Chapter I

Introduction and Review of Literature

COTTON

Cotton (*Gossypium hirsutum* L.) has been cultivated for thousands of years in most parts of the world and is the most important textile fiber used by man. The invention of the cotton gin in 1794 by Eli Whitney greatly reduced labor demands and fostered large-scale cotton production. Cotton is planted on close to 6.3 million U.S. ha, and is now the fourth largest crop in the United States (Anonymous 2001b). Cotton production is estimated to stimulate the nation's economy with $120 billion in business revenue yearly, the most of any crop (Anonymous 2001a). While cotton is biologically a perennial, herbaceous plant with tropical origins (Edmisten 2001), it is grown as an annual crop in most of the world. Classified in the Malvaceae family, cotton can be divided into three groups: American-upland (*G. hirsutum*), American-pima (*G. barbadense* L.), and Asiatic (*G. arboreum* L. and *G. herbaceum* L.) (Brubaker et al. 1999). Forty-nine species are in the genus *Gossypium* with four used in cultivation (Brubaker et al. 1999). Upland varieties are grown on the vast majority of U.S. acreage (6.2 million ha) and pima varieties are grown on only 69,000 ha in the Southwest (Anonymous 2001b).

*Cotton in Virginia.* The importance of cotton as a Virginia commodity has grown in recent years. Immediately prior to 1987, only one Virginia county produced cotton, with 120 ha in annual production (Maitland 2001a). A steady production increase then occurred, with 742 ha in 1987, 8,324 ha in 1992, and 39,758 ha in 1997 (Anonymous 2001b). Today, 20 counties in Virginia plant over 41,700 ha of cotton each year with potential for additional acreage increases (Maitland 2001a). Recent increases in Virginia cotton production have been driven by several factors, the most important of which was the eradication of the boll weevil (*Anthonomus grandis* Boheman) (Maitland 2001b). The eradication program was started in 1977 in Virginia and North Carolina and successfully eradicated the species from both states in the 1980s. Other factors driving production increases included low prices of other commodities, and the re-introduction of modern gins into Virginia cotton growing regions (Maitland 2001a; 2001b).
Virginia has been able to produce a high-yielding crop. In 1994, growers averaged 1,040 kg/ha, the highest dry-land yield in the United States. According to yield averages from the last five years, Virginia produces the highest yield among the southeastern cotton-growing states (Maitland 2001a); another high yield occurred in 2001 with estimates of 890 kg/ha (Maitland 2001b). Southampton County ranks as the highest cotton producer in Virginia and in 1997 was ranked as the 80th highest producing county in the U. S. with 26,733 kg (Anonymous 2001b).

WEED CONTROL IN COTTON

Conventional cotton. Cotton must be kept as weed free as possible to prevent competition and obtain uncontaminated, clean fiber (Wilcut et al. 1995). While weed control options are greater today than just five years ago, current cotton herbicides do not control all weed species over the entire growing season. As a result, today's weed management programs in cotton often include several herbicides applied with multiple application timings. Many of the herbicides currently registered on cotton must be applied at specific growth stages or as post-directed (POSD) sprays in order to avoid or reduce cotton injury. In addition, the registration of the standard POSD herbicide, cyanazine (2-[[4-chloro-6-(ethyl-amino)-1,3,5-triazin-2-yl]amino]2-methylpropanenitrile), is being phased out in response to a Special Review initiated by the Environmental Protection Agency (EPA) on November 23, 1994 (Jones 2000).

Until the availability of pyrithiobac (2-chloro-6-[4,6-dimethoxy-2-pyrimidinyl]thio)benzoic acid) in 1996, no herbicide was available for postemergence (POST) application over-the-top of conventional cotton varieties without significant crop injury (Webster et al. 2000). Pyrithiobac is still the only herbicide for broad-spectrum broadleaf weed control in conventional cotton varieties (Webster et al. 2000). Growers must utilize a combination of application timings, multiple herbicides, and cultural methods to maintain season-long weed control (Wilcut et al. 1995; York and Culpepper 2001). A typical practice involves a preemergence (PRE) or pre-plant incorporated (PPI) application of a dinitroaniline herbicide for grass control and a PRE broadleaf herbicide (Wilcut et al. 1995). A POST broadleaf herbicide and a POSD application
would then follow with graminicides and cultivation used during the growing season as needed (York and Culpepper 2001).

