WEED MANAGEMENT IN ROUNDUP READY FLEX COTTON

by

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CHAPTER I

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) has played an important role in the United States economy for almost 200 years as a major cash crop and significant source of foreign exchange (Supak et al. 1992). Cotton remains an economic mainstay across the Cotton Belt, which spans from Virginia to California (Supak et al. 1992). Texas accounts for 25 to 30% of the total cotton produced in the United States (Smith 1995). The Texas High Plains produces the majority of this percentage, with growers harvesting between one and two million hectares of cotton annually (Anonymous 2004).

Crop losses caused by weeds are a direct result of competition with weeds for light, water, and mineral nutrients, as well as harvest problems and lowering of crop quality because of contamination by weed seed (Janick et al. 1981). In cotton, there are approximately 5.4 million hectares infested with one or more weeds. These populations resulted in a loss of 1.2 million bales out of a 17.7 million-bale crop (Byrd 2003). Ten weed species cause about 75% of all cotton losses and six of the ten species are common on the High Plains of Texas. These weeds include morningglory species (*Ipomoea* spp.), common cocklebur (*Xanthium strumarium* L.), pigweed species (*Amaranthus* spp.), Russian thistle [*Salsola iberica* (Sennen) Pau], johnsongrass [*Sorghum halapense* (L.) Pers.], and silverleaf nightshade (*Solanum elaeagnifolium* Cav.)

(Holm et al. 1977). An additional troublesome weed common to Texas and Oklahoma is devil's-claw [*Proboscidea louisianica* (Mill.) Thellung] (Dowler 1992).

On the Texas High Plains, crop competition for valuable resources such as light, water, and nutrients results in fewer bolls produced per plant and lower lint quality (Abernathy and McWhorter 1992). Cotton is planted in early- to mid-spring when temperatures may be too low for optimum growth. A number of annual and perennial weeds can germinate and thrive in the conditions that are too cool for cotton. This allows these weeds to become competitive early in the growing season; therefore, it is important that fields are maintained weed-free from emergence until the crop can become competitive with the weeds (Buchanan 1992). Studies have shown that if cotton is kept clean through the first eight to ten weeks after emergence, the crop is competitive enough to negate further competitive weed losses (Buchanan and Burns 1970).

Weed control in cotton has evolved from traditional hoes and cultivators to intense herbicide programs due to new crop resistance technology. With the development of these new technologies, producers on the Texas High Plains have the opportunity to implement a variety of weed control programs for weed species that include Palmer amaranth [*Amaranthus palmeri* (S.) Wats], devil's-claw, ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.], and silverleaf nightshade. Glyphosate-tolerant cotton was introduced in 1997, which allows POST applications of glyphosate through the four-leaf cotton growth stage. Glyphosate has been successful in controlling early-season weed flushes;

however, environmental conditions such as wind (causes drift) and rain (prevents equipment entering field) narrow the application window making it difficult to make timely applications to control these weeds. With the development of Roundup Ready Flex cotton, which allows POST applications of glyphosate past the 4-leaf cotton growth stage, there may be opportunities to more effectively manage weeds by allowing later season POST glyphosate applications. Therefore, field experiments were conducted to evaluate different weed control strategies for use in Roundup Ready Flex cotton systems.

CHAPTER II

REVIEW OF LITERATURE

Weediness is defined as the state or condition of a field, flowerbed, lawn, or other settings in which there is an abundance of weeds (Winburne 1962; Aldrich and Kremer 1997). To suggest that a crop is weedy implies that it has many weeds; enough to reduce yield. Although weeds have many other negative aspects, it is this threat to yield and the production of food that accounts for most of the effort devoted to their control since the beginning of agriculture (Aldrich and Kremer 1997). As these weeds continue to increase, so does their need for nutrients, water, and sunlight, which in turn decreases the availability to crops. Weeds are competitive by nature because many are prolific seed producers, and germinate and grow rapidly (Ashton et al. 1991). It is estimated that total crop losses due to weeds in the United States exceeds $6 billion annually (Bridges 1994). The cost associated with control of these weeds exceeds $9 billion, which totals $15 billion in economic impact (Bridges 1994).

The first major advancement in weed control technology included mechanical row-crop tractors, the steel plow, and in-crop cultivation to remove weeds (Supak et al. 1992). Weed management encompasses those practices whereby weed infestations are reduced but not necessarily eliminated. Weed control is a matter of degree and ranges from poor to excellent. The degree of weed control obtained is dependent on the population of the weed species present and the effectiveness of the control practice(s) used. Eradication is the extreme success of weed control but is rarely achieved. Eradication implies that a given weed species, including its seed and vegetative reproductive parts, has been killed or completely removed from a given area and that the weed will not reappear unless reintroduced into the area (Anderson 1996). Weed control practices may be grouped as preventative, cultural, mechanical (physical), chemical, and biological. For best control, a combination of two or more practices is often needed (Anderson 1996). In the United States, before the early 1900s, weeds were removed from cotton (*Gossypium hirsutum* L.) fields by hand hoeing (Coble and Byrd 1992). This process is still used today; however, chemicals have taken center stage in an effort to decrease the cost associated with weed control.

Biological control is the use of one organism to suppress a second organism. An alternate method of weed control is the use of pests or parasites that are agronomically or environmentally injurious to the plant (Smith 1982). Silverleaf nightshade (*Solanum elaeagnifolium* Cav.) is naturally parasitized by the parasitic nematode *Orrina phyllobia* (Orr and Morey 1974). Invasion of this leaf-feeding nematode either severely stunts or kills silverleaf nightshade. This method of control is not widely used due to unsatisfactory control on a widespread basis (Buchanan 1974). Kremer and Kennedy (1996) found that some rhizobacteria are able to suppress weed growth and reduce biomass and seed production. Early-season (April to June) applications of phytopathogenic bacterium *Pseudimonas syringae* pv*. tagetis* caused disease and injury in woollyleaf bursage [*Ambrosia grayi* (A.Nels.) Shinners] (Sheikh et al. 2001). The puncturevine seed weevil (*Microlarinus lareynii* Jac. Du Val) feeds on the inside of the puncturevine (*Tribulus terrestris* L.) seed bur (Daniels and Weise 1967). Rummel and Arnold (1992) reported that the 1962 release of the puncturevine seed weevil in west Texas had reached an ecological balance with its host by the mid-1970s.

The agricultural chemical industry began in the 1940s with the initial development of herbicides that currently comprise approximately 65% of all pesticide expenditures (Derr 2004). Today, herbicides are considered the major method of weed control used in the United States and mechanical tillage and hand hoeing are used as supplemental practices (Supak et al. 1992). There are four basic methods for applying herbicides: preplant incorporated (PPI), preemergence (PRE), postemergence (POST), and post-directed (PDIR). Often all four of these methods are utilized for effective broad-spectrum weed control.

The use of herbicides began primarily in the early 1950s with the development of chemicals such as diuron [*N*'-(3,4-dichlorophenyl)-*N,N*-dimethylurea]. The use of herbicides to adequately control weeds in cotton was not an overnight success. Initial reluctance to apply herbicides was justified in 1952 and 1953 when thousands of hectares of cotton were killed after dinoseb [2-(sec-butyl)-4,6-dinitrophenol] was applied PRE (Supak et al. 1992). Before 1960, less than 10% of cotton acres received a herbicide treatment. Herbicide use accelerated over the next decade into the 1970s when most cotton hectares received some type of herbicide treatment. This rapid increase in herbicide use can be contributed to the more selective and effective herbicides such as trifluralin (α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-p-toluidine) and DSMA/MSMA (disodium methanearsonate/monosodium methanearsonate) (Supak et al. 1992). Trifluralin and pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] are the most commonly used dinitroaniline herbicides and are often considered the foundation of most successful weed management systems; however, these herbicides provide little or no control of larger-seeded annual and perennial broadleaf weeds (Wilcut et al. 1997). Although not used in cotton, the discovery of the selective weed control properties of 2,4-D (2,4-dichlorophenoxyacetic acid) fueled a flurry of research and development in the chemical industry that led to a large number of additional selective herbicides (Aldrich and Kremer 1997). Selective chemical weed control may well have been the most important advancement of the 20th century in agriculture. It has had a direct impact on nearly every aspect of plant production (Aldrich and Kremer 1997).

The development of herbicide resistant crops has provided producers with another tool to use for weed management. Cotton resistance has been developed to herbicides such as bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), glyphosate [*N*- (phophonomethyl)glycine], and glufosinate [2-amino-4-(hydroxymethylphosphinyl)butanoic acid]. Bromoxynil-tolerance was developed by Rhone Poulenc Agriculture Company (BXN), and introduced by Stoneville Pedigreed Seed Company in 1994. Isgett et al. (1996) reported greater than 90% control of common cocklebur (*Xanthium strumarium* L.) and morningglory species (*Ipomoea* spp.) following the use of bromoxynil; however, bromoxynil provided poor control of pigweed species. Bromoxynil-tolerant cotton is no longer commercially available.

Glyphosate-tolerance was developed by Monsanto Company and introduced to cotton cultivars (Roundup Ready) by Delta and Pine Land Company in 1997. This technology allows glyphosate to be applied POST through the four-leaf crop stage for control of many annual and perennial broadleaf, grass, and sedge weeds. After the four-leaf stage, glyphosate must be applied PDIR to prevent crop injury (Johnson 1996; Jones and Snipes 1999; Sherrick 1996). Glyphosate does not provide residual control, but when used in conjunction with a residual herbicide, excellent season-long control has been observed (Culpepper and York 1998; Isgett et al. 1997). A new generation of glyphosate-tolerant cotton (Roundup Ready Flex) is set to be commercially available for the 2006 growing season. This technology will widen the application window of POST glyphosate applications from emergence through layby as well as allow higher application rates to be used.

