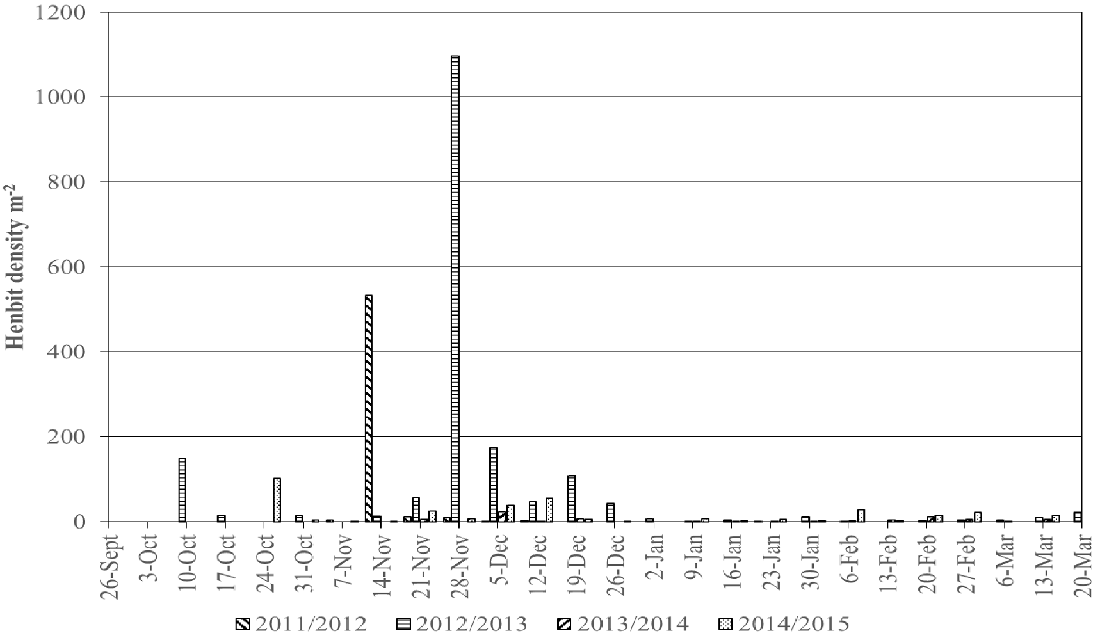

Figure 2.3. Henbit density m^{-2} at a producer field in Concordia Parish near Jonesville counted weekly from 26-Sept. through 20-Mar. in 2011/2012, 2012/2013, 2013/2014, and 2014/2015.

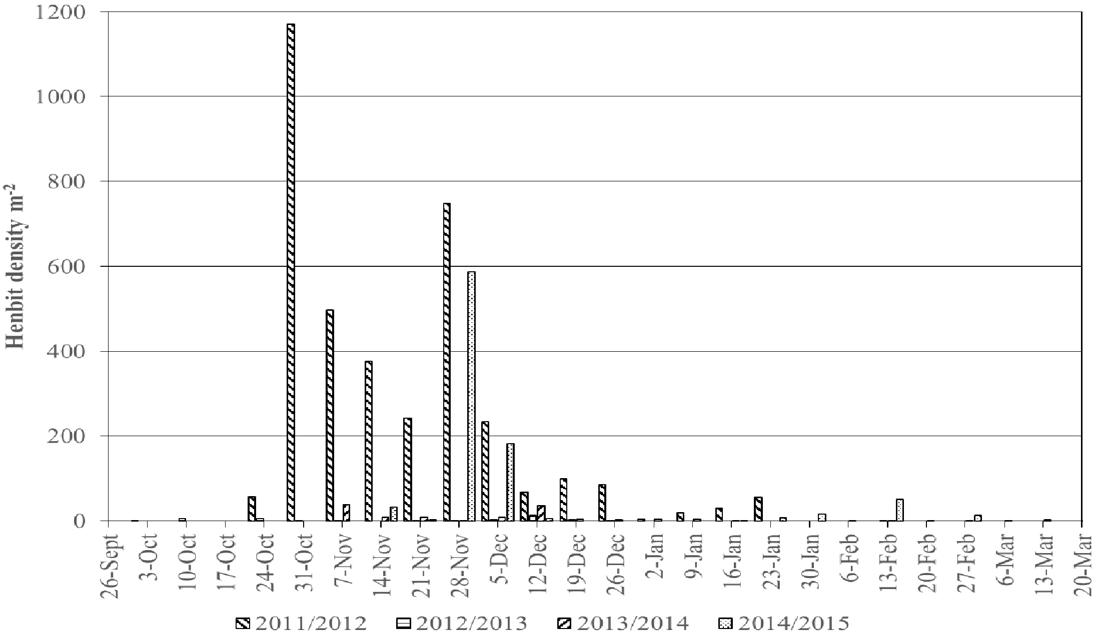

Figure 2.4. Henbit density m^{-2} at the Dean Lee Research and Extension Center near Alexandria counted weekly from 26-Sept. through 20-Mar. in 2011/2012, 2012/2013, 2013/2014, and 2014/2015.

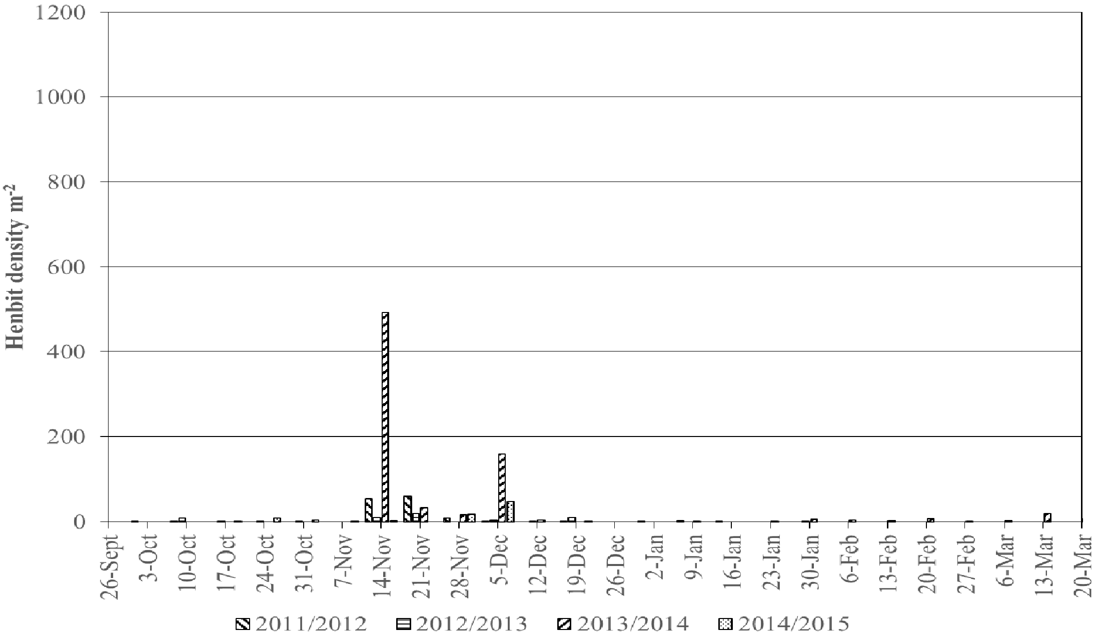

Figure 2.5. Henbit density m^{-2} at the Ben Hur Research Farm in Baton Rouge counted weekly from 26-Sept. through 20-Mar. in 2011/2012, 2012/2013, 2013/2014, and 2014/2015

However, henbit emergence, did not exceed 40 m^{-2} in 2012/2013 and 2013/2014, but densities of 588 and 182 m^{-2} were observed the weeks of 28-Nov and 5-Dec in 2014/2015, respectively. Regardless of year, henbit densities at the Ben Hur Research Farm were less than other locations (Figure 2.1). Densities greater than 50 m^{-2} was observed at Ben Hur the weeks of 14-Nov and 21-Nov in 2011/2012, 14-Nov in 2013/2014, and 5-Dec in 2013/2014 and 2014/2015 (Figure 2.5).

Although multivariate analysis showed that environmental conditions could not be used to predicted henbit emergence, data did show trend toward increased emergence when soil temperatures averaged between 10 and 18.5 C. At all locations in each year this range in soil temperature occurred during the weeks of 17-Oct to 12-Dec. Blackshaw et al. (2002) reported that henbit emerged when soil temperatures ranged from 5 to 25 C, and germination was 92% germination when soil temperature was 15 to 20 C.

Overall greatest henbit emergence generally occurred between mid-October through mid-December at all locations in Louisiana. Densities greater than 1000 m^{-2} were observed at the Northeast Research Station, Concordia Parish site, and the Dean Lee Research and Extension Center in some years, indicating the potential for severe henbit infestations at these locations. Therefore, an effective emergence management strategy should include use of residual herbicide applied in October to halt emergence of henbit, or tillage during the October through mid-December.

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CHAPTER 3
IMPACT OF EMERGENCE DATE ON HENBIT (Lamium amplexicaule L.) GROWTH

Introduction

Henbit (*Lamium amplexicaule* L.) is a winter annual weed belonging to the Labiatae family. Henbit is adapted the temperate areas of the world, a wide variety of soils (Holm et al. 1997), and now widely naturalized in the United States (USDA-NRCS 2015). Newly emerged henbit seedlings are oval with smooth cotyledons. Leaves are rounded, coarsely toothed, and palmately veined, flowers are tubular pink to purplish with a bearded upper and lobed spotted lower lip (Holm et al. 1997).