Cultural weed control methods are very important in cotton production. Between-row cultivation can reduce weed biomass and increase lint yield (Snipes and Mueller 1992; Snipes et al. 1992). Likewise, tillage can control biennials such as horseweed (*Conyza canadensis* (L.) Cronq.) (Brown and Whitwell 1988), reduce perennial weed populations by exposing rhizomes and stolons to cold temperatures (Wilcut et al. 1995), and suppress annual weed species. Other cultural methods, such as crop rotation and stale seedbed programs can provide additional weed control by exposing weeds to different herbicide modes of action (Wilcut et al. 1995; York and Culpepper 2001) and by depleting the seed bank before crop planting (Shaw 1996).

While cotton has traditionally been grown under conventional-tillage methods, more growers are utilizing reduced-tillage in an effort to lower equipment and labor expenses (York and Culpepper 2001). Successful weed control programs can be achieved in reduced-tillage operations (Brown and Whitwell 1985; Culpepper and York 1997), but weed control can be easier to obtain under conventional-tillage methods (Keeton et al. 1998). In the past, the inability to incorporate herbicides or to conduct between-row cultivation reduced weed control options; however, the introduction of transgenic technologies and reduced-tillage cultivators has helped growers achieve season-long weed control in reduced-tillage operations (Wilcut et al. 1995).

**Transgenic cotton.** Glyphosate *N*-((phosphonomethyl)glycine]-resistant cotton varieties, sold under the trade name Roundup Ready®, have been commercially available since 1997 (Askew and Wilcut 1999). These transgenic varieties have resistance to glyphosate through the introduction of the *Agrobacterium* sp. *cp4 epsps* gene that encodes a glyphosate resistant 5-enolpyruvylshikimate-3-phosphate synthase (E.C. 2.5.1.19) protein (Nida et al. 1996). This protein serves as the site of action for glyphosate herbicidal action (Nida et al. 1996; Anonymous 2001c).

Resistance to glyphosate in Roundup Ready® cotton is growth-stage dependent, and POST applications should be made before cotton reaches the five-leaf stage of growth. After this stage,
glyphosate applications must be POSD in order to minimize herbicide contact with the foliage (Anonymous 2000). Although glyphosate is registered for POSD use, Pline et al. (2001) report translocation of glyphosate from cotton stems to reproductive tissue and a subsequent accumulation of $^{14}$C-glyphosate in cotton squares. In the field, POST applications of glyphosate to glyphosate-resistant cotton before the five-leaf growth stage usually cause no visible injury (Vencill 1996; Askew and Wilcut 1999). Also, no differences in germination or growth characteristics have been observed with glyphosate-resistant cotton when compared to conventional cotton (Vencill 1996; File 1998).

As many weeds are controlled by glyphosate, the necessity of PRE or PPI treatments can be questioned. Vencill (1996) reported equivalent yield from two POST glyphosate applications when compared to a conventional weed control program comprising PRE, POST, and POSD applications. Likewise, two glyphosate applications controlled weeds equivalent to a conventional program of trifluralin (2,6-dinitro-$N,N$-dipropyl-4-(trifluoromethyl)benzenamine) PPI, fluometuron ($N,N$-dimethyl-$N'$-[3-trifluromethyl]phenyl)urea) PRE, pyrithiobac POST and cyanazine plus MSMA (monosodium methanearsonate) POSD. Cotton fiber and net returns were not different between the two treatments (Culpepper and York 1998). However, in a study conducted in ultra-narrow row cotton, Culpepper and York (2000) reported that soil applied herbicides prior to POST glyphosate application increased cotton yield and net return.

Weed control programs that utilize glyphosate with Roundup Ready® technology may cost less than conventional weed control programs while providing equivalent weed control and greater yield (Askew and Wilcut 1999). Single applications of glyphosate in cotton can control multiple weed species (Askew and Wilcut 1999), but can often fail to control some broadleaf weeds such as common cocklebur and annual morningglory species (Culpepper and York 1998). Likewise, the use of a residual broadleaf herbicide can reduce the number of glyphosate applications required for full season weed control (Goldmon et al. 1996).