Glyphosate-tolerance was conferred to cotton by the incorporation of a 5-enolpyruvylshikimate-3-phosphate synthase (EC 2.5.1.19) gene cloned from *Agrobacterium* sp. strain CP4 (CP4-EPSPS). The expression of the CP4-EPSPS gene produces a glyphosate resistant EPSPS enzyme, which can overcome the inhibition of native EPSPS in the presence of glyphosate, allowing sufficient production of aromatic amino acids and secondary metabolites (Nida et al. 1996). This technology allows for POST applications of glyphosate from ground crack through the four-leaf stage of development and PDIR applications in Roundup Ready cotton that is five-leaves or larger (Johnson 1996; Jones and Snipes 1999; Sherrick 1996). The maximum rate allowed for POST or PDIR applications is 0.84 kg/ha (Johnson 1996). Glyphosate applied after the four-leaf stage can compromise the reproductive tolerance (Martens et al. 2003). Glyphosate applications at late developmental stages indicate that the CP4-EPSPS gene is not well expressed in male flower tissues (Chen et al. 2003; Pline et al. 2003). There have been performance and yield loss complaints in glyphosate-tolerant cotton, due to an increase in lower fruiting branch boll abortions and misshapen bolls (Ferreira et al. 1998; Vargas et al. 1998).

Glufosinate-tolerant cotton (LibertyLink) was commercially available in 2004 that allowed season-long POST applications of glufosinate to be used for control of many annual and perennial broadleaf and grass weeds. Blair (1999) reported 55 to 84% Palmer amaranth [*Amaranthus palmeri* (S.) Wats] control 11 weeks after planting when glufosinate was applied (0.40 kg/ha) followed by (fb) cultivation. When glufosinate was used in a system that included trifluralin and prometryn (*N,N'*-bis(1-methylethyl)-1,3,5-triazine-2,4-diamine), Palmer amaranth control increased to nearly 100%. Culpepper et al. (2002) reported 90% Palmer amaranth control with two POST applications of glufosinate. The addition of soil applied herbicides such as trifluralin and pendimethalin improved Palmer amaranth control to nearly 100%. Dotray et al. (2002) reported that trifluralin fb glufosinate in-season provided season-long control of Palmer amaranth, devil's-claw [*Proboscidea louisianica* (Mill.) Thellung], and silverleaf nightshade.

Cotton producers throughout the Texas Southern High Plains must control many annual and perennial weeds that reduce crop yields each year. Residual herbicides applied PPI and PRE are successful during early-season managing annual weeds such as Palmer amaranth (Keeling et al. 1997). However, as the residual activity declines, producers struggle to control late-season escapes of Palmer amaranth and other difficult to control annuals including devil's-claw and ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] (Everitt et al. 2002; Keeling et al. 1997). These weeds compete with cotton, reducing yields dramatically, and complicating harvest.

Palmer amaranth is a major annual weed problem present on the Texas High Plains (Smith and Cooley 1973). Palmer amaranth populations are greatest in the southwestern to midwestern sections of the United States and are often found near to or in irrigated or cultivated fields (Correll and Johnston 1979). The plant is an erect, branched herbaceous annual that has the ability to reach heights up to two meters. Male and female flowers are found on separate plants, which have the ability to hybridize with other pigweed (*Amaranthus* spp.) species. Palmer amaranth is considered one of the more aggressive pigweeds (Whitson et al. 1996). Keeley and Thullen (1989) found that weed seed production for Palmer amaranth averaged 6308 million seed/ha. Palmer amaranth has the ability to produce a vast amount of seed and grows rapidly, which is why it is the most common weed found in Texas cotton fields. Byrd (2000) reported that Texas cotton farmers' yield was reduced by 12% with over 4.9 million hectares infested with the *Amaranthus* spp. Cotton fiber qualities seem to be unaffected by Palmer amaranth; however, Morgan et al. (1998) reported that yields decreased linear from 26 to 65% with four to twelve weeds per 9 m of cotton row. Rowland and Murray (1997) found a linear relationship between lint yields and weed density for densities up to 8 weeds per 10 m of row. Kempen (1982) reported similar reductions in California cotton fields.

Keeling et al. (1991) reported that effective (>80%) early-season Palmer amaranth control was achieved with trifluralin or pendimethalin in conjunction with PRE herbicides. However, PRE herbicides alone did not adequately control Palmer amaranth season-long. Grichar et al. (2004) reported that pendimethalin applied PPI fb metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)–*N*-(2-methoxy-1-methylethyl) applied early POST controlled Palmer amaranth 92%. All herbicide systems in this study that included glyphosate controlled Palmer amaranth at least 97%.

Devil's-claw is an annual that grows upright and is covered with secretory trichomes which gives the plant an unusually strong scent. Plants have hollow stems and large heart-shaped leaves and reach heights of 0.6 m (Cooley et al.

1973). Devil's-claw is also known as ram's horn or unicorn plant (due to the unique seed pod formation) and is part of the Martyniaceae family (Correll and Johnston 1979). Devil's-claw is capable of producing 122 pods per plant with approximately 71 seeds per pod. Seed produced have the ability to germinate over an extended period. After a period of 8 months, fewer than 50% of the seed germinated; however, most of the remaining seed were still viable (Riffle et al. 1988). Cooley et al. (1973) reported that devil's-claw is highly competitive with cotton due to its ability to rapidly produce a canopy over the crop. They also found that due to its large canopy adjacent cotton plants had reduced yield as well. Cotton grown weed-free produced 672 kg of lint per hectare, while cotton grown weed-free, adjacent to weedy plots produced 279 kg per hectare and cotton infested with devil's-claw produced only 111 kg of lint per hectare. Mercer and Murray (1984) reported that lint yield was reduced by 25% when devil's-claw had a density of two plants in 40 m^2. In 1999, devil's-claw accounted for 4% of the lost cotton crop in Texas and over 600,000 hectares were infested (Byrd 2000).

The unique growth of devil's-claw can complicate harvest and reduce lint yield 74% with three plants per meter of row (Mercer et al. 1987). Herbicides applied PRE in cotton have limited activity on devil's-claw and POST herbicides lose effectiveness once this weed reaches 10-cm in height (Smith et al. 1973). Applications of diuron or prometryn PDIR effectively control devil's-claw; however, due to its timely emergence with cotton, the necessary height differential often does not exist. In this instance, POST herbicides would be an effective choice if selective herbicides were available. Pyrithiobac {2-chloro-6-[(4,6-dimethoxypyrimidin-2-yl)thio]benzoate} applied POST effectively controlled devil's-claw without injuring cotton (Keeling et al. 1993; Bryson et al. 1991). Dotray et al. (1996) reported 73 to 97% devil's-claw control at 12 weeks after treatment when pyrithiobac at 0.07 kg ai/ha was applied POST. Likewise, Prostko and Chandler (1998) found pyrithiobac at 0.07 and 0.14 kg/ha applied POST controlled devil's-claw 88 and 91%, respectively, at 49 days after treatment.

Morningglory is an annual that can quickly produce vines, which may form a dense canopy over the top of cotton if left uncontrolled (Cooley and Smith 1973a). Morningglory species are difficult to control with current herbicide programs, which may cause problems for the producer when defoliating and harvesting (Wright et al. 1997). Byrd (1991) reported yield reduction estimates as high as 20% from morningglory interference. Morningglory species accounted for 12% of the total crop loss in 1999, and they infested 283,000 hectares in Texas cotton fields (Byrd 2000). Many studies conducted on morningglories have emphasized the importance of herbicide application timing (Jordan et al. 1997; Marsh 2001; McCloskey et al. 2004; Tingle et al. 1996; Warrick 1996).

Glyphosate is marginally effective on morningglory (Culpepper et al. 2001; Jordan et al. 1997). Glyphosate often requires higher application rates and more timely applications to control morningglory (Jordan et al. 1997; Tingle et al.

1996). Keeton and Murdock (1997) reported excellent ivyleaf morningglory control (92 to 96%) 7 weeks after planting with pendimethalin + fluometuron (*N,N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea) fb pyrithiobac or glyphosate. Similarly, Askew et al. (1998) reported that fluometuron fb pyrithiobac, bromoxynil or glyphosate fb a layby treatment effectively controlled ivyleaf morningglory.

Silverleaf nightshade is a deep-rooted, perennial weed that propagates by means of seed, creeping rhizomes, and root fragments (Cuthbertson 1976). Infestations throughout cropland in Texas and Oklahoma cover more than 814,000 hectares (Abernathy and Keeling 1979). Weeds that are allowed to grow undisturbed can reach 30 to 90 cm in height (Correll and Johnston 1979). Silverleaf nightshade has roots that can reach depths of 274 cm (Davis et al. 1945), which is nearly twice the depth of cotton. The fruit of silverleaf nightshade is a round berry that turns from green to yellow as the plant matures. Each berry contains from 40 to 120 seeds (Alexander et al. 1990) and a dense population of silverleaf nightshade can produce 2.5 million seed/ha (Cooley and Smith 1973b).

Silverleaf nightshade can be moderately controlled by mechanical, chemical, and biological measures (Everitt et al. 2000; Orr and Morey 1974). Dotray and Keeling (1996) reported that fall application of glyphosate at rates as low as 0.8 kg ae/ha may provide effective long-term silverleaf nightshade control. Schoenhals and Weise (1988) reported that glyphosate at 3.37 kg/ha controlled silverleaf nightshade an averaged of 86% with three years of annual applications.

Westerman and Murray (1989) reported 96% silverleaf nightshade control with a single in-season spot treatment application of glyphosate made 7 weeks after crop emergence.

Keeling et al. (1997) found that the use of glyphosate in glyphosate-tolerant cotton improved silverleaf nightshade control over standard soil-applied herbicides and conventional tillage systems. The addition of glyphosate POST to residual herbicides controlled silverleaf nightshade 50 to 70%. The addition of glyphosate PDIR improved season-long control compared to using one POST application alone (Keeling et al. 1999). The addition of a cultivation in a glyphosate system increased control from 88 to 99% (Everitt et al. 2000).

Many producers have had success controlling these weeds by planting Roundup Ready (glyphosate-tolerant) cotton and applying glyphosate POST and PDIR. Askew et al. (1998) reported that repeated glyphosate applications or glyphosate with soil-applied and PDIR herbicides controlled weeds at least 95%. Wilcut and Hinton (1997) reported that soil-applied herbicides were not necessary for weed control when glyphosate was applied repeatedly; however, residuals often reduced the number of glyphosate applications needed for adequate control (Wilcut et al. 1998). Glyphosate can only be applied POST in cotton until the four to five leaf crop stage (Johnson 1996; Jones and Snipes 1999; Sherrick 1996).