Although henbit is a winter annual weed, Webster (2013) stated that henbit is the fifth and sixth most troublesome weed in Louisiana cotton and soybean, respectively. Henbit's troublesome nature in Louisiana cotton and soybean may be due to the difficulty in control following spring herbicide applications prior to seeding a summer annual crop (D. O. Stephenson, IV, personal communication). Growth, performance, and survival of a plant species is dictated by timing or date of emergence (Miller 1987). Differences in germination and rates of growth among weedy species have been documented. Sulfonylurea-susceptible prickly lettuce (*Lactuca serriola* L.) gained 31% more aboveground biomass 52% faster than the resistant biotype (Alcocer-Ruthling et al. 1992a). However, germination was faster in sulfonylurea-resistant prickly lettuce than the susceptible biotype, but no differences were found in their fecundity or seed viability (Alcocer-Ruthling et al. 1992b). Similiarly, cumulative germination of chlorsulfuron-resistant and -susceptible kochia [*Kochia scoparia* (L.) Schrad.] biotypes were similar at 28 C; however, the resistant biotype germinated faster at 8 and 18 C (Thompson et al.

1994a). Additionally, no differences in growth, competitiveness, or seed production was observed with both biotypes producing 12,000 seed per plant with a relative competiveness of 0.75 and 0.85 for the resistant and susceptible biotypes, respectively (Thompson et al. 1994b).

A plants ability to adapt when subjected to variables inherent to a local environment has been documented by others. Accessions of entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray) from southern latitudes remained vegetative longer which lead to increased biomass compared to northern accessions (Klingaman and Oliver 1996). Similarly, differences in vine length, leaf size and shape, and days to flower initiation was observed among pitted morningglory (*Ipomoea lacunosa* L.) accessions collected from different geographic locations (Stephenson et al. 2006). Furthermore, accessions of Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.] differed in height, node formation, branching, flower, and fruiting habits (Cardina and Brecke 1989).

Plant growth analysis can elucidate competitive ability of a species utilizing parameters to determine growth and development of plant systems in a controlled, semi-natural, or natural condition (Hunt 2003). Total dry matter production and leaf area are basic processes of vegetative growth (Radosevich et al. 1997). Therefore, growth measurements such as dry weights of a plant and leaf area recorded over time can show the relative size, productivity, and photosynthetic capability of the plant. Ragweed parthenium growth during summer and winter months was compared by Pandey et al. (2003) using various growth parameters. Lower net assimilation rate (NAR) and relative growth rate (RGR) was observed when ragweed parthenium grew during the winter months due to a decrease in net photosynthetic rate caused by low air temperatures. Net assimilation rate is the measure of total dry matter net gain per unit of leaf area (James and Drenovsky 2007; Lambers et al. 2008; Poorter and Remkes 1990). NAR determines photosynthetic efficiency by reflecting the ratio of carbon gain during photosynthesis and carbon loss through respiration (Forbes and Watson 1992; Poorter and Bergkotte 1992). Environmental conditions can reduce this efficiency (Williams 1946). Additionally, RGR is the increase of the total dry weight of a plant over a unit of time, and is a central parameter in plant growth analysis which is determined by differences in physiology, morphology, and partitioning assimilates to biomass (Kriedemann et al. 1999). Furthermore, favorable environments for plant growth typically leads to higher RGR. High leaf area ratio can indicate competitive advantage in weedy species. While evaluating accessions from various locations in the US, both Bond and Oliver (2006) and VanGessel et al. (1998) found accessions, Palmer amaranth (*Amaranthus palmeri* S. Wats) and spurred anoda [*Anoda cristata* (L.) Schllecht.], respectively, originating from warmer climates produced higher leaf area ratio, indicating a competitive advantage for these populations. Plant LAR is the most important variable for whole plant growth and a unit measure of plant leafiness, thereby measuring photosynthetic capacity of a plant (Radosevich et al. 1997).

An understanding of weed development and growth rate would be important in development of effective management strategies, because poor weed control can result from improper timing of herbicide applications (Horak and Loughlin 2002). Therefore, the objectives of this research were to compare growth characteristics of henbit accessions differentiated by emergence date and to investigate growth changes during the growing season.

Materials and Methods

Research was conducted in 2013/2014, 2014/2015, and 2015/2016 at the Louisiana State University Agricultural Center Dean Lee Research and Extension Center near Alexandria to evaluate growth characteristics of henbit. A factorial arranged in a completely randomized design was used in all studies. Factors included henbit emergence dates of September, October, or November and destructive harvest intervals of 2, 3, 4, 6, 8, 10, and 12 wk after emergence (WAE). Individual plants were considered separate experimental units. For the emergence date treatments cotyledon henbit collected were transplanted in early September, October, or November of each year to 31 by 46 cm pots (GL 6900S #10 Squat, BWI Companies, Forest Hill, LA 71430) containing 50/50 mix of potting soil (Metro-Mix 840, Sungro Horticulture, Agawam, MA 01001) and inert sand.. Metro-Mix 840 contains a proprietary blend of starter nutrient with gypsum and slow release nitrogen. Each pot contained 50.5 liters soil, and no additional nutrients were added over duration of the trial. At each of the destructive harvest intervals, eights henbit plants were clipped at the soil surface and leaves were separated from stems and petioles. Below ground biomass was not evaluated. Total leaf area was measured photometrically (LI-COR 3100 leaf area meter, 4647 Superior Street, Lincoln, NE 68504). Leaves and stems of each plant were oven-dried separately at 56 C for 7 d. After drying, leaf and stems with petioles weight were measured and used to determine total dry weights. Average monthly temperatures and rainfall totals were recorded and compiled for September through February of each growing season from the Louisiana Agriclimatic Information System (LAIS) automated weather station located at the Dean Lee Research and Extension Center (Table 3.1).

Table 3.1. Maximum and minimum air temperature and rainfall average for each month of study duration in 2013 through 2016.

3 year average	Sept	Oct	Nov	Dec	Jan	Feb
Maximum temperature[a]	32.2	27.2	19.4	17.2	14.4	16.6
Minimum temperature[a]	20.5	14.4	7.7	6.6	2.2	5.0
Rainfall[b]	11.7	15.5	15.5	10.2	10.4	8.9

[a] Temperature in Celsius

[b] Rainfall in centimeters

Values of leaf area ratio (LAR), net assimilation rate (NAR), relative growth rate (RGR), specific leaf area (SLA), specific leaf weight (SLW), and stem-to-leaf ratio (SLR) were calculated on a per-plant basis at each harvest interval. These values were calculated with the following formulas:

$$LAR = L_a \times W_t^{-1}$$

$$NAR = [(W_{t2} - W_{t1}) \times (T_2 - T_1)^{-1}] \times [(\ln L_{a2} - \ln L_{a1}) \times (L_{a2} - L_{a1})^{-1}]$$

$$RGR = (\ln W_{t2} - \ln W_{t1}) \times (T_2 - T_1)^{-1}$$

$$SLA = L_a \times W_l^{-1}$$

$$SLR = W_s \times W_l^{-1}$$

$$SLW = W_l \times L_a^{-1}$$

where L_a is total leaf area, L_{a1} is total leaf area at time 1; L_{a2} is total leaf area at time 2, W_t, W_l, W_s are dry weights of whole plants (total), leaves, and stems, respectively; W_{t1} is whole plant weight at time 1; W_{t2} is whole plant weight at time 2; T_1 is harvest time at time 1; T_2 is harvest time at time 2.

All data were subjected to analysis of variance using PROC GLIMMIX in SAS (SAS/STAT, version 9.3, SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513) with emergence date, harvest interval, and their interaction as fixed effects and years, plant, and their interaction as random variables. Considering year an environmental or random effect permits inferences about treatments to be made over a range of environments (Blouin et al. 2011; Carmer et al. 1989). Least square means were calculated for main effects and their interactions, and separated using Tukey's honest significant difference test at the $P \leq 0.05$.

Results and Discussions

Leaf Area Ratio. (Horak and Loughlin 2000) LAR is a measure of the proportion of plant biomass invested in leaf area= leaf area x total plant dry weight; thus, greater plant LAR may have greater photosynthetic capacity. Main effects of emergence date and harvest interval were detected for LAR (Table 3.2). Leaf area ratio for henbit emerging in September, October, and November was were 0.012, 0.01, and 0.008 $cm^2\ g^{-1}$ respectively, with the November henbit having 33% less LAR then the September emerged henbit (Table 3.3). In addition, averaged across emergence dates, henbit LAR was greater at the 2, 3, and 4 WAE harvest intervals compared with 8, 10, and 12 WAE (Table 3.4). Leaf area ratio data show that September emerged plants regardless of harvest interval were larger than November emerged henbit, which may be a function of greater photosynthetic capacity. Visual observations noted that September emerged henbit plants were larger and more vigorous than plants emerging in November. Additionally, the reduced LAR from 8 to 12 WAE harvest intervals may suggest that allocation of resources to leaf production was greater for henbit emerging at 4 weeks and earlier (Table 3.4).

Table 3.2. Significance of the main effects of emergence date, harvest interval, and interactions among main effects. [a, b]

Parameter	Date	Harvest	Date x Harvest
		P-value	
Leaf area ratio (LAR)	0.0036	<.0001	0.7037
Net assimilation rate (NAR)	0.1439	0.3073	0.6055
Relative growth rate (RGR)	<.0001	0.2848	0.9425
Specific leaf area (SLA)	0.8243	0.2307	0.5804
Stem leaf ratio (SLR)	0.1739	0.3973	0.4486
Specific leaf weight (SLW)	0.0114	0.7138	0.7274

[a] Main effects and interactions considered significant for Type III error if $P \leq 0.05$.

[b] Data for main effects and interactions not significant at $P \leq 0.05$ are shown in Appendix 3.1 through 3.3.

Table 3.3. Leaf area ratio, relative growth rate, and specific leaf weight as influenced by henbit emergence date.