Another transgenic option available to cotton growers is BXN® cotton. These modified varieties have resistance to bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) through the introduction of a nitrilase gene cloned from the soil bacterium Klebsiella ozaenae that induces
expression of bromoxynil nitrilase (E.C.3.5.5.6), which rapidly metabolizes the herbicide molecule (Stalker et al. 1988). Unlike glyphosate-resistant varieties, bromoxynil-resistant cotton varieties have herbicide resistance throughout all cotton growth stages. Initial studies indicated transgenic tolerance was eight times normal bromoxynil field rates (Stalker et al. 1988). McLaughlin (1992) later reported crop safety at rates greater than 30 times those needed for weed control in field studies. Adequate weed control from bromoxynil programs and net returns equal to conventional programs have also been reported (Culpepper and York 1997; Culpepper and York 2000). While glyphosate-resistant programs may not require PRE herbicides (Vencill 1996), control of grass and some broadleaf weeds is improved in bromoxynil-resistant programs with the use of PRE herbicides (Culpepper and York 1997; Culpepper and York 2000).

A third transgenic cotton variety with herbicide resistance is currently in development. Glufosinate [2-amino-4-(hydroxymethylphosphinyl)butanoic acid]-resistant cotton has complete tolerance to glufosinate without any effect on fiber yield or quality (Blair-Kerth et al. 2001). Glufosinate resistance, like that of bromoxynil, is achieved through metabolism of the herbicide molecule (Tsaftaris 1996), which also results in crop tolerance to glufosinate throughout the growing season (Somerville et al. 2000). The bialaphos resistance gene isolated from *Streptomyces hygroscopicus* was inserted into cotton to produce glufosinate-resistant varieties (Tsaftaris 1996).

**Nutsedge control.** Yellow (*Cyperus esculentus* L.) and purple (*C. rotundus* L.) nutsedge are two of the worst and most common weeds in Virginia cotton (Swann 1998). Both nutsedge species compete with cotton for resources and can assimilate biomass faster than cotton (Holt and Orcutt 1991). Control of these species, however, is often difficult to achieve. Ackley et al. (1996) evaluated yellow nutsedge response to nine acetolactate synthase (ALS, E.C.4.1.3.18) inhibitors over three years. Only halosulfuron (methyl 5-{{[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonylaminosulfonfyl} -3-chloro-1-methyl-1-\textit{H}-pyrazole-4-carboxylate) provided adequate control (>80%) in each year of the study. Control with pyrithiobac, the only ALS inhibitor registered for use in cotton, was 41 to 74% over three years. Wilcut (1998) described similar results from POST applications of pyrithiobac, but found PRE and PPI applications controlled yellow and purple nutsedge more effectively. Wilcut et al. (1997) also
reported adequate control of yellow nutsedge from PRE fluometuron plus fomesafen (5-[2-chloro-4-(trifluromethyl)phenoxy]-N-(methylsulfonyl)-2-nitrobenzamide). Two applications of glyphosate will normally control yellow nutsedge in glyphosate-resistant varieties (York and Culpepper 2001), although sequential applications have not improved control of purple nutsedge (Edenfield et al. 1998).

**Cotton herbicides.** Currently, fewer than 20 chemicals are registered for broadleaf weed control in cotton. Of these, six must be applied prior to crop emergence, and the majority of the remaining herbicides should be POSD to avoid crop injury. Only five herbicides are registered for POST applications; two of these, bromoxynil and glyphosate, must be applied over transgenic cotton varieties.

Clomazone (2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone) is a bleaching herbicide that must either be applied with a safening insecticide or as a low-rate band in order to minimize cotton injury. Clomazone will control some annual grasses (York and Culpepper 2001) and jimsonweed (*Datura stramonium* L.), common lambsquarters (*Chenopodium album* L.), tropic croton (*Croton glandulosus* var. septentrionalis Muell), common ragweed (*Ambrosia artemisiifolia* L.), smartweed species (*Polygonum* spp.), spurred anoda (*Anoda cristata* (L.) Schlecht.), prickly sida (*Sida spinosa* L.), and velvetleaf (*Abutilon theophrasti* Medicus) (Wilcut et al 1995; Swann and Wilson 2001).