Due to the limitation of the current Roundup Ready cotton, an enhanced glyphosate-tolerant genotype has been introduced. Roundup Ready Flex cotton, event MON 88913, was created by transforming Coker 312 plant material using a disarmed *Agrobacterium tumefaciens* method and a CP4-EPSPS gene construct. The CP4-EPSPS protein as expressed in the Roundup Ready Flex cotton is the same protein as contained in the current Roundup Ready cotton product. The CP4-EPSPS protein is expressed in both vegetative as well as reproductive tissues necessary to provide tolerance to glyphosate (Burns et al. 2004). Sequential applications of glyphosate rates at 1.68 and 2.52 kg/ha at the 3, 6, 10, and 14-leaf stages did not effect yield or fiber quality compared to the untreated control (May and Culpepper 2002; Martens et al. 2003). Based upon research conducted to date, an expanded window of application is expected with the use of glyphosate on Roundup Ready Flex cotton (Croon et al. 2003).

Glyphosate provides excellent control of Palmer amaranth, devil's-claw, and silverleaf nightshade; however, due to a limited application window, season-long control may be difficult (Everitt et al. 2002; Keeling et al. 1997). Application timing is a factor for achieving desirable levels of weed control (Jordan et al. 1997; McCloskey et al. 2004; Tingle 1996). The impact of weed density on cotton yields becomes curvilinear at higher weed populations when intraspecific interference among weeds becomes a factor (Coble and Byrd 1992). Current weed management systems in Roundup Ready cotton provide producers with tools needed to control early-season weeds. Late-season control requires the use of specialized sprayer equipment (Burns et al. 2004). With the introduction of Roundup Ready Flex cotton there is a need to determine optimum glyphosate rates, timing, and determine the use of residual herbicides that will provide the most efficient control of these weeds in cotton.

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted in 2003 at Lubbock, TX and Hockley County and in 2004 at Lubbock, TX to evaluate Palmer amaranth [*Amaranthus palmeri* (S.) Wats], devil's-claw [*Proboscidea louisianica* (Mill.) Thellung], silverleaf nightshade (*Solanum elaeagnifolium* Cav.), and ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] control in Roundup Ready Flex cotton. The soil type at the Lubbock location was an Acuff clay loam (Fine-loamy, mixed, thermic Aridic Paleustolls) with less than 1.0% organic matter and pH 7.4. The soil type at the Hockley County location was an Amarillo fine sandy loam (Fine-loamy, mixed, superactive, thermic Aridic Paleustalfs) with less than 1.0% organic matter and pH 7.5.

Treatments were replicated three times in each experiment. Cotton (Paymaster 2326 RR and MON 88913) was planted at a depth of 5 cm on 102-cm rows at a seeding rate of 17 kg/ha and treated with aldicarb [2-methyl-2-(methylthio)propionaldehyde 0-(methylcarbamoyl)oxime] at 0.42 kg/ha. Rainfall totaled 234 mm in 2003 and 868 mm in 2004 (Table 3.1). In 2003, the ivyleaf morningglory test was over-head irrigated with 133 mm of supplemental water. All other tests were furrow-irrigated with 152 mm of supplemental water in 2003 and 51 mm in 2004.

A tractor-mounted compressed air sprayer or CO_2 pressurized backpack sprayer calibrated to deliver 93.5 L/ha was used for POST herbicide applications. The tractor sprayer was operated at 241 kPa with TeeJet 110015VS nozzles (Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60188) at 4.8 km/h. The backpack sprayer was operated at 179 kPa with TeeJet flat-fan 80015VS nozzles at 4.8 km/h. A commercial standard treatment was used and required the use of a Red Ball 420 Lay-By hooded sprayer (Redball, LLC, 140 30th Avenue SE, Benson, MN 56215-0159) calibrated to deliver 93 L/ha at a speed of 8 km/hr. Spray tips used for the postemergence-directed applications were TeeJet 8001EVS and 8003EVS flat-fan nozzles.

Percent weed control was estimated each week throughout the season using a scale of 0 to 100, with 0 meaning no control or injury and 100 meaning complete control or injury (Frans et al. 1986). Cotton lint was harvested in 2004 from all Roundup Ready Flex varieties using a sample size of 2 rows by 2 m. Samples were weighed and a 22 percent turnout was applied to bur cotton weight.

<u>Ivyleaf Morningglory Control</u>.

In 2003 and 2004, a study was established in Hockley County, TX and Lubbock, TX respectively, to evaluate ivyleaf morningglory control in a Roundup Ready Flex weed management system (Table 3.2). A natural infestation of ivyleaf morningglory was present in both years. Plot size was 4 rows by 9 m in length. Trifluralin (α,α,α,-trifluoro-2,6-dinitro-*N, N*-dipropyl-p-toluidine) was applied at 0.84 kg ai/ha and incorporated to a depth of 8 cm with a spring-tooth harrow before planting. Glyphosate [*N*- (phophonomethyl)glycine] was applied postemergence-topical (POST) at either 0.84 or 1.68 kg ae/ha in three weed management systems based on crop growth stage (CS), as-needed (ASN: two to three inch weeds), or a combination of CS and ASN.

Palmer Amaranth, Devil's-claw and Silverleaf Nightshade Control.

In 2003 and 2004, studies were established in Lubbock, TX to evaluate Palmer amaranth, devil's-claw and silverleaf nightshade control in a Roundup Ready Flex weed management system (Table 3.3). A natural infestation of all three weed species was present in both years. Plot size was 8 rows by 9 m in length. Trifluralin was applied at 0.84 kg ai/ha and incorporated to a depth of 8 cm with a spring-tooth harrow before planting. Glyphosate was applied postemergence-topical (POST) at either 0.84 or 1.68 kg ae/ha rates in three weed management systems based on CS, ASN, or a combination of CS and ASN.

Glyphosate with Residual Herbicide Systems.

In 2003 and 2004, studies were established in Lubbock, TX to evaluate Palmer amaranth and devil's-claw control in a Roundup Ready Flex residual herbicide system (Table 3.4 and 3.5). Glyphosate (0.84, 1.26, and 1.68 kg/ha in 2003 and 0.84 kg/ha only in 2004) was used alone or following trifluralin preplant incorporated at 0.84 kg ai/ha, or in combination with metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl) –*N*-(2-methoxy-1-methylethyl)] at 1.12 kg ai/ha, or pyrithiobac-sodium {2-chloro-6-[(4,6-dimethoxypyrimidin-2-yl)thio]benzoate} at 0.04 kg ai/ha POST (Table 3.4 and 3.5). Plot size was 4 rows by 9 m in length.

All experiments were arranged as a randomized block design with a factorial arrangement. Data was subjected to an analysis of variance and means were separated using Fisher's Protected LSD test at the 5% probability level. Percent weed control data were arcsine transformed before analysis for stability. However, non-transformed data are presented with transformed mean separation used.

Table 3.1. Rainfall distribution for 2003, 2004, and the 30-year average.

	Yearly Rainfall		
Month	2003	2004	30-year Average
	mm		
Jan	3	49	13
Feb	2	41	18
Mar	7	45	19
Apr	27	62	33
May	36	21	59
Jun	109	78	77
Jul	0	64	54
Aug	13	53	60
Sep	3	147	65
Oct	16	59	43
Nov	18	137	18
Dec	0	112	17
Total	234	868	476

Table 3.2. Postemergence-topical glyphosate treatments for ivyleaf morningglory control: application dates, crop and weed growth stages for 2003 and 2004[a].

	2003			2004		
Application	Date	Crop Stage	Weed Stage	Date	Crop Stage	Weed Stage
POST I	May 29[b]	cot to 1 lf	cot	May 24[c]	1 lf	2 lf
POST II	N/A	N/A	N/A	Jun 1[b]	3 to 4 lf	cot to 2 lf
POST III	Jun 11[b]	3 to 4 lf	cot to 2 lf	N/A	N/A	N/A
POST IV	N/A	N/A	N/A	Jun 15[c]	6 to 8 lf	cot to 2 lf
POST V	Jun 25[c]	8 lf	cot to 4 lf	Jun 23[c]	10 to 12 lf	cot to 3 lf
POST VI	Jul 1[c]	10 to 11 lf	cot to 4 lf	Jul 1[c]	12 to 14 nodes	cot to 4 lf
POST VII	Jul 9[c]	11 to 12 lf	cot to 2 lf	N/A	N/A	N/A
POST VII	Jul 30[c]	early-bloom	cot to 4 lf	Jul 21[c]	early-bloom	cot to 4 lf
POST IX	Sep 3[c]	peak-bloom	cot to 4 lf	Aug 4[c]	peak-bloom	cot to 2 lf

[a] Abbreviations: cot, cotyledon; lf, leaf; POST, postemergence-topical.

[b] Glyphosate applied at 1.68 kg ae/ha.

[c] Glyphosate applied at both 0.84 and 1.68 kg ae/ha.

Table 3.3. Postemergence-topical glyphosate rate and timing treatments for Palmer amaranth, devil's-claw, and silverleaf nightshade control[a].

Applications 2003	Date	Crop Stage	Palmer amaranth	devil's-claw	silverleaf nightshade
				cm	
POST I[b]	Jun 11	cot to 1 lf	0	0	10
POST II[c]	Jul 1	5 to 6 lf	0	0 to 10	25
POST III[c]	Jul 11	6 to 8 lf	0	10	3 to 18
POST IV[c]	Jul 15	10 to 11 lf	15	10	15
POST V[c]	Jul 21	10 to 12 lf	10	10	15
POSTVI[c]	Jul 29	early-bloom	5	30	13
Applications 2004					
POST I[c]	May 24	2 lf	0	cot to 7	2 to 10
POST II[b]	Jun 1	3 to 4 lf	0	7 to 10	2 to 15
POST III[c]	Jun 15	6 to 8 lf	cot to 2	cot to 2	1 to 7
POST IV[c]	Jun 23	10 to 12 lf	cot to 7	cot to 10	1 to 13
POST V[c]	Aug 4	early-bloom	cot to 30	cot to 30	1 to 20

[a] Abbreviations: cot, cotyledon; lf, leaf; POST, postemergence-topical.

[b] Glyphosate applied at 1.68 kg ae/ha.

[c] Glyphosate applied at both 0.84 and 1.68 kg ae/ha.

Table 3.4. Residual herbicide applications in a Roundup Ready Flex weed management system 2003[a].