Emergence date	Leaf area ratio	Relative growth rate	Specific leaf weight
	cm^{2} g^{-1}	g g^{-1} d^{-1}	g cm^{-2}
September	0.012 a	0.194 a	53.7 b
October	0.010 ab	0.121 b	88.7 ab
November	0.008 b	0.092 b	119.0 a

[a] Data pooled over harvest interval. Means followed by the same letter for each parameter are not significantly different according to Tukey’s honest significant difference test at $P \leq 0.05$.

Table 3.4. Leaf area ratio as influenced by henbit harvest interval.[a]

	cm^{2} g^{-1}
wk 2	0.013 a
wk 3	0.013 a
wk 4	0.013 a
wk 6	0.011 ab
wk 8	0.008 b
wk 10	0.007 b
wk 12	0.007 b

[a] Data pooled over emergence date. Means followed by the same letter are not significantly different according to Tukey’s honest significant difference test at $P \leq 0.05$.

Net Assimilation Rate. Net assimilation rate is a net gain in total dry matter per unit leaf area at each harvest interval (James and Drenovsky 2007). This measurement determines photosynthetic efficiency by reflecting the ratio of carbon gain during photosynthesis and carbon loss through respiration (Forbes and Watson 1992). For NAR significant effects due to henbit emergence date, harvest interval, and their interaction were not observed (Table 3.2). For September, October, and November emerged henbit, NAR ranged from -122.8 to 226.0 g cm^{-2} d^{-1} (data not shown; Appendix 3.1). In addition, harvest interval NAR ranged from -286.6 to 252.9 g cm^{-2} d^{-1} (data not shown; Appendix 3.2). Light is important in net assimilation with longer illumination times indicating more biomass. Compensation point is where light intensity and photosynthesis cancel each other out which is called zero net assimilation rate (Forbes and Watson 1992). The lack of differences observed possibly indicates that October emerged henbit may better balance photosynthesis and respiration, whereas September and November populations at -122.8 and 226.0 respectively, (data not shown; Appendix 3.1) have greater photosynthetic/respiration imbalance due to carbon allocation. This carbon allocation may be better reflected by LAR and RGR. Faster growing plants like September emerged henbit assimilate carbon in new growth, especially leaf growth, whereas November emerged plants, which were slower growing, use more carbon in respiration and root growth (Lambers et al. 2008).

Relative Growth Rate. Differences in henbit emergence date for RGR were observed, but there were no differences among harvest intervals or for the interaction (Table 3.2). September emerged henbit RGR was 0.194 g g^{-1} d^{-1}, which was greater than both October and November emerged henbit with 0.121 and 0.092 g g^{-1} d^{-1}, respectively (Table 3.3). Relative growth rate is the rate of increase of the total dry weight of a plant over a unit of time, which is calculated utilizing LAR and NAR (Kriedemann et al. 1999). In addition, they noted that the role of LAR as a driving variable in a plant's relative growth rate and thus is more important than its net assimilation rate. Poorter and Remkes (1990) found NAR to be not strongly correlated to RGR. Therefore, more light was available for leaf production, inducing greater LAR for the September emerged henbit. This higher leaf area intercepted more light then the November population, leading to the increase in the September population's RGR compared to November. Henbit harvest interval RGR ranged from 0.121 to 0.154 g g^{-1} d^{-1} (data not shown; Appendix 3.2).

Specific Leaf Area. Specific leaf area is a calculation of leaf area of the plant to dry leaf weight (Kvet et al 1971), thus reflects the density or relative thickness of leaves. However, prevailing view states that SLA reflects plant utilization of resources in rich or poor environments (Wilson et al. 1999). Henbit emergence date, harvest interval, and their interaction were not significant (Table 3.2). Specific leaf area for the September, October, and November populations ranged from 0.016 to 0.018 cm^2 g^{-1} (data not shown; Appendix 3.1). The range of SLA over harvest interval was 0.013 to 0.023 cm^2 g^{-1} (data not shown; Appendix 3.3). All cotyledon plants were transplanted and grown for the trial duration in 50.5 liters of Metro-Mix 840, which contain a starter nutrient with gypsum and slow release nitrogen; therefore, all plants were subject to equal growing conditions, thus eliminating a variable that would cause significant difference in SLA.

Specific Leaf Weight. Specific leaf weight is a predictive index of previous light environment and net photosynthetic potential (Barden 1977; Pearce et al 1969). Although SLW and SLA both measure leaf thickness, SLW assesses the physiological processes occurring in the functioning of total plant leaf area or total canopy by taking into account light, nitrogen status, and other stressors and SLA measures the change in leaf area index as a plant adds growth through nutrients assimilation (Field and Mooney 1986).

Differences in henbit emergence date were observed for SLW, but there were no-significant differences among harvest intervals or for their interaction (Table 3.2). Specific leaf weight for November emerged henbit was 119 g cm^{-2}, which was equal to October (88.7 g cm^{-2}), but greater than September (53.7 g cm^{-2}) (Table 3.3). Poorter and Bergkotte (1992) reported that low SLW is associated with high RGR, thus greater leaf area with ability to intercept more light. Henbit emerging in November had greater SLW than henbit emerging in September (Table 3.3), but smaller leaf area and lower RGR (Table 3.3). November emerging henbit populations were subject to less available daylight (approximately 10.5 hours) compared with henbit emerging in September and October (approximately 12.5 and 11.5 daylight hours, respectively). This may help explain why November henbit populations had thicker leaves and thus a higher SLW. A greater concentration of photosynthetic apparatus per unit leaf area with more sun facing leaves to increase net photosynthetic potential in a lower light environment has been reported by Brown and Byrd (1997). It should also be noted that henbit emerging in November would have been under greater environmental stress than September and October populations due to increased rainfall and cooler growing temperatures over the 12 wk harvest intervals (Table 3.1), providing yet another factor that may increase SLW.

Stem-to-Leaf Ratio. Henbit emergence date, harvest interval, and their interaction were not significant (Table 3.1). Stem-to-leaf ratio was 0.623, 0.630, and 0.985 g g^{-1} for the September, October, and November emerged henbit, respectively (data not shown; Appendix 3.1). Furthermore, SLR ranged from 0.374 to 1.015 g g^{-1} across henbit harvest intervals (data not shown; Appendix 3.3). SLR is a ratio of stem to leaf dry matter describing plant allocation of resources (Bond and Oliver 2006). The flow of assimilates shifts from leaves to meristematic tissue and fruit structure components within a plant, are dictated by developmental lifecycle needs (Singh et al. 2008). Although not significant, the SLR of 0.717 g g^{-1} at the 2 wk suggests production of more leaves, and then a gradual increase of allocations to reproduction for weeks 6 to 12; 0.809 and 1.015 g g^{-1}, respectively (Appendix 3.3). It is possible that differences would have been found if henbit was harvested at 14 and 16 week intervals.

Differences in henbit growth and development were observed among emergence dates and were reflected in LAR, RGR and SLW. Photosynthetic capacity and efficiency were greater for September emerged henbit, which may indicate a competitive advantage over November emerged henbit. October populations had similar trends and were not different than September emerged henbit, conceding that any competitive advantage September may have over October is slight. November emerged henbit was subject to colder environmental conditions with less daylight and greater rainfall, thus allocating resources and maintaining fitness over 12 weeks is more difficult metabolically. Low temperatures reduces net photosynthesis by slowing photosynthetic. Slow photosynthetic rate reduces new leaf development because plants depend on photosynthetic area and rate for growth (Beale et al. 1996). Leaf area ratio, RGR, and SLW for November emerged henbit substantiate field observations of much smaller overall plants, with thickened leaves. Differences in henbit growth was also observed among henbit intervals for LAR. It was observed that September emerged henbit has begun to senesce 12 WAE, which may indicate a shorter lifecycle than October and November populations; however, this was not reflected in the data. It is possible that greater differences in emergence date, harvest interval, and their interaction could have been documented if harvest interval was extended to 16 or 18 WAE. Overall, the data suggests that difficultly in controlling henbit emerging in September and/or October with herbicide treatments in the spring of the year maybe due to hardening off and senescence, which would reduce leaf area potentially leading to reduced herbicide absorption and subsequent translocation.

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CHAPTER 4
EVALUATION OF FALL-APPLIED RESIDUAL HERBICIDES FOR CONTROL OF HENBIT (LAMIUM AMPLEXICAULE L.)

Introduction

Henbit (*Lamium amplexicaule* L.) is a winter annual weed that is prevalent in more than 50 crops as well as ditch banks, roads, and field edges (Holm et al. 1997). Henbit is adapted to temperate areas and a wide variety of soils. It is naturalized in the United States; but native to Europe and the Mediterranean region (USDA-NRCS 2015). Henbit seedlings have oval, smooth cotyledons. Characteristics distinctive to henbit include, palmately veined leaves, occurring in opposite pairs along the stem, tubular pink to purplish flowers and a lobed spotted lower lip (DeFelice 2005; Holm et al. 1997). Webster (2013) stated that henbit is the fifth and sixth most troublesome weed in Louisiana cotton and soybean, respectively. Henbit's troublesome nature in Louisiana crops may be due to the difficulty in control with spring herbicide applications prior to seeding a summer annual crop (D. O. Stephenson, IV, personal communication).