Treatment[b]	Rate	Date	Crop Stage	weed size: Palmer amaranth	weed size: Devil's-claw	weed size: Silverleaf nightshade
	kg ae/ha			cm		
glyphosate	0.84	Jun 11	3 to 4 lf	0 to 10	2 to 10	2 to 10
glyphosate	0.84	Jul 1	12 lf	5 to 8	5 to 8	5 to 15
glyphosate	1.26	Jun 11	3 to 4 lf	0 to 10	2 to 10	2 to 10
glyphosate	1.26	Jul 11	14 lf	0 to 18	0 to 18	2 to 15
glyphosate	1.68	Jun 11	3 to 4 lf	0 to 10	2 to 10	2 to 10
glyphosate	1.68	Jul 11	14 lf	0 to 18	0 to 18	2 to 15

[a] Abreviation: lf, leaf.

[b] All treatments applied alone or in combination with either trifluralin preplant incorporated on March 27 at 0.84 kg ai/ha, pyrithiobac postemergence-topical at 0.04 kg ai/ha, or metolachlor postemergence-topical at 1.12 kg ai/ha.

Table 3.5. Residual herbicide applications in a Roundup Ready Flex weed management system 2004.

				weed size		
Treatment[b]	Timing	Date	Crop Stage	Palmer amaranth	devil's-claw	silverleaf nightshade
				cm		
glyphosate	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jul 2	12 to 14 lf	0 to 12	0 to 10	2 to 12
glyphosate	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	PDIR	Jun 23	10 to 12 lf	0 to 10	0 to 8	2 to 12
glyphosate+pyrithiobac	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jul 2	12 to 14 lf	0 to 12	0 to 10	2 to 12
glyhposate+metolachlor	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jul 8	14 to 16 lf	2 to 10	2 to 8	2 to 8
glyphosate+pyrithiobac	MPOST	Jun 9	4 to 6 lf	2 to 15	2 to 15	2 to 20
glyphosate	POST	Jul 21	peak-bloom	2 to 13	2 to 13	5 to 15
glyhposate+metolachlor	MPOST	Jun 9	4 to 6 lf	2 to 15	2 to 15	2 to 20
glyhposate	POST	Jul 8	14 to 16 lf	2 to 10	2 to 8	2 to 8

[a] Abbreviations: EPOST, early postemergence; lf, leaf; MPOST, mid-postemergence; PDIR, postemergence-directed; POST, postemergence-topical.

[b] Trifluralin applied preplant incorporated at 0.84 kg ai/ha on March 23; rates=0.84 kg ae/ha, glyphosate; 0.04 kg ai/ha, pyrithiobac; 1.12 kg ai/ha, metolachlor.

Table 3.6. In-season residual herbicides and glyphosate in a Roundup Ready Flex weed management system 2004[a].

Treatment[b]	Timing	Date	Crop Stage	weed size: Palmer amaranth	weed size: devil's-claw	weed size: silverleaf nightshade
				cm		
glyphosate	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jun 23	10 to 12 lf	0 to 10	0 to 8	2 to 12
glyphosate	POST	Jul 21	peak-bloom	2 to 13	2 to 13	5 to 15
glyphosate	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	PDIR	Jun 23	10 to 12 lf	0 to 10	0 to 8	2 to 12
glyphosate	PDIR	Jul 21	peak-bloom	2 to 13	2 to 13	5 to 15
glyphosate+pyrithiobac	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jun 23	10 to 12 lf	0 to 10	0 to 8	2 to 12
glyhposate+metolachlor	EPOST	Jun 1	3 to 4 lf	5 to 8	8 to 10	2 to 15
glyphosate	POST	Jul 2	12 to 14 lf	0 to 12	0 to 10	2 to 12
glyphosate+pyrithiobac	MPOST	Jun 9	4 to 6 lf	2 to 15	2 to 15	2 to 20
glyphosate	POST	Jul 8	14 to 16 lf	2 to 10	2 to 8	2 to 8
glyhposate+metolachlor	MPOST	Jun 9	4 to 6 lf	2 to 15	2 to 15	2 to 20
glyhposate	POST	Jul 8	14 to 16 lf	2 to 10	2 to 8	2 to 8

[a] Abbreviations: EPOST, early postemergence; lf, leaf; MPOST, mid-postemergence; PDIR, postemergence-directed; POST, postemergence-topical.

[b] Rate=0.84 kg ae/ha, glyphosate; 0.04 kg ai/ha, pyrithiobac; 1.12 kg ai/ha, metolachlor.

Table 3.7. Application description of ivyleaf morningglory control in Hockley County 2003[a].

	POST I	POST II	POST III	POST IV	POST V	POST VI	POST VII
Application date	May 29	Jun 11	Jun 25	Jul 1	Jul 9	Jul 30	Sep 3
Air temperature (ºC)	30	29	32	34	34	26	28
Relative Humidity (%)	28	32	34	26	35	54	33
Wind speed (kph)	5	10	0	13	10	5	3
Soil surface temp (ºC)	28	32	37	39	42	34	30
Cloud cover (%)	0	0	90	60	15	70	80

[a] Abreviations: POST, postemergence-topical.

Table 3.8. Application description of ivyleaf morningglory control in Lubbock 2004[a].

	POST I	POST II	POST III	POST IV	POST V	POST VI	POST VII
Application date	May 24	Jun 1	Jun 15	Jun 23	Jul 1	Jul 21	Aug 4
Air temperature (ºC)	34	33	24	27	27	32	32
Relative Humidity (%)	11	14	76	43	68	39	39
Wind speed (kph)	16	16	16	10	16	10	6
Soil surface temp (ºC)	27	31	24	29	32	32	29
Cloud cover (%)	5	20	0	40	10	10	15

[a] Abreviations: POST, postemergence-topical.

Table 3.9. Application description of Palmer amaranth, devil's-claw, and silverleaf nightshade control 2003[a].

	POST I	POST II	POST III	POST IV	POST V	POST VI
Application date	Jun 11	Jul 1	Jul 11	Jul 15	Jul 21	Jul 29
Air temperature (ºC)	23	22	24	33	29	26
Relative Humidity (%)	50	62	52	20	47	56
Wind speed (kph)	8	11	2	5	13	13
Soil surface temp (ºC)	26	28	29	34	31	29
Cloud cover (%)	5	0	5	0	0	10

[a] Abreviations: POST, postemergence-topical.

Table 3.10. Application description of Palmer amaranth, devil's-claw, and silverleaf nightshade control 2004[a].

	POST I	POST II	POST III	POST IV	POST V
Application date	May 24	Jun 1	Jun 15	Jun 23	Aug 4
Air temperature (ºC)	36	33	24	27	33
Relative Humidity (%)	11	14	76	43	35
Wind speed (kph)	16	16	16	10	6
Soil surface temp (ºC)	27	31	24	29	31
Cloud cover (%)	5	15	0	40	15

[a] Abreviations: POST, postemergence-topical.

Table 3.11. Application description of glyphosate and residual herbicide systems 2003[a].

	PPI	POST I	POST II	POST III	POST IV	POST V	POST VI
Application date	Mar 27	May 29	Jun 4	Jun 11	Jun 19	Jul 1	Jul 11
Air temperature (ºC)	19	24	21	27	28	27	21
Relative Humidity (%)	44	40	68	50	78	60	55
Wind speed (kph)	8	8	8	8	11	11	2
Soil surface temp (ºC)	17	21	24	26	32	28	29
Cloud cover (%)	90	0	75	5	5	0	5

[a] Abreviations: PPI, preplant incorporated; POST, postemergence-topical.

Table 3.12. Application description of glyphosate and residual herbicide systems 2004[a].

	PPI	POST I	POST II	POST III	POST IV	POST V	POST VI
Application date	Mar 23	Jun 1	Jun 9	Jun 23	Jul 2	Jul 8	Jul 21
Air temperature (ºC)	13	32	21	23	22	36	32
Relative Humidity (%)	75	14	90	61	87	35	39
Wind speed (kph)	16	16	14	5	13	13	10
Soil surface temp (ºC)	7	31	29	29	29	35	29
Cloud cover (%)	50	15	90	40	0	0	0

[a] Abreviations: PPI, preplant incorporated; POST, postemergence-topical.

CHAPTER IV

RESULTS AND DISCUSSION

Ivyleaf Morningglory Control

2003.

A weed management system by rate interaction was not observed in early- or mid-season ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] control 2003; therefore, data was averaged over weed management system and rate. A weed management system by rate interaction was observed in late-season ivyleaf morningglory control 2003; therefore, data was not averaged across weed management system or rate.

Early-season ivyleaf morningglory control was greater with the 1.68 (81%) than the 0.84 (72%) kg ae/ha rate while similar between systems (Table 4.1). Similar mid-season ivyleaf morningglory control was observed in all weed management systems (94 to 99%) and at both rates of glyphosate [*N*-(phophonomethyl)glycine] (96 to 98%) when combined across weed management systems and rates. Late-season ivyleaf morningglory control was improved by increasing the glyphosate rate to 1.68 irregardless of weed management system. The CS/ASN and ASN systems controlled ivyleaf morningglory better than the CS system at both the 0.84 and 1.68 rates.

Application timing was essential in achieving effective ivyleaf morningglory control. Rainfall in January to March totaled 13 mm with an additional 188 mm recorded throughout the growing season (April to September). Due to the drier early-season, ivyleaf morningglory emergence was limited, which decreased the need for early-season CS applications. More effective control was achieved with the same amount of glyphosate when applied based upon weed density and size (Table 4.1).

2004.

A weed management system by rate interaction was not observed early-season 2004; therefore, data was averaged over weed management system and rate (Table 4.2). A weed management system by rate interaction was observed mid- and late-season 2004; therefore, data was not averaged over weed management system or rate.

Similar early-season ivyleaf morningglory control (89 to 91%) was achieved with all weed management systems in 2004 (Table 4.2). Glyphosate at 1.68 kg/ha provided greater ivyleaf morningglory control (94%) than glyphosate at 0.84 kg/ha (85%), when averaged over weed management systems. Mid-season control was not different between weed management systems at each glyphosate rate. However, glyphosate at 1.68 kg/ha achieved greater ivyleaf morningglory control than glyphosate at 0.84 kg/ha in the ASN and CS/ASN weed management systems. Effective season-long control (98%) was achieved with five glyphosate applications at 1.68 kg/ha in the CS/ASN and ASN weed management systems (Table 4.2). Three glyphosate applications in the CS weed management system did not provide adequate control (at least 80%) at either glyphosate rate.

Similar to 2003, environmental conditions in 2004 affected ivyleaf morningglory emergence and control. Above average rainfall was recorded with January to March rainfall totaling 135 mm and a growing season (April to September) total of 425 mm. Due to these conditions, early-season CS applications were more beneficial than in 2003 (Tables 4.1 to 4.2). However, to achieve season-long control additional ASN applications were necessary to effectively control ivyleaf morningglory. An increase in glyphosate rate was also necessary to effectively control ivyleaf morningglory. Similar results have been reported that glyphosate requires higher application rates and timely applications to control ivyleaf morningglory (Jordan et al. 1997; McCloskey et al. 2004; Tingle et al. 1996).

<u>Palmer amaranth, devil's-claw, and silverleaf nightshade control 2003</u>.

A weed management system by rate interaction was not observed in early or late-season for any of the three weed species; therefore, data was averaged over weed management system and rate (Table 4.3). A weed management system by rate interaction was not observed for Palmer amaranth [*Amaranthus palmeri* (S.) Wats] mid-season but was for devil's-claw [*Proboscidea louisianica* (Mill.) Thellung] and silverleaf nightshade (*Solanum elaeagnifolium* Cav.) mid-season; therefore, data was not averaged across weed management system or rate when there was an interaction.

Palmer amaranth was effectively controlled season-long regardless of application timing or rate (at least 99%) (Table 4.3). All weed management systems effectively controlled devil's-claw (at least 99%) with the exception of the mid-season ASN weed management system at the 0.84 kg/ha rate (85%). This difference was a function of fewer applications and weed densities rather than weed management system or rate. Early-season silverleaf nightshade control was not as effective as Palmer amaranth and devil's-claw control. However, glyphosate at 1.68 kg/ha controlled silverleaf nightshade 81%, which was greater than 74% control at 0.84 kg/ha, when averaged across weed management systems. Similar to mid-season devil's-claw control, a difference in silverleaf nightshade control was observed in the ASN weed management system. Three glyphosate applications regardless of rate effectively controlled silverleaf nightshade late-season with at least 93% control observed (Table 4.3). These data suggests that an increase in glyphosate rate was not necessary to gain effective season-long control of all three weeds. This supports Croon et al. (2003) who reported that an increase in glyphosate rate might be less important than timely applications.

2004.

A weed management system by rate interaction was not observed in Palmer amaranth, devil's-claw, or early- or late-season silverleaf nightshade control (Table 4.4). Therefore, data was averaged over weed management system and rate. A weed management system by rate interaction was observed in mid-season silverleaf nightshade control; therefore, data was not averaged over weed management system or rate.

All weed management systems effectively controlled Palmer amaranth and devil's-claw regardless of application timing or rate (Table 4.4). Silverleaf nightshade was not controlled as effectively as Palmer amaranth or devil's-claw early-season in 2004; however, there were no differences in control when averaged across weed management systems or rates. Three glyphosate applications at 0.84 kg/ha in the CS weed management system provided greater mid-season silverleaf nightshade control (92%) than two applications in the CS/ASN (83%) and ASN (86%) weed management systems. Within the 1.68 kg/ha rate, there were no differences in silverleaf nightshade control. All weed management systems and rates effectively controlled silverleaf nightshade (at least 93%) season-long with three glyphosate applications in 2004.

These data suggest that Palmer amaranth, devil's-claw, and silverleaf nightshade can be effectively controlled season-long when glyphosate is applied at 0.84 kg/ha based upon either CS or ASN application timings (Table 4.4). Previous research by Dotray and Keeling (1996) reported that a fall application of glyphosate at 0.84 kg/ha provided effective long-term control of silverleaf nightshade. This may not be necessary when Palmer amaranth and devil's-claw is present in the field, which requires in-season applications of glyphosate. Furthermore, Keeling et al (1999) reported that an additional postemergence-directed application of glyphosate improved season-long control of silverleaf nightshade.

2004 Yield.

Glyphosate rate and weed management system had no effect on cotton lint yield when averaged across rates (Table 4.5). Yield was in agreement with the weed control results.

Glyphosate and Residual Herbicide Systems

2003.

A weed management system by rate interaction was not observed seven days after treatment one (7 DAT 1) or ten days after treatment two (10 DAT 2); therefore, data was averaged across rates and weed management systems (Tables 4.6 to 4.7). A weed management system by rate interaction was observed the day of treatment two (DOT 2); therefore, data was not averaged across rates or weed management systems.

All weed management systems effectively controlled Palmer amaranth and devil's-claw (at least 98%) 7 DAT 1 and 10 DAT 2 (Tables 4.6 to 4.7). Within weed management systems at DOT 2, glyphosate at 0.84 kg/ha controlled Palmer amaranth 92%, and greater rates did not improve control (Table 4.6). Glyphosate alone [without trifluralin (α,α,α,-trifluoro-2,6-dinitro-*N, N*-dipropyl-p-toluidine) in the system] was able to maintain effective Palmer amaranth control (92%). Similar results were achieved in devil's-claw control with at least 86% control in the glyphosate and trifluralin followed by (fb) glyphosate weed management systems.

Trifluralin fb glyphosate + pyrithiobac {2-chloro-6-[(4,6-dimethoxypyrimidin-2-yl)thio]benzoate} or metolachlor [(2-chloro-*N*-(2-ethyl-6-methylphenyl)–*N*-(2-methoxy-1-methylethyl)] controlled Palmer amaranth at least 96% and devil's-claw at least 81% at DOT 2 within the 0.84 kg/ha glyphosate rate (Table 4.7). Palmer amaranth control was increased at DOT 2 with the addition of an in-season residual except at the 1.68 kg/ha rate of glyphosate. An increase in glyphosate rate did not increase control of either weed, and in some circumstances control decreased. Due to USDA regulations for regulated crops, the plot area was destroyed on July 21; therefore, little time was available to evaluate the use of residuals in a Roundup Ready Flex weed management system in 2003.

<u>2004</u>.

A weed management system by timing interaction was observed at 14 DAT in Palmer amaranth control; therefore, data was not averaged across weed management systems or timings. A weed management system by timing interaction was not observed at any other rating date; therefore, data was averaged across weed management systems and timings.

Devil's-claw control with and without trifluralin was at least 97% except with glyphosate alone 14 DAT (Table 4.8). When these treatments were applied in combination with trifluralin Palmer amaranth control was at least 97% season-long. Palmer amaranth control 14 DAT without trifluralin PPI was at least 95% except with glyphosate applied alone EPOST or MPOST and glyphosate +

pyrithiobac EPOST. Palmer amaranth control was at least 95% with all treatment combinations late-season. The glyphosate only system supports the report by York and Culpepper (2004) who reported 100% Palmer amaranth control with glyphosate.

The addition of trifluralin PPI, pyrithiobac or metolachlor POST reduced the number of glyphosate applications required in-season (from three to two) to control Palmer amaranth (Table 4.8). This is consistent with earlier reports by Culpepper et al. (2000) who reported that the addition of a residual herbicide primarily allows for flexibility in glyphosate timing; however, residuals often reduced the number of glyphosate applications needed for adequate control (Wilcut et al. 1998). Similar to results in this research, Wilcut and Hinton (1997) reported that soil-applied herbicides were not necessary for weed control when glyphosate was applied repeatedly. These results support Isgett et al. (1997) who reported that glyphosate used in conjunction with a residual herbicide provides excellent season long control.

2004 Yield.

Cotton lint yield was not affected by weed management system or application timing, when averaged across application timings or weed management systems with or without trifluralin (Table 4.21). Cotton lint yields ranged from 583 to 618 kg/ha without trifluralin and 577 to 642 kg/ha with trifluralin, when averaged across weed management systems.

Table 4.1. Effect of glyphosate rate and weed management system on ivyleaf morningglory control in 2003[a].

Evaluation Timing	Weed Management System	Rate[b] 0.84	1.68	avg
		— % —		
early-season	CS (2 lf)	70	83	77 A[c]
	CS/ASN (2 lf)	73	79	76 A
	ASN[d]	N/A	N/A	N/A
	avg	72 Y[e]	81 X	
mid-season	CS (2 fb 7 fb 11 lf)	99	99	99 A
	CS/ASN (2 fb 7 lf)	97	98	98 A
	ASN (11 lf)	91	97	94 A
	avg	96 X	98 X	
late-season	CS (2 fb 7 fb 11 lf)	55 b[f]y[g]	65 bx	60
	CS/ASN (2 fb 7 fb 17 fb 19 lf)	89 ay	99 ax	94
	ASN (11 fb 17 fb 19 lf)	87 ay	97 ax	92
	avg	77	87	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; fb, followed by; lf, leaf.

[b] Rate = kg ae/ha.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Ivyleaf morningglory emergence was limited by dry conditions; therefore, no applications were required in the ASN weed management system.

[e] Rate means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[g] Rate means within a weed management system follwed by the same lower case letter (x, y) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.2. Effect of glyphosate rate and weed management system on ivyleaf morningglory control in 2004[a].

Evaluation Timing	Weed Management System	Rate[b] 0.84	1.68	avg
		——— % ———		
early-season	CS (1 fb 7 lf)	89	92	91 A[c]
	CS/ASN (1 fb 7 lf)	85	94	90 A
	ASN (1 fb 7 lf)	82	96	89 A
	avg	85 Y[d]	94 X	
mid-season	CS (1 fb 7 fb 11 lf)	89 a[e]x[f]	96 ax	93
	CS/ASN (1 fb 7 lf fb 13 nd)	85 ay	96 ax	91
	ASN (1 fb 7 lf fb 13 nd)	79 ay	94 ax	87
	avg	84	95	
late-season	CS (1 fb 7 fb 11 lf)	73 bx	79 bx	76
	CS/ASN (1 fb 7 lf fb 13 nd fb EB fb PB)	86 ay	98 ax	92
	ASN (1 fb 7 lf fb 13 nd fb EB fb PB)	80 aby	98 ax	89
	avg	80	92	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; fb, followed by; lf, leaf.