Winter weed vegetation following several months of growth prior to planting a summer annual crop can reach heights up to 1 m (Stougaard et al. 1984). Fall applied herbicides targeting winter weeds when small provided greater control than spring applications (Hasty et al. 2004). Fall applied herbicide provided excellent control of winter weeds (Young and Krausz 2001). Fall-applied residual herbicides such as atrazine, rimsulfuron plus thifensulfuron, and simazine controlled mouseear chickweed [*Cerastium fontanum ssp. vulgare* (Hartman) Greuter & Burdet] and henbit 93% prior to planting a spring annual crop (Krausz et al. 2003) Similarly, Monnig and Bradley (2007) reported henbit control of 94% at soybean planting after application of residual herbicides in the fall. Co-application of 2, 4-D with residual herbicides, applied 7 days before planting, controlled of annual fleabane (*Erigeron annuus* (L.) Pers.), corn speedwell (*Veronica arvensis* L.), field pennycress (*Thlaspi arvense* L.), henbit, and shepherd's-purse [*Capsella bursa-pastoris* (L.) Medik.] 37 to 75% at planting (Monnig and Bradley 2007). These same herbicide treatments applied in the fall controlled weeds was greater than 95%. Likewise, chlorimuron plus metribuzin or sulfentrazone with or without glyphosate plus 2, 4-D applied in fall provided 99% control of purple deadnettle (*Lamium purpureum* L.), another *Lamium* species like henbit, at soybean planting compared to 48% control following glyphosate plus 2,4-D applied 30 d preplant (Hasty et al. 2004), also showing an advantage to fall-applied herbicide application for control of lamium spp. Although fall glyphosate-resistant (GR) horseweed [*Conyza Canadensis* (L.) *Cronq.*] applied residual herbicides controlled greater than 86% 190 days after application herbicide degradation due to spring moisture and increased temperatures warranted a spring herbicide application (Owen et al. 2009). Cotton (*Gossipium hirsutum* L.) yields were greater when residual herbicides were applied in fall compared with dicamba applied alone in the spring.

When seeding a summer annual crop, uncontrolled henbit may interfere with crop planting, growth, and development via direct competition or through harboring of other pests. Application of efficacious herbicides in fall can reduce producer workload in spring and aid in timely planting of the crop (Hasty et al. 2004; Krausz et al. 2003). Additionally, reduced vegetative cover following fall herbicide applications can result in increased soil temperatures in the spring (Bruce et al. 2000). A weed free seed bed would be beneficial to crop emergence and summer crops must compete with winter annual weeds for nutrients and water resources (Bernards and Sandell 2011). Presence of winter vegetation can be detrimental to crop growth and yield because some annual weeds can serve as host for soybean cyst nematode (*Heterodera glycines*) (Creech et al. 2007; Venkatesh et al. 2000; Werle et al. 2013).

Considering the significant populations of henbit in Louisiana along with the poor control reported by Louisiana crop producers with spring-applied herbicides, there is a need for development of control programs for henbit. The objective of this research was to investigate the effect of application dates and residual herbicides for henbit control.

Materials and Methods

Experiments were conducted in 2012/2013, 2013/2014, and 2014/2015 at the Louisiana State University Agricultural Center Dean Lee Research and Extension Center near Alexandria. Soil was a Coushatta silt loam (fine-silty, mixed, superactive, thermic Fluventic Entrudept), with a pH of 8.0 and 1.5% organic matter. An augmented factorial arranged in a randomized complete block design replicated four times was used in all studies. Factors consisted of five application dates, seven herbicide treatments, and a nontreated. The five application dates were Oct 15, Nov 1, Nov 15, Dec 1, and Dec 15 +/- 3 days. The seven herbicide treatments were diuron at 840 g ai ha^{-1}, flumioxazin at 72 g ai ha^{-1}, oxyfluorfen at 280 g ai ha^{-1}, pyroxasulfone at 150 g ai ha^{-1}, prepackaged mixture of rimsulfuron: thifensulfuron-methyl at 18:18 g ai ha^{-1}, *S*-metolachlor at 1420 g ai ha^{-1}, and a non-residual herbicide treatment. Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v was co-applied with all residual herbicide treatments to control emerged henbit at time of application and allow for evaluation of residual herbicides. Plot size was 2 m wide by 9 m in length. All herbicide treatments were applied with a CO_2-pressurized sprayer calibrated to deliver 187 L ha^{-1} at 145 kPa using TeeJet 11002 flat-fan nozzles (Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189).

Visual evaluations of henbit control (0 = no control; 100 = no henbit plants present) were collected 28, 50, 85, and 100 d after each application; however, only 28 and 100 DAT control data are presented to illustrate short- and long-term henbit control. Henbit density and heights were recorded in three, randomly selected m^2 in each plot 28 and 100 DAT, but only 100 DAT density and height are presented. Prior to analysis, henbit height and density were converted to a percentage of the nontreated. Control data collected 50 and 85 DAT and henbit density and height as a percent of the nontreated collected 28 DAT are shown in Appendices 4.1 through 4.12.

Homogeneity of data was tested with PROC UNIVARIATE in SAS (SAS/STAT, version 9.3, SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513). Analysis indicated that data did not follow a normal distribution; therefore, henbit control, height, and density were arcsine square-root transformed. Using appropriate transformation allows for correction of data that may have non-normality, non-additivity, and heterogeneity of variance (Ahrens et al. 1990; Bartlett 1947; Fernandez 1992; Finney 1989). Transformed data were subjected to PROC GLIMMIX in SAS with year, application date, and herbicide as fixed effects and replication as a random effect. Analysis indicated a year interaction, therefore, data were reanalyzed separately by year. Least square means were calculated and separated using Tukey’s honest significant difference test at $P \leq 0.05$. Non-transformed means for each year are presented for discussion.

Results and Discussions

Precipitation, either via rainfall or irrigation, is required for activation of residual herbicides. Norsworthy et al. (2012) stated that environmental conditions, such as temperature, rainfall, and soil moisture, may influence the application or activation of residual herbicides. In these studies, rainfall greatly influenced the efficacy of residual herbicides at all application dates. Table 4.1 provides the number of days following application until first rain event, the rainfall amount at the first event, and total rainfall recorded during the month following each application to highlight the lack of or excessive rainfall that influenced the data.

Table 4.1. Number of days between the herbicide application and first rainfall event, amount of rainfall at first event, and total amount of rainfall for the month following the application for each application date in 2013, 2014, and 2015

Year	Application Date	Days between herbicide application and first rainfall event	Rainfall amount at first event	Rainfall amount total for the month following the application
		no. of d	cm	
2012/2013	Oct 15	0	0.13	1.40
	Nov 1	3	0.79	1.60
	Nov 15	11	0.33	4.30
	Dec 1	3	0.10	16.50
	Dec 15	2	4.40	41.50
	Average	4	1.10	13.10
2013/2014	Oct 15	2	0.03	8.80
	Nov 1	0	0.03	9.80
	Nov 15	2	0.03	11.70
	Dec 1	2	0.25	3.80
	Dec 15	5	1.40	6.80
	Average	2	0.36	8.20
2014/2015	Oct 15	6	0.03	8.20
	Nov 1	1	0.18	8.20
	Nov 15	2	5.56	7.80
	Dec 1	12	1.52	13.90
	Dec 15	0	0.03	22.90
	Average	4	1.47	12.20

Improper activation or excessive rainfall following the application of residual herbicides can lead to variability in visual control, density, and height. Oftentimes the environmental effect can be explained; however, reasons for herbicide failure sometimes cannot be determined. Therefore, data will be discussed as general trends of the application date and/or herbicide that were the most consistent across environments, i.e.at least 70% control 28 and 100 DAT in 2 or more years, for henbit control and reduction in density and height.

The interaction of application date and herbicide were significant 28 and 100 DAT for 2012/2013, 2013/2014, and 2014/2015 (Table 4.2). Furthermore, an interaction was observed for henbit density and height as a percent of the nontreated in 2012/2013 and 2014/2015. In 2013/2014, an application date main effect was observed for henbit height as a percent of the nontreated and the herbicide main effect was detected for henbit density and height.

Overall, residual herbicides provided at least 70% henbit control 28 and 100 DAT when applied Nov 1, Nov 15, or Dec 1 (Tables 4.3; 4.4; 4.5; 4.6; 4.7; 4.8). Henbit density and height as a percent of the nontreated did not support control observations when all herbicides were applied on these three application dates due to variability among years and herbicides, but flumioxazin, oxyfluorfen, and rimsulfuron:thifensulfuron did reduce density and height to a range of 0 to 70% of the nontreated when applied Nov 1, Nov 15, or Dec 1 (Tables 4.9; 4.10; 4.11; 4.12; 4.13). Additionally, henbit height was influenced by application date in 2013/2014 with all application dates reducing height to 16 to 38% of the nontreated compared to the Oct 15 application date, which reduced height to 64% of the nontreated (data not shown; Appendix 4.13). Research of henbit emergence determined that a majority of henbit emerged between mid-October through mid-December (Chapter 2). This information supports the control values observed in these studies due to targeting either small or pre-germinated henbit with paraquat plus a residual herbicide. Multiple studies concluded that increased weed control was observed following herbicides applied to weeds 5 cm or less (Baldwin et al. 1991; Baldwin and Frans 1972; Barrentine 1989; Deflice et al. 1989; Harrison et al. 1989; Oliver 1989).

Table 4.2. Significance of the main effects of application date, herbicide, and their interactions for henbit control 28 and 100 d after treatment and henbit density and height as a percent of the nontreated 100 DAT in 2012/2013, 2013/2014, and 2014/2015.[a,b,c]

		Control		Density	Height
Year	Effect	28 DAT	100 DAT	100 DAT	100 DAT
		P-value			
2012/2013	Date	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	0.0001	0.0003
2013/2014	Date	< 0.0001	< 0.0001	0.1577	< 0.0001
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	0.8291	0.2743
2014/2015	Date	< 0.0001	< 0.0001	0.0024	0.0005
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	< 0.0001	0.0235

[a] Abbreviations: DAT, d after treatment.

[b] Main effects and their interactions are considered significant at $P \leq 0.05$.

[c] Henbit control data 50 and 85 d after treatment and henbit density and height as a percent of the nontreated 28 DAT for each year are shown in the Appendix.

Table 4.3. Henbit control as influenced by application date and herbicide 28 d after treatment in 2012/2013.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	0 j	74 cdef	90 abc	86 abcde	51 fgh
flumioxazin	29 hi	81 bcde	92 abc	91 abc	96 ab
oxyfluorfen	88 abcd	99 a	99 a	96 ab	99 a
pyroxasulfone	0 j	92 abc	91 abc	93 ab	35 ghi
rimsulfuron:thifensulfuron	0 j	84 abcde	90 abc	89 abc	60 efg
S-metolachlor	0 j	86 abcd	91 abc	97 ab	20 i
no residual	0 j	75 cdef	0 j	63 defg	0 j

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.4. Henbit control as influenced by application date and herbicide 100 d after treatment in 2012/2013.[a]

Herbicide[b]	Application date				
	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	0 e	83 ab	36 d	92 ab	0 e
flumioxazin	41 d	96 ab	92 ab	99 a	75 ab
oxyfluorfen	99 a	99 a	90 ab	97 a	80 ab
pyroxasulfone	0 e	90 ab	50 cd	85 a	0 e
rimsulfuron:thifensulfuron	0 e	91 ab	98 a	99 a	94 ab
S-metolachlor	0 e	92 ab	84 ab	92 ab	0 e
no residual	0 e	0 e	0 e	15 e	0 e

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.5. Henbit control as influenced by application date and herbicide 28 d after treatment in 2013/2014.[a]

Herbicide[b]	Application date				
	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	95 ab	85 abc	97 a	98 a	94 ab
flumioxazin	98 a	99 a	99 a	93 ab	96 abc
oxyfluorfen	97 a	99 a	97 a	99 a	98 a
pyroxasulfone	70 bc	95 ab	92 ab	61 c	90 abc
rimsulfuron:thifensulfuron	95 ab	95 ab	97 a	90 abc	86 abc
S-metolachlor	97 a	99 a	96 ab	92 ab	81 abc
no residual	0 e	19 de	86 abc	0 e	21 d

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.6. Henbit control as influenced by application date and herbicide 100 d after treatment in 2013/2014.[a]

Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	Application date				
	%				
diuron	70 efg	75 bcdefg	84 abcdefg	98 ab	96 abcd
flumioxazin	80 abcdefg	90 abcdef	90 abcdef	97 abc	99 a
oxyfluorfen	85 abcdefg	97 abc	95 abcde	99 a	97 abc
pyroxasulfone	61 fg	81 abcdefg	86 abcdefg	69 defg	85 abcdefg
rimsulfuron:thifensulfuron	85 abcdefg	95 abcde	95 abcde	95 abcde	94 abcd
S-metolachlor	75 cdefg	92 abcde	90 abcdef	95 abcd	80 abcdefg
no residual	0 h	0 h	55 g	0 h	0 h

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.7 Henbit control as influenced by application date and herbicide 28 d after treatment in 2014/2015.[a]

Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	Application date				
	%				
diuron	48 ghi	68 defghi	81 abcdef	96 abc	79 abcdefg
flumioxazin	97 ab	85 Abcde	93 abcd	98 ab	99 a
oxyfluorfen	93 abc	97 Ab	95 abc	99 a	99 a
pyroxasulfone	74 cdefgh	83 abcde	85 abcde	77 abcedfg	41 hi
rimsulfuron:thifensulfuron	81 abcdefg	83 abcde	88 abcd	97 ab	10 j
S-metolachlor	39 i	63 efghi	96 abc	97 ab	61 fghi
no residual	0 j	54 fghi	68 defghi	48 ghi	78 bcdefg

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.8 Henbit control as influenced by application date and herbicide 100 d after treatment in 2014/2015.[a]

Herbicide[b]	Application date Oct 15		Nov 1		Nov 15		Dec 1		Dec 15	
	%									
diuron	46	fghi	30	defgh	39	hi	70	bcdefg	71	bcde
flumioxazin	44	ghi	61	abcd	88	abc	88	ab	93	a
oxyfluorfen	76	abcde	78	ab	76	abcde	79	abcde	90	ab
pyroxasulfone	0	j	60	abcde	65	cdefg	58	efgh	8	j
rimsulfuron:thifensulfuron	38	hi	88	a	86	abc	90	ab	78	abcde
S-metolachlor	25	i	9	i	80	abcde	88	abc	0	j
no residual	0	j	0	j	0	j	0	j	0	j

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at P ≤ 0.05.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.9. Henbit density as a percent of the nontreated as influenced by application date and herbicide treatment 100 d after treatment in 2012/2013.[a]

Herbicide[b]	Application date Oct 15		Nov 1		Nov 15		Dec 1		Dec 15	
	%									
diuron	88	abcd	89	abc	36	abcde	15	bcde	62	abcde
flumioxazin	48	abcde	0	e	0	e	0	e	0	e
oxyfluorfen	0	e	0	e	0	e	0	e	0	e
pyroxasulfone	100	a	50	abcde	93	ab	3	cde	98	ab
rimsulfuron:thifensulfuron	29	abcde	0	e	0	e	0	e	0	e
S-metolachlor	85	abcd	18	bcde	0	e	3	cde	100	a
no residual	81	abcd	0	e	48	abcde	1	de	29	abcde

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at P ≤ 0.05.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.10. Henbit height as a percent of the nontreated as influenced by application date and herbicide treatment 100 d after treatment in 2012/2013.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	100 a	100 a	50 ab	9 ab	85 ab
flumioxazin	85 ab	0 b	0 b	0 b	0 b
oxyfluorfen	0 b	0 b	0 b	0 b	0 b
pyroxasulfone	100 a	50 ab	100 a	10 ab	100 a
rimsulfuron:thifensulfuron	48 ab	0 b	0 b	0 b	0 b
S-metolachlor	85 ab	50 ab	0 b	15 ab	100 a
no residual	85 ab	0 b	78 ab	15 ab	44 ab

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.11. Henbit density and height as a percent of nontreated as influenced by herbicide treatment 100 d after treatment in 2013/2014.[a]

Herbicide[b]	Density	Height
	% of nontreated	
diuron	14 bc	39 bc
flumioxazin	7 c	17 cd
oxyfluorfen	5 c	10 d
pyroxasulfone	39 ab	44 b
rimsulfuron:thifensulfuron	5 c	12 d
S-metolachlor	26 abc	40 bc
no residual	61 a	79 a

[a] Data pooled over application date. Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.12. Henbit density as a percent of the nontreated as influenced by application date and herbicide treatment 100 d after treatment in 2014/2015.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	76 abcdef	33 abcdef	81 abcde	67 abcdef	96 ab
flumioxazin	3 ef	27 bcdef	20 bcdef	70 abcdef	7 def
oxyfluorfen	9 cdef	2 f	1 f	7 def	1 f
pyroxasulfone	94 ab	83 abcd	89 abcd	26 bcdef	62 abcdef
rimsulfuron:thifensulfuron	49 abcdef	2 f	6 def	9 cdef	3 ef
S-metolachlor	88 abcd	30 bcdef	56 abcdef	34 abccdef	65 abcdef
no residual	100 a	90 abc	85 abcd	10 cdef	30 bcdef

[a] Means followed by the same letter are not significantly different according to Tukey’s honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Table 4.13. Henbit height as a percent of the nontreated as influenced by application date and herbicide treatment 100 d after treatment in 2014/2015.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	93 abcd	54 abcdefg	87 abcdef	33 abcdefg	79 abcdefg
flumioxazin	44 abcdefg	25 abcdefg	35 abcdefg	19 abcdefg	13 cdefg
oxyfluorfen	52 abcdefg	52 abcdefg	3 fg	4 fg	0 g
pyroxasulfone	18 bcdefg	83 abcdef	53 abcdefg	41 abcdefg	64 abcdefg
rimsulfuron:thifensulfuron	31 abcdefg	6 defg	10 cdefg	3 fg	2 fg
S-metolachlor	51 abcdefg	95 abc	29 abcdefg	17 bcdefg	88 abcde
no residual	99 ab	100 a	61 abcdefg	69 abcdefg	62 abcdefg

[a] Means followed by the same letter are not significantly different according to Tukey’s honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Regardless of year or application timing, oxyfluorfen provided at least 88 and 76% henbit control 28 and 100 DAT, respectively (Tables 4.3; 4.4; 4.5; 4.6; 4.7; 4.8), which indicates that it was the most consistent fall-applied residual herbicide for henbit control. Furthermore, henbit density and height ranged from 0 to 9% and 0 to 52% of the nontreated, respectively, following oxyfluorfen 100 DAT (Tables 4.9; 4.10; 4.11; 4.12; 4.13), which corroborates control observations. Flumioxazin, rimsulfuron:thifensulfuron, and *S*-metolachlor controlled henbit 74 to 99% in at least two of three years 28 and 100 DAT when applied Nov 1, Nov 15, or Dec 1, showing that these herbicides are also options for henbit control. Furthermore, when the residual herbicide application was delayed until Dec 15, only flumioxazin and oxyfluorfen provided at least 75% control 28 and 100 DAT in all years. Diuron and pyroxasulfone provided at least 70% control only when applied Nov 1 in 2012/2013 and 2013/2014 (Tables 4.3; 4.4; 4.5; 4.6), demonstrating that they are viable fall-applied options for henbit management when applied only on Nov 1.