[b] Rate = kg ae/ha.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Rate means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Rate means within a weed management system follwed by the same lower case letter (x, y) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.3. Effect of glyphosate rate and timing on Palmer amaranth, devil's-claw, and silverleaf nightshade control 2003[a].

Evaluation		Palmer amaranth			devil's-claw			silverleaf nightshade		
		Rate[b]			Rate			Rate		
Timing	Weed Management System	0.84	1.68	avg	0.84	1.68	avg	0.84	1.68	avg
		%								
early-season	CS (2 lf)	100	100	100 A[c]	100	100	100 A	73	80	77 A
	CS/ASN (2 lf)	100	100	100 A	100	100	100 A	76	80	78 A
	ASN (2 lf)	100	100	100 A	100	100	100 A	73	82	78 A
	avg	100 X[d]	100 X		100 X	100 X		74 Y	81 X	
mid-season	CS (2 fb 7 fb 12 lf)	100	100	100 A	100 a[e]x[f]	99 ax	99	94 ax	97 ax	96
	CS/ASN (2 fb 5[g] fb 10 lf)	100	100	100 A	99 ax	100 ax	99	93 ax	93 ax	93
	ASN (2 fb 5 lf)	99	100	99 A	85 by	99 ax	92	85 by	93 ax	89
	avg	100 X	100 X		95	99		91	94	
late-season	CS (2 fb 7 fb 12 lf)	100	100	100 A	100	100	100 A	95	98	97 A
	CS/ASN (2 fb 5[g] fb 10 lf)	99	99	99 A	100	100	100 A	94	92	93 A
	ASN (2 fb 5 fb 14 lf)	99	99	99 A	100	100	100 A	97	96	97 A
	avg	99 X	99 X		100 X	100 X		95 X	95 X	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; lf, leaf.

[b] Rate = kg ae/ha.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Rate means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Rate means within a weed management system follwed by the same lower case letter (x, y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[g] 5 lf application at 0.84 kg ae/ha only.

Table 4.4. Effect of glyphosate rate and timing on Palmer amaranth, devil's-claw, and silverleaf nightshade control 2004[a].

Evaluation		Palmer amaranth			devil's-claw			silverleaf nightshade		
		Rate[b]			Rate			Rate		
Timing	Weed Management System	0.84	1.68	avg	0.84	1.68	avg	0.84	1.68	avg
		%								
early-season	CS (2 lf)	100	100	100 A[c]	99	98	99 A	72	80	76 A
	CS/ASN (2 lf)	100	100	100 A	100	100	100 A	70	68	69 A
	ASN (2 lf)	100	100	100 A	98	100	99 A	73	83	78 A
	avg	100 X[d]	100 X		99 X	99 X		72 X	77 X	
mid-season	CS (2 fb 7 fb 11 lf)	100	99	99 A	99	98	99 A	92 a[e]y[f]	99 ax	96
	CS/ASN (2 fb 11 lf)	100	100	100 A	99	99	99 A	83 by	95 ax	89
	ASN (2 fb 11 lf)	100	100	100 A	99	99	99 A	86 by	95 ax	91
	avg	100 X	100 X		99 X	99 X		87	96	
late-season	CS (2 fb 7 fb 11 lf)	99	99	99 A	99	99	99 A	97	99	98 A
	CS/ASN (2 fb 11 lf fb EB)	99	99	99 A	100	100	100 A	92	94	93 A
	ASN (2 fb 11 lf fb EB)	99	99	99 A	100	100	100 A	96	96	96 A
	avg	99 X	99 X		99 X	99 X		95 X	96 X	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; lf, leaf.

[b] Rate = kg ae/ha.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Rate means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Rate means within a weed management system follwed by the same lower case letter (x, y) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.5. Effect of glyphosate rate and timing on cotton lint yield in 2004[a].

Weed Management System	Rate[b] 0.84	1.68	avg
	kg/ha		
CS (2 fb 7 fb 11 lf)	637	603	620 A[c]
CS/ASN (2 fb 11 lf fb EB)	647	578	613 A
ASN (2 fb 11 lf fb EB)	563	630	597 A
avg	616 X[d]	604 X	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; EB, early-bloom; fb, followed by; lf, leaf.

[b] Rate = kg ae/ha.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Rate means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.6. Effect of glyphosate and residual herbicide on Palmer amaranth and devil's-claw control in a Roundup Ready Flex weed management system 2003[a].

Weed	Weed Management System[b]	7 DAT 1				DOT 2				10 DAT 2			
		0.84	1.26	1.68	avg	0.84	1.26	1.68	avg	0.84	1.26	1.68	avg
		%											
Palmer	gly fb gly	100	99	100	100 A[c]	92 a[e]x[f]	76 ay	81 by	83	100	100	99	100 A
amaranth	trifl fb gly fb gly	100	100	100	100 A	89 ax	80 ay	91 ax	87	99	99	100	99 A
	avg	100 X[d]	99 X	100 X		91	78	86		99 X	99 X	99 X	
devil's-claw	gly fb gly	98	99	99	99 A	86 ax	80 ay	76 ay	81	98	99	96	98 A
	trifl fb gly fb gly	97	98	100	98 A	86 ax	74 by	81 ax	80	97	98	99	98 A
	avg	98 X	99 X	99 X		86	77	79		98 X	99 X	98 X	

[a] Abbreviations: avg, average; DAT, days-after-treatment; DOT, day-of-treatment; fb, followed by; gly, glyphosate; trifl, trifluralin.

[b] Rate=0.84 kg ai/ha, trifluralin.

[c] Weed management system means followed by the same upper case letter (A, B) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Timing percent control means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means within a timing followed by the same lower case letter (a, b) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Timing percent control means within a weed management system follwed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.7. Effect of glyphosate and residual herbicides on Palmer amaranth and devil's-claw control in a Roundup Ready Flex weed management system 2003[a].

	Weed Management	7 DAT 1				DOT 2				10 DAT 2			
Weed	System[b]	0.84	1.26	1.68	avg	0.84	1.26	1.68	avg	0.84	1.26	1.68	avg
		%											
Palmer	trifl fb gly fb gly	100	100	100	100 A[c]	89 b[e]x[f]	80 cy	91 ax	87	99	99	100	99 A
amaranth	trifl fb gly + pyr fb gly	100	100	100	100 A	96 ax	97 ax	89 ay	94	99	100	100	100 A
	trifl fb gly + met fb gly	100	100	100	100 A	98 ax	88 by	93 axy	93	100	100	100	100 A
	avg	100 X[d]	100 X	100 X		94	88	91		99 X	100 X	100 X	
devil's-claw	trifl fb gly fb gly	97	98	100	98 A	86 ax	74 by	81 ax	80	97	98	99	98 A
	trifl fb gly + pyr fb gly	98	99	100	99 A	81 ax	85 ax	80 ax	82	94	99	100	98 A
	trifl fb gly + met fb gly	99	100	100	100 A	84 ax	80 abx	81 ax	82	98	100	99	99 A
	avg	98 X	99 X	100 X		84	80	81		96 X	99 X	99 X	

[a] Abbreviations: avg, average; DAT, days-after-treatment; DOT, day-of-treatment; fb, followed by; gly, glyphosate; met, metolachlor; pyr, pyrithiobac; trifl, trifluralin.

[b] Rate=0.84 kg ai/ha, trifluralin; kg ae/ha, glyphosate; 0.04 kg ai/ha, pyrithiobac; 1.12 kg ai/ha, metolachlor.

[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Timing percent control means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means within a timing followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Timing percent control means within a weed management system follwed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.

Table 4.8. Effects of glyphosate and residual herbicides on Palmer amaranth and devil's-claw control in 2004[a].

Evaluation		Palmer amaranth						devil's-claw					
		without trifluralin			with trifluralin			without trifluralin			with trifluralin		
Timing	Weed Management System[b]	EP	MP	avg	EP	MP	avg	EP	MP	avg	EP	MP	avg
		%											
14 DAT	glyphosate	87 b[c]x[d]	85 bx	86	95	98	97 A[e]	93	92	93 B	97	97	97 A
	glyphosate+pyrithiobac	91 by	100 ax	96	99	100	99 A	98	99	99 A	100	98	99 A
	glyphosate+metolachlor	97 ax	97 ax	97	100	100	100 A	100	99	99 A	96	100	98 A
	avg	92	94		98 X[f]	99 X		97 X	97 X		98 X	98 X	
late-season	glyphosate fb glyphosate fb glyphosate[g]	99	99	99 A	98	96	97 A	99	99	99 A	99	98	99 A
	glyphosate+pyrithiobac fb glyphosate	96	94	95 B	99	99	99 A	97	97	97 B	99	99	99 A
	glyphosate+metolachlor fb glyphosate	98	96	97 AB	98	99	99 A	99	98	99 A	99	100	99 A
	avg	98 X	96 X		98 X	98 X		98 X	98 X		99 X	99 X	

[a] Abbreviations: avg, average; DAT, days after treatment; EP, early-post; MP, mid-post.

[b] Rates=0.84 kg ai/ha, trifluralin; 0.84 kg ae/ha, glyphosate; 0.04 kg ai/ha, pyrithiobac; 1.12 kg ai/ha, metolachlor.

[c] Weed management system means within a timing followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.

[d] Timing percent control means within a weed management system follwed by the same lower case letter (x, y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[f] Timing percent control means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

[g] Treatments treated with trifluralin PPI did not receive the last glyphosate application.

Table 4.9. Effects of glyphosate and residual herbicides on yield in a Roundup Ready Flex weed management system 2004[a].

Weed Management System[b]	without trifluralin			with trifluralin		
	EP	MP	avg	EP	MP	avg
	kg/ha					
glyphosate fb glyphosate fb glyphosate[c]	563	627	595 A[d]	553	618	586 A
glyphosate+pyrithiobac fb glyphosate	608	613	611 A	647	546	597 A
glyphosate+metolachlor fb glyphosate	578	613	596 A	726	568	647 A
avg	583 X[e]	618 X		642 X	577 X	

[a] Abbreviations: avg, average; EP, early-post; fb, followed by; MP, mid-post.

[b] Rates=0.84 kg ai/ha, trifluralin; 0.84 kg ae/ha, glyphosate; 0.04 kg ai/ha, pyrithiobac; 1.12 kg ai/ha, metolachlor.

[c] Treatments treated with trifluralin PPI did not receive the last glyphosate application.

[d] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.