Residual herbicides require water, via rainfall or irrigation, for activation to provide control of weeds. However, efficacy is greatly affected by the amount of rainfall or irrigation a residual herbicide is subjected to. Physical characteristics of a herbicide such as vapor pressure, photodegradation potential, water solubility, soil adsorption coefficient (K_{oc}), and chemical and/or microbial degradation are factors that can influence residual herbicide efficacy in situations where too little or too much rainfall or irrigation occurs. Following the Oct 15 application date in 2012/2013, 0.13 cm of rainfall was recorded on the day of application and only 1.40 cm of rainfall was observed for the following month. The lack of rainfall may be the reason diuron, flumioxazin, pyroxasulfone, rimsulfuron:thifensulfuron, and *S*-metolachlor controlled henbit 41% or less 28 and 100 DAT (Tables 4.3; 4.4). However, oxyfluorfen provided 88 and 99% henbit control when applied Oct 15 in 2012/2013. Oxyfluorfen has a vapor pressure of 2.67 x 10^{-4} Pa, is not susceptible to photodegradation, a water solubility of 0.1 mg L^{-1}, and a K_{oc} of 100,000 ml g^{-1}, indicating that it will not likely be lost in either dry or wet environments (Shaner 2014). Oxyfluorfen's physical characteristics may be the reason greater efficacy was observed following the Oct 15 2012/2013 application date because it remained in henbit's germination zone. Diuron and *S*-metolachlor are both susceptible to photodegradation (Shaner 2014), which may be a possible reason for poor control following the Oct 15 2012/2013 application date. The lack of efficacy following the application of flumioxazin, pyroxasulfone, rimsulfuron:thifensulfuron cannot be explained because no physical characteristic such as photodegradation, vapor pressure, water solubility, or K_{oc} provide a reason for their failure with applied Oct 15 (Table 4.3; 4.4).

Rainfall recorded the month following the Dec 15 application dates in 2012/2013 and 2014/2015 was 41.5 and 22.9 cm of rainfall, respectively (Table 4.1). Following the Dec 15 2012/2013 and 2014/2015 applications, flumioxazin and oxyfluorfen controlled henbit at least 96% 28 DAT (Table 4.3; 4.7). However, at 100 DAT, flumioxazin, oxyfluorfen, and rimsulfuron:thifensulfuron provided 75 to 94% henbit control in 2012/2013 and 2014/2015 (Table 4.4; 4.8). Control data is supported by henbit density and height as a percent of the nontreated with density of 0% and height ranging from 0 to 13% of the nontreated (Tables 4.9; 4.10; 4.13; 4.14). Low water solubility and high K_{oc} values of flumioxazin, oxyfluorfen, rimsulfuron, and thifensulfuron, indicating low leaching potential through the soil profile and high adsorbed to soil (Shaner 2014), may be two reasons these herbicides provided greater than 70% control following high rainfall amounts in the month following application. Diuron did not control henbit 100 DAT and henbit density and height were 62 and 85% of the nontreated in

2012/2013 (Table 4.4; 4.9; 4.10). Although water solubility and K_{oc} do not indicate that diuron would likely leach from henbit's germination zone, the lack of control at 28 and 100 DAT in 2012/2013 shows that potential following 41.5 cm of rainfall. However, in 2014/2015, diuron applied Dec 15 controlled henbit 79 and 71% 28 and 100 DAT, respectively (Table 4.8), following 22.9 cm of rainfall the month after application. However, henbit density and height 100 DAT following diuron applied Dec 15 2014/2015 was 96 and 79% of the nontreated, respectively (4.13; 4.14), indicating that visual control does not match with density and height data. The lack of control following 41.5 cm of rain, but greater than 70% control following 22.9 cm of rain appears to be the primary difference between 2012/2013 and 2014/2015 for diuron. Pyroxasulfone and *S*-metolachlor both provided 0% control 100 DAT in 2012/2013 and 8 and 0% control 100 DAT in 2014/2015, respectively, when applied Dec 15 (Table 4.4; 4.8) when 41.5 and 22.9 cm of rainfall was recorded during the month following their application (Table 4.1). Henbit density and height data support the control data with density and height ranging from 62 to 100% of the nontreated in 2012/2013 and 2014/2015 (Tables 4.9; 4.10; 4.13; 4.14). Pyroxasulfone and *S*-metolachlor are not extremely mobile and are moderately adsorbed to soil, so there is not an identifiable reason for the poor control observed following their Dec 15 application in 2012/2013 and 2014/2015.

Although variability in control due to variable rainfall was observed results do provide valuable information. Choice of application date is herbicide dependent, but the most consistent control was observed following a Nov 1 through Dec 1 application date. Following all application dates, oxyfluorfen provided 76% or greater henbit control 100 DAT, indicating that it is the best option for henbit management. Flumioxazin and rimsulfuron:thifensulfuron should be applied Nov 1 through Dec 15 to achieve greater than 70% henbit control 100 DAT. Producers struggle controlling henbit with herbicide applications in the spring. Data demonstrates that a paraquat plus flumioxazin, oxyfluorfen, or rimsulfuron:thifensulfuron applied between Nov 1 and Dec 1 will control henbit throughout the winter and early-spring.

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CHAPTER 5
SUMMARY

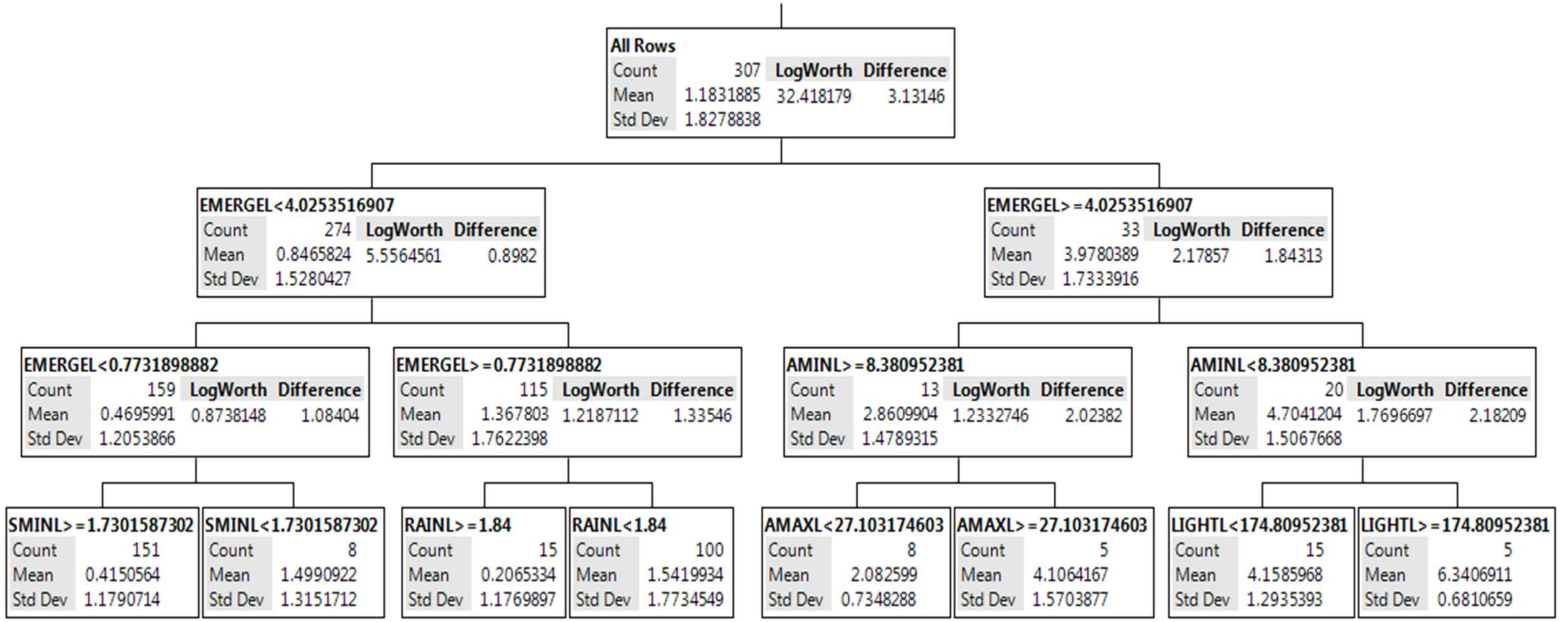
Trials were conducted to elucidate emergence patterns for henbit (*Lamium amplexicaule* L). Four sites, Northeast Research Station in St. Joseph, a producer's field in Concordia Parish, Dean Lee Research and Extension near Alexandria, and Ben Hur Research Farm in Baton Rouge, were selected from northern to southern across Louisiana to evaluate emergence of henbit. Six 1 m^{-2} plots were established mid-September at each of four locations, with each m^2 counted weekly from mid-September to late-March. Data indicated an association of emergence when soil temperatures averaged between 10 and 18.5 C, which corresponded to soil temperatures during the weeks of Oct 17 to Dec 12 at all locations in each year. Densities of at least 50 henbit m^{-2} were counted each week approximately Oct 20 through Dec 20 for the three northern most sites, Northeast Research Station, Concordia parish, and Dean Lee Research Station in the 2011/2012. Large spikes occurred in certain years during November at all three northern most locations with henbit 1000 henbit m^{-2}, indicating potential for high henbit density at these locations. Henbit densities of at least 50 henbit m^{-2} were counted each week approximately Oct 20 through Dec 20 2012/2013, 2013/2014 and 2014/2015 at Northeast Research Station and Concordia Parish, however, densities were more sporadic at Dean Lee Research Station with densities not exceeding 40 henbit m^{-2} in 2012/2013 and 2013/2014. Larger spikes at did occur between mid- Oct to mid-Dec at those locations. Regardless of year, densities at the southernmost Ben Hur Research Farm location were less overall. This work confirms that henbit emerges in large numbers in Louisiana between mid-October and mid-December.

Comparative growth of henbit based on emergence date studies compared the growth and development of September, October, and November emerged henbit. Factors included henbit emergence dates of September, October, or November and destructive harvest intervals of 2, 3, 4, 6, 8, 10, and 12 wk after emergence Data averaged across harvest intervals, found leaf area ratio (LAR) for September and October were not significantly different at 0.012 and 0.010 cm^2 g^{-1}, respectively, however November LAR was 67% less. Specific leaf weight (SLW) for November was 119.0 g cm^{-2} , which is higher than September and October populations at 54 and 89 g cm^{-2} respectively. Additionally, averaged across emergence dates, henbit LAR was greatest at the 2, 3, and 4 WAE harvest intervals this may indicate the allocation of resources to leaf production in the earliest weeks of henbit growth. Additionally, relative growth rate (RGR) for September emerged henbit averaged across harvest intervals was 0.194 g g^{-1} d^{-1}, this is greater than both October and November emerged henbit with 0.121 and 0.092 g g^{-1} d^{-1}, respectively. This data indicate September emerged henbit has a competitive advantage over November, and a not significant, but slight advantage over October emergence.

Trials were conducted for three years to assess control of henbit with fall-applied residual herbicides. Treatments included five application dates, seven herbicide treatments, and a nontreated. The five application dates were Oct 15, Nov 1, Nov 15, Dec 1, and Dec 15 +/- 3 days. The seven herbicide treatments were diuron at 840 g ai ha^{-1}, flumioxazin at 72 g ai ha^{-1}, oxyfluorfen at 280 g ai ha^{-1}, pyroxasulfone at 150 g ai ha^{-1}, prepackaged mixture of rimsulfuron: thifensulfuron-methyl at 18:18 g ai ha^{-1}, *S*-metolachlor at 1420 g ai ha^{-1}, and a non-residual herbicide treatment. Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v was co-applied with all residual herbicide treatments to control emerged henbit at time of application. Data indicated rainfall can greatly influenced the efficacy of residual herbicides. Although variability across years existed, November 1 through December 1 application timings provided the most consistent henbit control. Choice of application date is herbicide dependent, however, flumioxazin, oxyfluorfen, or rimsulfuron: thifensulfuron provide the most consistent control at these timings. Data indicates that flumioxazin, oxyfluorfen, or rimsulfuron: thifensulfuron applied November 1 through December 1 will provide the greatest henbit control, density and height. Oxyfluorfen provided 76% or greater henbit control 100 DAT following all application dates, indicating that it is the best option for henbit management. Furthermore, flumioxazin and rimsulfuron: thifensulfuron should be applied Nov 1 through Dec 15 to achieve greater than 70% henbit control 100 DAT.

In conclusion, optimum timing for applying a herbicide to greatest efficacy is when a weedy species is small. The comparative growth data verifies September and/or October emerged henbit may be the populations producers have difficulty controlling with herbicide treatments in the spring of the year due to hardening off and senescing, which reduces their leaf area potentially leading to reduced herbicide absorption and translocation. Data evaluating henbit emergence shows that greatest flush of seedling henbit occur between mid-October to mid-December. This emergence timing correlates with control data that concluded November 1 through December 1 application timings provided the most consistent henbit control. Additionally, data indicate that flumioxazin, oxyfluorfen, or rimsulfuron:thifensulfuron are the most consistent herbicides for henbit control, density and height reduction. Furthermore, oxyfluorfen is the best option for henbit management providing 76% or greater henbit control 100 DAT. Flumioxazin and rimsulfuron:thifensulfuron should be applied Nov 1 through Dec 15 to achieve greater than 70% henbit control 100 DAT. Data demonstrates that a paraquat plus flumioxazin, oxyfluorfen, or rimsulfuron:thifensulfuron applied between Nov 1 and Dec 1 will control henbit throughout the winter and early-spring

APPENDIX



Appendix 2.1. Decision tree outputted by PROC DTREE in SAS, which indicates that henbit emergence is the primary variable to predict emergence.

Appendix 2.2. PROC REG output in SAS using R-square and Mallows' C_p selection methods to determine if environmental variables could predict henbit emergence.[a]

Variable no. in model	R-square[b]	Mallows' C_p[b]	Variables in model
1	0.2972	2.7472	Emerg.
1	0.0137	126.0863	Air max. T.
1	0.0077	128.6867	Soil min. T.
1	0.0045	130.0836	Rainfall
1	0.0010	131.5923	Soil max. T.
1	0.0004	131.8769	Air min.T.
1	0.0000	132.0385	Solar rad.
2	0.3020	2.6687	Emerg.; Air max. T.
2	0.2990	3.9462	Emerg.; Soil min. T.
2	0.2990	3.9840	Emerg.; Rainfall
2	0.2976	4.5799	Emerg.; Solar rad.
2	0.2973	4.6935	Emerg.; Soil max. T.
2	0.2972	4.7287	Emerg.; Air max. T
2	0.0795	99.4753	Soil min. T; Air max. T.
3	0.3117	0.4340	Emerg.; Air min. T.; Air max. T.
3	0.3052	3.2599	Emerg.; Soil max. T.; Air min. T.
3	0.3037	3.9263	Emerg.; Air min. T.; Rainfall
3	0.3029	4.2683	Emerg.; Soil min. T.; Air max. T.
3	0.3024	4.4871	Emerg.; Air min. T.; Solar rad.
3	0.3024	4.4874	Emerg.; Soil min. T.; Air min. T.
3	0.3014	4.9259	Emerg.; Soil min. T.; Soil max. T.
4	0.3121	2.2548	Emerg.; Air min. T.; Air max. T.; Rainfall
4	0.3121	2.2807	Emerg.; Soil min. T.; Air min. T.; Air max. T.
4	0.3120	2.2992	Emerg.; Soil max. T.; Air min. T.; Air max. T.
4	0.3118	2.4179	Emerg.; Air min. T.; Air max. T.; Solar rad.
4	0.3062	4.8329	Emerg.; Soil max. T.; Air min. T.; Air min. T.
4	0.3057	5.0427	Emerg.; Soil min. T.; Soil max. T.; Air min. T.
4	0.3053	5.2465	Emerg.; Soil max. T.; Air min. T.; Solar rad.

[a] Abbreviations: Air max. T, average weekly maximum air temperature; Air min. T., average weekly minimum air temperature; Emerg. , no. of henbit emerged each week; Rainfall, sum of weekly amount of rainfall; Soil max. T., average weekly maximum soil temperature; Soil min. T., average weekly minimum soil temperature; solar rad., average weekly solar radiation.

[b] R-square values nearest to 1.0 indicates the best model to predict henbit emergence at $P \leq 0.05$. Mallows' C_p values nearest to the number of variables in a model plus one indicates the best model to predict henbit emergence at $P \leq 0.05$.

Appendix 3.1. Net assimilation rate, specific leaf area, and stem-to-leaf ratio as influenced by henbit emergence date.[a]

Emergence date	Net assimilation rate		Specific leaf area		Stem-to-leaf ratio	
	$g\ cm^{-2}\ d^{-1}$		$cm^2\ g^{-1}$		$g\ g^{-1}$	
September	-122.8	a	0.018	a	0.623	a
October	56.8	a	0.016	a	0.630	a
November	226.0	a	0.016	a	0.985	a

[a] Data pooled over harvest interval. Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference test at $P \leq 0.05$.

Appendix 3.2. Net assimilation rate and relative growth rate as influenced by henbit harvest interval.[a]

Weekly harvest interval	Net assimilation rate		Relative growth rate	
	$g\ cm^{-2}\ d^{-1}$		$g\ g^{-1}\ d^{-1}$	
wk 2 to 3	70.5	a	0.154	a
wk 3 to 4	-286.6	a	0.116	a
wk 4 to 6	252.9	a	0.152	a
wk 6 to 8	-2.03	a	0.130	a
wk 8 to 10	143.3	a	0.141	a
wk 10 to 12	141.7	a	0.121	a

[a] Data pooled over henbit emergence date. Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference test at $P \leq 0.05$.

Appendix 3.3. Specific leaf area, stem-to-leaf ratio, and specific leaf weight as influenced by henbit harvest interval.[a]

Harvest interval	Specific leaf area		Stem-to-leaf ratio		Specific leaf weight	
	$cm^2\ g^{-1}$		$g\ g^{-1}$		$g\ cm^{-2}$	
wk 2	0.023	a	0.717	a	76.9	a
wk 3	0.018	a	0.374	a	69.9	a
wk 4	0.021	a	0.450	a	108.4	a
wk 6	0.017	a	0.809	a	72.0	a
wk 8	0.013	a	0.946	a	103.0	a
wk 10	0.014	a	0.911	a	80.7	a
wk 12	0.013	a	1.015	a	99.0	a

[a] Data pooled over henbit emergence date. Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference test at $P \leq 0.05$.

Appendix 4.1. Significance of the main effects of application date, herbicide, and their interactions 50 and 100 d after treatment for henbit control and 28 DAT for henbit density and height 2012/2013, 2013/2014, 2014/2015.[a, b]

		Control		Density	Height
Year	Effect	50 DAT	85 DAT	28 DAT	28 DAT
		P-value			
2012/2013	Date	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	0.0603	0.0002
2013/2014	Date	< 0.0001	< 0.0001	0.0002	< 0.0001
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	0.1692	0.3318
2014/2015	Date	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Date x herb	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[a] Abbreviations: DAT, d after treatment.

[b] Main effects and their interactions are considered significant at $P \leq 0.05$.