[e] Timing percent control means followed by the same upper case letter (X, Y) are not significantly different (P=0.05) using Fisher's Protected LSD.

CHAPTER V

SUMMARY AND CONCLUSIONS

Glyphosate [*N*- (phophonomethyl)glycine] rate and timing was essential to effectively control ivyleaf morningglory (*Ipomoea hederacea* (L.) Jacq.). Early-season applications made based on crop stage (CS) timings were unnecessary in 2003 due to a lack of early-season rainfall, however in 2004 these timings were beneficial as well as two additional as-needed (ASN) late-season applications. Late-season control ratings also demonstrated the importance of increasing glyphosate rate from 0.84 to 1.68 kg ae/ha (Tables 4.1 and 4.2). Glyphosate applied at 1.68 kg/ha controlled ivyleaf morningglory at least 97% in 2003 and 98% in 2004 season-long when applications were made based on weed growth stage and density.

In more common annual and perennial weed situations where Palmer amaranth [*Amaranthus palmeri* (S.) Wats], devil's-claw [*Proboscidea louisianica* (Mill.) Thellung], and silverleaf nightshade (*Solanum elaeagnifolium* Cav.) are present, rate and timing was not important for season-long control (Tables 4.3 and 4.4). In both years three glyphosate applications made either based on CS or weed growth stage and density, provided effective control of all three weed species. Lint yields were unaffected by glyphosate rate or timing in 2004 (Table 4.5).

All glyphosate and residual herbicide weed management systems controlled Palmer amaranth and devil's-claw season-long (Tables 4.8). The addition of trifluralin (α,α,α,-trifluoro-2,6-dinitro-*N, N*-dipropyl-p-toluidine) preplant incorporated, pyrithiobac ((2-chloro-6-[(4,6-dimethoxypyrimidin-2-yl)thio]benzoate) or metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl) –*N*-(2-methoxy-1-methylethyl) postemergence reduced the number of ASN glyphosate applications by one. However, trifluralin fb glyphosate + pyrithiobac or metolachlor did not reduce ASN glyphosate applications compared to glyphosate + pyrithiobac or metolachlor. No differences in cotton lint yield were observed (Table 4.9).

LITERATURE CITED

Abernathy, J.R. and J.W. Keeling. 1979. Silverleaf nightshade control in cotton with glyphosate. Proc. South. Weed Sci. Soc. 32:380.

Abernathy, J.R. and C.G. McWhorter. 1992. Evolution of weed control in cotton. In C.G. McWhorter and J.R. Abernathy (eds.) Weeds of Cotton: Characterization and Control. The Cotton Foundation. Memphis, TN. p. 1-8.

Aldrich, R.J. and R.J. Kremer 1997. Principles in Weed Management. Ames, Iowa: Iowa State University Press. 2:3-33.

Alexander, U.U., B.E. Warrick, and D.N. Weaver. 1990. Silverleaf nightshade control in west Texas cotton. Texas Agric. Ext. Ser. Misc. Pub. L-2436.

Anderson, W.P. 1996. *Weed Science Principles and Applications*. St. Paul, Minnesota: West Publishing Company. p. 39, 40, 43-65.

Anonymous. 2004. National Agricultural Statistics Service. [database on-line]. Available from http://www.nass.usda.gov. Internet. Accessed 15 December 2004.

Ashton, F.M., T.J. Monaco, and M. Barrett. 1991. Weed Science: Principles and Practices. John Wiley & Sons, Inc. New York, NY. p. 5.

Askew, S.D., W.A. Bailey, J.W. Wilcut, and J.D. Hinton. 1998. Weed control in cotton with different tillage systems and herbicide resistances. P. Dugger and D.A. Richter (eds.) Proc. Beltwide Cotton Conf. 1:866.

Blair, L.K. 1999. Glufosinate-tolerant cotton: tolerance and weed management. M.S. Thesis, Texas Tech University, Lubbock, TX. p. 61-63.

Bridges, D.C. 1994. Impact of Weeds on Human Endeavors. Weed Technol. 8:392-395.

Bryson, C.T., C.E. Snipes, and D.R. Shaw. 1991. Effects of DPX-PE350 on weed control and cotton growth yield. D.J. Herber and D.A. Richter (eds.). Proc. Beltwide Cotton Conf. p. 957.

Buchanan, G.A. 1974. New Developments in Cotton Weed Control. Proc. Beltwide Cotton Production-Mechanical Conf. p. 8-9.

Buchanan, G.A. 1992. Trends in weed control methods. In C.G. McWhorter and J.R. Abernathy (eds.). Weeds of Cotton: Characterization and Control. The Cotton Foundation. Memphis, TN. p. 47-72.

Buchanan, G.A. and E.R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18:149-154.

Burns, J.A., R.E. Cerny, K.A. Croon, R.A. Ihrig, M.E. Oppenhuizen, B. Sammons, and R.D. Voth. 2004. An update on Roundup Ready Flex cotton. Proc. Beltwide Cotton Conf. CD-ROM.

Byrd, J.D., Jr. 1991. Report of the 1990 cotton weed loss committee. Proc. Beltwide Cotton Conf. p. 949.

Byrd, J.D., Jr. 2000. Report of the 1999 cotton weed loss committee. Proc. Beltwide Cotton Conf. CD-ROM.

Byrd, J.D., Jr. 2003. Report of the 2002 cotton weed loss committee. Proc. Beltwide Cotton Conf. CD-ROM.

Chen, Y.S., C.Hubmeier, M. Tran, A. Martens, and R.E. Cerny. 2003. Glyphosate-resistant EPSPS expression in microspores and tapetum cells provides reproductive tolerance in Roundup Ready Flex cotton. Proc. Beltwide Cotton Conf. CD-ROM.

Coble, H.D. and J.D. Byrd. 1992. Interference of weeds with cotton. *In* C.G. McWhorter and J.R. Abernathy (eds.). Weeds of Cotton: Characterization and Control. The Cotton Foundation. Memphis. p. 75.

Cooley, A.W. and D.T. Smith. 1973a. Germination and emergence of buffalobur, morningglory, and cocklebur. Weed and Herbicide Research in West Texas. Texas Agric. Exp. Stn. p.11-14 Prog. Rep. PR-3200.

Cooley, A.W. and D.T. Smith. 1973b. Silverleaf nightshade (whiteweed) establishment from seed and clipped seedlings. Weed and Herbicide Research in West Texas. Texas Agric. Exp. Stn. p. 6-9 Prog. Rep. PR-3198.

Cooley, A.W., D.T. Smith, and L.E. Smith. 1973. Devil's-claw – germination, growth, and competition. Weed and Herbicide Research in West Texas. Texas Agric. Exp. Stn. p. 14-17 Prog. Rep. PR-3201.

Correll, D.S. and M.C. Johnston. 1979. Manual of the vascular plants of Texas. Vol 6. The University of Texas at Dallas. Richardson, TX. p. 1446-1449.

Croon, K.A., R. Ihrig, C.B. Coots, D. Pitts, D. Haines, L. Hawf, C. Corkern, A. Mills, R. Montgomery, L. Ganann, D. Jost, and S. Murdock. 2003. Weed management in Roundup Ready Flex cotton. Proc. Beltwide Cotton Conf. CD-ROM.

Culpepper, A.S. and A.C. York. 1998. Weed management in glyphosate-tolerant cotton. J. Cotton Sci. 2:174-185.

Culpepper, A.S., A.C. York, and R.B. Batts. 2000. Are preemergence herbicides needed in Roundup Ready (glyphosate-tolerant) cotton? Proc. Beltwide Cotton Conf. CD-ROM.

Culpepper, A.S., A.E. Gimenez, A.C. York, R.G. Batts, and J.W. Wilcut. 2001. Morningglory (*Ipomoea* spp.) and large crabgrass (*Digitaria sanguinalis*) control with glyphosate and 2,4-DB mixtures in glyphosate-resistant soybean (*Glcine max*). Weed Tech. 15:56-61.

Culpepper, A.S., E.C. Murdock, A.C. York, J.W. Wilcut, and J. Sanderson. 2002. Weed management with Liberty Link cotton in southeastern United States. Proc. Beltwide Cotton Conf. CD-ROM.

Cuthbertson, E.G. 1976. Silverleaf nightshade-a potential threat to agriculture. *Agriculture Gazette NSW.* 87:11-13.

Daniels, N.E. and A.F. Wiese. 1967. Survival and spread of the puncturevine seed weevil in Texas. Texas Agricultural Experiment Station. MP-827.

Davis, C.H., J.J. Smith, and R.S. Hawkins. 1945. Eradication of the white horsenettle in southern Arizona. Ariz. Agric. Exp. Stn. Bull. No. 195. p. 14.

Derr, J.F. 2004. The status of weed science at universities and experiment stations in the northeastern United States. Weed Technol. 18:1150-1156.

Dotray, P.A., B.C. Burns, and J.W. Keeling. 2002. Weed management systems in Liberty,-Roundup-, and Buctril-tolerant cotton. Proc. Beltwide Cotton Conf. CD-ROM.

Dotray, P.A., J.W. Keeling, C.G. Henniger, and J.R. Abernathy. 1996. Palmer amaranth (*Amaranthus palmeri*) and devil's-claw (*Proboscidea louisianica*) control in cotton (*Gossypium hirsutum*) with pyrithiobac. Weed Technol. 10:7-12.

Dotray, P.A. and J.W. Keeling. 1996. Silverleaf Nightshade (*Solanum Elaeagnifolium*) control in cotton with glyphosate at reduced rates. Texas Journal of Agricultural and Natural Resources. 9:33-41.

Dowler, C.C. 1992. Weed survey-southern states. Proc. South. Weed Sci. Soc. 45:396.

Everitt, J.D., J.W. Keeling, P.A. Dotray, and L.L. Lyon. 2002 Weed control in Roundup Ready cotton with residual herbicides. Proc. Beltwide Cotton Conf. CD-ROM.

Everitt, J.D., J.W. Keeling, P.A. Dotray, and T.S. Osborne. 2000. Perennial weed management in Roundup Ready (glyphosate-tolerant) and BXN (bromoxynil-tolerant) cotton on the Texas Southern High Plains. Proc. Beltwide Cotton Conf. CD-ROM.