Appendix 4.2. Henbit control as influenced by application date and herbicide 50 d after treatment in 2012/2013.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	0 g	66 de	92 abc	98 a	51 e
flumioxazin	23 f	86 abcd	97 a	96 a	98 a
oxyfluorfen	97 a	99 a	99 a	99 a	99 a
pyroxasulfone	0 g	91 abc	91 abc	97 a	49 e
rimsulfuron:thifensulfuron	0 g	79 bcd	97 a	98 a	89 abc
S-metolachlor	0 f	86 abcd	99 a	98 a	0 g
no residual	0 g	0 g	0 g	71 cde	0 g

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.3. Henbit control as influenced by application date and herbicide 85 d after treatment in 2012/2013.[a]

Herbicide[b]	Application date Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	0 d	80 b	85 ab	91 ab	31 c
flumioxazin	24 c	96 ab	99 a	88 ab	92 ab
oxyfluorfen	99 a	99 a	97 ab	96 ab	95 ab
pyroxasulfone	0 d	86 ab	91 ab	84 ab	6 d
rimsulfuron:thifensulfuron	0 d	90 ab	99 a	98 ab	99 a
S-metolachlor	0 d	91 ab	99 a	86 ab	0 d
no residual	0 d	0 d	0 d	36 c	0 d

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.4. Henbit control as influenced by application date and herbicide 50 d after treatment in 2013/2014.[a]

Herbicide[b]	Application date Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	92 ab	75 bc	90 abc	98 a	98 a
flumioxazin	99 ab	97 ab	92 ab	93 ab	99 a
oxyfluorfen	99 ab	98 a	97 ab	99 a	99 a
pyroxasulfone	70 bc	89 abc	86 abc	64 c	92 ab
rimsulfuron:thifensulfuron	99 ab	91 ab	92 ab	91 abc	98 a
S-metolachlor	93 ab	95 ab	93 ab	92 ab	76 bc
no residual	0 d	0 d	78 bc	0 d	3 d

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.5. Henbit control as influenced by application date and herbicide 85 d after treatment in 2013/2014.[a]

Herbicide[b]	Application date Oct 15	 Nov 1	 Nov 15	 Dec 1	 Dec 15
	%				
diuron	70 cdef	80 abcdef	88 abcdef	99 a	96 abcd
flumioxazin	80 abcdef	94 abcde	95 abcd	97 a	99 a
oxyfluorfen	84 abcdef	97 a	97 a	99 a	97 abc
pyroxasulfone	69 def	86 abcdef	90 abcdef	62 ef	91 abcdefg
rimsulfuron:thifensulfuron	85 abcdef	95 abc	93 abcd	95 abc	94 abcd
S-metolachlor	71 bcdef	95 abcd	95 abc	89 abcdef	80 abcdefg
no residual	0 g	0 g	61 f	0 g	0 h

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.6. Henbit control as influenced by application date and herbicide 50 d after treatment in 2014/2015.[a]

Herbicide[b]	Application date Oct 15	 Nov 1	 Nov 15	 Dec 1	 Dec 15
	%				
diuron	56 fghij	70 defghi	80 bcdef	98 ab	75 bcdefg
flumioxazin	97 ab	84 abcdef	90 abcd	99 a	99 a
oxyfluorfen	83 abcdef	93 abcd	98 abc	99 a	97 ab
pyroxasulfone	29 j	84 abcdef	79 abcdefgh	75 bcdefgh	33 j
rimsulfuron:thifensulfuron	71 cdefghi	88 abcde	96 abc	99 a	3 k
S-metolachlor	53 fghij	64 defghi	96 abc	99 a	48 ghij
no residual	0 j	38 ij	45 hij	36 ij	81 abcdefg

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.7. Henbit control as influenced by application date and herbicide 85 d after treatment in 2014/2015.[a]

Herbicide[b]	Application date Oct 15	 Nov 1	 Nov 15	 Dec 1	 Dec 15
	%				
diuron	53 defgh	60 cdefg	71 abcde	78 abcd	71 abcde
flumioxazin	53 defgh	84 abc	85 ab	93 a	93 a
oxyfluorfen	76 abcd	90 a	93 a	85 abc	90 a
pyroxasulfone	0 i	79 abcd	74 abcde	64 bcdef	8 i
rimsulfuron:thifensulfuron	45 efgh	93 a	91 a	93 a	0 i
S-metolachlor	31 gh	29 h	93 a	91 a	0 i
no residual	0 i	0 i	40 fgh	0 i	78 abcd

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.8. Henbit density and height as a percent of nontreated as influenced by application date 28 d after treatment in 2012/2013 and 2013/2014.[a]

Application date	Density 2012/2013	 2013/2014	Height 2013/2014
	% of nontreated		
Oct 15	94 a	16 ab	35 ab
Nov 1	62 b	2 c	16 bc
Nov 15	20 c	10 bc	19 bc
Dec 1	28 bc	11 abc	47 a
Dec 15	36 bc	32 a	8 c

[a] Data pooled over herbicide treatment. Means followed by the same letter for each year are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

Appendix 4.9. Henbit density and height as a percent of nontreated as influenced by herbicide treatment 28 d after treatment in 2012/2013 and 2013/2014.[a]

	Density		Height
Herbicide[b]	2012/2013	2013/2014	2013/2014
	% of nontreated		
diuron	59 ab	4 bcd	22 bc
flumioxazin	43 bc	1 cd	5 cd
oxyfluorfen	13 c	0 d	0 d
pyroxasulfone	41 bc	23 b	42 ab
rimsulfuron:thifensulfuron	50 bc	12 bc	30 abc
S-metolachlor	42 bc	16 bc	33 ab
no residual	94 a	66 a	61 a

[a] Data pooled over application date. Means followed by the same letter for each year are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.10. Henbit density percent of the nontreated as influenced by application date and herbicide treatment 28 d after treatment in 2014/2015.[a]

	Application date				
Herbicide[b]	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	77 abcdefgh	54 abcdefghij	80 abcdefgh	4 ijk	14 fghijk
flumioxazin	80 abcdef	3 jk	5 ijk	0 k	0 k
oxyfluorfen	15 efghijk	1 jk	12 ghijk	0 k	0 k
pyroxasulfone	98 abc	13 fghijk	36 cdefghijk	32 defghijk	99 ab
rimsulfuron:thifensulfuron	62 abcdefghij	37 cdefghijk	100 a	10 ghijk	61 abcdefghij
S-metolachlor	92 abcd	29 defghijk	8 hijk	2 jk	55 abcdefghij
no residual	99 abc	46 bcdefghijk	72 abcdefghi	86 abcdef	88 abcd

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.11. Henbit height percent of the nontreated as influenced by application date and herbicide 28 d after treatment in 2012/2013.[a]

Herbicide[b]	Application date				
	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	100 ab	100 a	24 cdefghij	27 cdefghij	67 abcdefghi
flumioxazin	100 ab	85 abcdefg	9 ghij	66 abcdefghi	3 ij
oxyfluorfen	92 abcdef	1 ij	0 j	2 ij	0 j
pyroxasulfone	97 abcd	99 abc	34 bcdefghij	15 fghij	74 abcdefghi
rimsulfuron:thifensulfuron	90 abcdef	99 abc	23 defghij	19 efghij	24 cdefghij
S-metolachlor	95 abcde	86 abcdefg	4 hij	5 hij	80 abcdefgh
no residual	97 abcd	100 a	47 abcdefghi	89 abcdefg	83 abcdefgh

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.12. Henbit height percent of the nontreated as influenced by application date and herbicide 28 d after treatment in 2014/2015.[a]

Herbicide	Application date				
	Oct 15	Nov 1	Nov 15	Dec 1	Dec 15
	%				
diuron	96 a	56 bcde	11 ghijk	31 defghi	32 defghi
flumioxazin	91 ab	49 cdefg	5 ijk	1 jk	0 k
oxyfluorfen	55 bcde	12 ghijk	10 hijk	0 k	0 k
pyroxasulfone	94 a	52 cdef	20 defghij	27 defghi	39 defgh
rimsulfuron:thifensulfuron	94 a	40 defgh	10 hijk	23 defghij	41 defgh
S-metolachlor	87 abc	57 bcd	15 fghijk	25 defghi	45 defgh
no residual	100 a	60 bcd	17 efghjik	35 defghi	51 cdef

[a] Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

[b] Paraquat at 840 g ai ha^{-1} plus a non-ionic surfactant at 0.25% v/v applied with all residual herbicides on all application dates.

Appendix 4.13. Henbit height as a percent of nontreated as influenced by application date 100 d after treatment in 2013/2014.[a]

Application date	% of nontreated
Oct 15	64 a
Nov 1	33 bc
Nov 15	38 b
Dec 1	16 c
Dec 15	18 bc

[a] Data pooled over herbicide treatment. Means followed by the same letter are not significantly different according to Tukey's honest significant difference at $P \leq 0.05$.

VITA

Brandi Cheri Woolam was born in Macomb, IL, located in the west central portion of the state. She grew up south of town on a small farm (148.6 acres) owned and farmed by her grandparents and father. She attended Logan elementary, Edison Junior High, and Macomb Junior Senior High School in Macomb Illinois. During that time she was involved in 4-H, and other activities. Summer jobs started at age 14 for Pioneer Seed Company detasseling corn, and she managed other odd jobs over the years while attend High School and College.

She graduated with a B.S. in Science in 2001 from Western Illinois University and later moved to Winnsboro, Louisiana. She applied and was hired as a Temporary Research Associate with the LSU AgCenter by Dr. Rogers Leonard to work in his entomology program. She transferred later that year into a permanent Research Associate position with Dr. Boyd Padgett in plant pathology.

After about a year and a half in Winnsboro, LA, she moved to Alexandria, LA having applied and being hired for a position with Dr. Alexander Stewart as an Extension Cotton Research Associate. She worked eight years in that program. She now continues her education in the Weed Science program for Dr. Daniel O. Stephenson, IV as a Research Associate. She enrolled in School of Plant, Environmental, and Soil Sciences under the direction of Dr. Daniel O Stephenson, IV. and James L. Griffin in 2012 and is currently a candidate for the Master of Science degree with a focus in Weed Science.