Ferreira, K.L., D.J. Jost, G.A. Dixon, and D.W. Albers. 1998. Roundup Ready cotton fruiting pattern response to over the top applications of Roundup Ultra after the 4-leaf stage. Proc. Beltwide Cotton Conf. CD-ROM.

Frans, R., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. In N.D. Camper ed. Research methods in Weed Science, 3rd ed. Champaign, IL: South. Weed Sci. Soc. p. 37.

Grichar, J.W., B.A. Besler, K.D. Brewer, and B.W. Minton. 2004. Using soil-applied herbicides in combination with glyphosate in a glyphosate-resistant cotton herbicide program. Crop Prot. 23:1007-1010.

Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1977. The world's worst weeds: Distribution and biology. University Press of Hawaii, Honolulu, HI.

Isgett, T.D., E.C. Murdock, and A. Keeton. 1997. Weed control in Roundup Ready cotton. P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf. 21:787.

Isgett, T.D., E.C. Murdock, and A. Kendig. 1996. Weed control in BXN cotton-performance in 1995. Applied research and growers fields. P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf. p. 1535.

Janick, J., R.W. Schery, F.W. Woods, and V.W. Ruttan. 1981. Plant Science an Introduction to World Crops. San Francisco, CA: W.H. Freeman and Company. p. 443.

Jones, M.A. and C.E. Snipes. 1999. Tolerance of transgenic cotton to topical applications of glyphosate. J. Cotton Sci. 3:19-26.

Johnson, E.M. 1996. Roundup Ready gene in cotton. Proc. Beltwide Cotton Conf. CD-ROM.

Jordan, D.L., A.C. York, J.L. Griffin, P.A. Clay, P.R. Vidrine, and D.B. Reynolds. 1997. Influence of application variables on efficacy of glyphosate. Weed Tech. 11:354-362.

Keeley, P.E. and R.J. Thullen. 1989. Growth and competition of black nightshade (*Solanum nigrum*) and Palmer amaranth (*Amaranthus palmeri*) with cotton (*Gossypium hirsutum*). Weed Sci. 37:326-324.

Keeling, J.W., C.G. Henniger, and J.R. Abernathy. 1993. Broadleaf weed control in cotton with DPX-PE350. D.J. Herber and D.A. Richter (eds.). Proc. Beltwide Cotton Conf. p. 1529.

Keeling, J.W., K.T. Siders, and J.R. Abernathy. 1991. Palmer Amaranth (*Amaranthus palmeri*) control in a conservation tillage system for cotton (*Gossypium hirsutum*). Weed Technol. 5:137-141.

Keeling, J.W., P.A. Dotray, and T.S. Osborne. 1997. Roundup Ready cotton: weed management in conservation tillage systems. Proc. South. Weed Sci. Soc. 50:49.

Keeling, J.W., P.A. Dotray, T.S. Osborne, and J.D. Everitt. 1999. Efficacy of residual herbicides in Roundup Ready cotton systems. Proc. South. Weed Sci. Soc. 52:3.

Keeton, A. and E.C. Murdock. 1997. Weed control in Roundup Ready conservation tillage cotton. Proc. Beltwide Cotton Conf. 1:781.

Kempen, H.M. 1982. Competition devastates cotton crop. California-Arizona Farm Press. 4:26-36.

Kremer, R.J. and A.C. Kennedy. 1996. Rhizobacteria as biocontrol agents of weeds. Weed Technol. 10:601-609.

Marsh, B.H. 2001. Annual morningglory control for transgenic cotton in the San Joaquin Valley. Proc. Beltwide Cotton Conf. p. 1231.

Martens, A., J. Hart, B. Sammons, E. Cerny, S. Huber, and M. Oppenhuizen. 2003. 2002 results of Roundup Ready Flex cotton trials. Proc. Beltwide Cotton Conf. CD-ROM.

May, O.L. and A.S. Culpepper. 2002. Two years of experience with Monsanto's enhanced glyphosate tolerant cotton. Proc. Beltwide Cotton Conf. CD-ROM.

McCloskey, W.B., K.O. Adu-Tutu, and T.V. Hicks. 2004. Roundup Ready Flex cotton: glyphosate tolerance and weed management. Arizona Cotton Report. p. 138.

Mercer, K.L. and D.S. Murray. 1984. Interference of devil's-claw with cotton. Proc. South. Weed Sci. Soc. 37:311.

Mercer, K.L., D.S. Murray, and L.M. Verhalen. 1987. Interference of unicorn-plant (*Proboscidea louisianica*) with cotton (*Gossypium hirsutum*). Weed Sci. 35:807-812.

Morgan, G.D., P.A. Baumann, J.M. Chandler, and J.W. Smith. 1998. Cotton development as affected by Palmer amaranth (*Amaranthus palmeri*) competition. P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf. p. 869.

Nida, D.L., K.H. Kolacz, R.E. Buehler, W.R. Deaton, W.R. Schuler, T.A. Armstrong, M.L. Taylor, C.C. Ebert, G.J. Rogan, S.R. Padgette, R.L. Fuchs. 1996. Glyphosate-tolerant cotton: genetic characterization and protein expression. J. Agric. Food Chem. 44:1960-1966.

Orr, C.C. and E.D. Morey. 1974. Resistance reactions of Castor and guar to root-knot nematodes. (*Meloidogyne Incognita acrita*). Phtopathology. 64:1533-1536.

Pline, W.A., K.L. Edmisten, J.W. Wilcut, R. Wells, and J. Thomas. 2003. Glyphosate-induced reductions in pollen viability and seed set in glyphosate-resistant cotton and attempted remediation by gibberellic acid (GA3). Weed Sci. 51:19-27.

Prostko, E.P. and J.M. Chandler. 1998. Devil's-claw (*Proboscidea louisianica*) and smellmellon (*Cucumis melo var.* dudaim) control in cotton (*Gossypium hirsutum*) with pyrithiobac. Weed Technol. 12:19-22.

Riffle, M.S., W.E. Thilsted, D.S. Murray, R.M. Ahring, and G.R. Waller. 1988. Germination and seed production of unicorn-plant (*Proboscidea louisianica*). Weed Sci. 36:787-791.

Rowland, M.W. and D.S. Murray. 1997. Interference of Palmer amaranth (*Amaranthus palmeri*) with cotton. Proc. South. Weed Sci. Soc. 50:148.

Rummel, D.R. and M.D. Arnold. 1992. Status of the puncturevine seed weevil in the Texas Southern High Plains. Southwestern Entomologist Scientific Note. 17:347-349.

Schoenhals, M.G. and A. F. Wiese. 1988. Control of blueweed and silverleaf nightshade. Proc. South. Weed Sci. Soc. 41:89.

Sheikh, T., T.A. Wheeler, P.A. Dotray, and J.C. Zak. 2001. Biological control of woollyleaf bursage [*Ambrosia grayi* (A.) Nels) Shinners] with *Pseudomonas syringae* pv*. tagetis.* Weed Tech. 15:375-381.

Sherrick, S. 1996. Roundup Ready cotton: marketing plains and weed control programs using Roundup Ultra. Proc. Beltwide Cotton Conf. CD-ROM.

Smith, C.W. 1995. Crop Production: Evolution, History, and Technology. John Wiley & Sons, Inc. New York, NY. p. 324-328.

Smith, D. T. and A. W. Cooley. 1973. Pigweed competition in cotton. Weed and Herbicide Research in West Texas. Texas Agric. Exp. Stn. p. 22-24 Prog. Rep. PR-3205.

Smith, D.T., R.C. Berner, and A.W. Cooley. 1973. Devil's-claw herbicidal control. Texas Agric. Exp. Stn. Prog. Rep. 3202.

Smith, R.J., Jr. 1982 *In* R. Charudattan and H.L. Walker (eds.) Biological Control of Weeds with Plant Pathogens. John Wiley & Sons, Inc. New York, NY. p. 189-203.

Supak, J.R., C.G. Anderson, and W.D. Mayfield. 1992. Trends in Cotton Production: History, culture, mechanization, and economics. In C.G. Mcwhorter and J.R. Abernathy (eds.) Weeds of Cotton: Characterization and Control. The Cotton Foundation. Memphis, TN. p. 9-41.

Tingle, C.H., D.R. Shaw, and J. Hall. 1996. Timing and rate of Roundup in Roundup-Ready soybean. Proc. South. Weed Sci. Soc. 49:55.

Vargas, R.N., S. Wright, and T.M. Martin-Duvall. 1998. Tolerance of Roundup Ready cotton to Roundup Ultra applied at various growth stages. Proc. Beltwide Cotton Conf. CD-ROM.

Warrick, B.E. 1996. Postemergence application of staple for broadleaf weed control in the Southern Rolling Plains of Texas. Proc. Beltwide Cotton Conf. p. 1522-1524.

Westerman, R.B. and D.S. Murray. 1989. Management of silverleaf nightshade in cotton. Proc. South. Weed Sci. Soc. 42:93.

Wilcut, J.W. and J.D. Hinton. 1997. Weed management in no-till and conventional-tillage Roundup Ready cotton. Proc. Beltwide Cotton Conf. 1:780.

Wilcut, J.W., C.E. Snipes, R.L. Nichols, R.M. Hayes, J.M. Chandler, D.C. Bridges, and B.J. Brecke. 1998. A regional evaluation of new technologies for weed management in conventional-tillage cotton. Proc. South. Weed Sci. Soc. 51:52-53.

Wilcut, J.W., D.L. Jordan, W.K. Vencill, and J.S. Richburg, III. 1997. Weed management in cotton (*Gossypium hirsutum*) with soil-applied and PDIR herbicides. Weed Technol. 11:221-226.

Winburne, J.N. 1962. A Dictionary of Agricultural and Applied Terminology. E. Lansing: Michigan State University Press.

Whitson, T.D., L.C. Burrill, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, and R. Parker. 1996. Weeds of the West. Pioneer of Jackson Hole. Jackson, WY. p. 11.

Wright, S.D., R.N. Vargas, M.R. Jimenez Jr., M.P. Keeley, and R. Delgado. 1997. Annual morningglory (*Ipomea* spp.) control in cotton. Proc. Beltwide Cotton Conf. p. 795.

York, A.C. and A.S. Culpepper. 2004 Weed management in LibertyLink and Roundup Ready Flex cotton. Proc. Beltwide Cotton. Conf. CD-ROM.

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