Fluometuron is classified as a urea and binds to the D1 protein in photosystem II, thus blocking electron transport (Ahrens 1994). It is the PRE broadleaf herbicide typically recommended in North Carolina (York and Culpepper 2001). Fluometuron suppresses many broadleaf weeds and controls common lambsquarters, pigweed species (*Amaranthus* spp.), common ragweed, and prickly sida. Fluometuron may be applied POST to 8- to 15-cm cotton. Crop injury is likely from POST applications, and these applications should only be made in salvage situations. Fluometuron may also be tankmixed with MSMA as a POSD treatment for several broadleaf weeds (Swann and Wilson 2001). Fluometuron and a similar compound diuron (N’-(3,4-dichlorophenyl)-N,N-dimethylurea), were applied to 40% of cotton acreage in 2000 (Anonymous 2001b).
Metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide), a chloroacetamide herbicide (Ahrens 1994), may be applied PRE, POST, or POSD in cotton. Applications control annual grass and suppress yellow nutsedge (Swann and Wilson 2001) but have little activity on purple nutsedge (York and Culpepper 2001). Some small-seeded broadleaf weeds may also be controlled or suppressed by metolachlor.

Norflurazon (4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2H)-pyridazinone) is a phytoene desaturase inhibitor classified in the pyridazinone family (Ahrens 1994). PRE application will control most annual grasses except Texas panicum (Panicum texanum Buckl.), suppress yellow and purple nutsedge, and control or suppress several broadleaf weeds (Wilcut et al 1995). Norflurazon carryover may injure many rotational crops including small grains, corn (Zea mays L.), tobacco (Nicotiana tabacum L.), grain sorghum [Sorghum bicolor (L.) Pers.], and many vegetable crops (York and Culpepper 2001).

Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) and trifluralin are similar compounds for control of annual grass and suppression of certain small-seeded broadleaf weeds (York and Culpepper 2001). Both are classified in the dinitroaniline family and inhibit microtubule formation (Ahrens 1994). These compounds must be incorporated within 7 days or 24 hours, respectively, for maximum efficacy (Swann and Wilson 2001). High rates or incorporation too deep may result in cotton stunting and a delay in maturity (York and Culpepper 2001). Between them, pendimethalin and trifluralin are applied to 61% of cotton acreage (Anonymous 2001b).

Pyrithiobac can be applied PRE or POST to transgenic and non-transgenic crop varieties. Pyrithiobac controls pigweeds, jimsonweed, spurred anoda, velvetleaf, hemp sesbania [Sesbania exaltata (Raf.) Rydb. ex A.W.Hill], prickly sida and Pennsylvania smartweed (Polygonum pensylvanicum L.) (Swann and Wilson 2001; York and Culpepper 2001). Injury may result from application under cool temperatures, cotton stress, or in tank-mixes with the insecticide malathion [0,0-dimethyl-S-(1,2-dicarbethoxyethyl) dithiophosphate] (Allen and Snipes 1995).
Pyrithiobac will also antagonize graminicides when tank-mixed (York and Culpepper 2001). The chemical structure of pyrithiobac is shown in Figure 1.1.A.

The nitrile herbicide bromoxynil may be applied POST to bromoxynil-resistant cotton varieties only. Like fluometuron, this herbicide binds to the Q$_B$-binding site on the D1 protein eventually causing the release of free radicals (Ahrens 1994). Applications can control many important broadleaf weeds including common cocklebur (*Xanthium strumarium* L.), jimsonweed, and common ragweed, and may suppress many others (York and Culpepper 2001). Only 6% of cotton acreage received bromoxynil application in 2000 (Anonymous 2001b).

Certain glyphosate products may be applied to glyphosate-resistant varieties POST or POSD, or applied with a hooded sprayer to conventional varieties. Glyphosate was applied to 56% of cotton acreage in 2000, the most of any crop protection chemical (Anonymous 2001b). Up to two POST applications may be made before cotton reaches a five-leaf stage after which treatments must be POSD. Glyphosate controls many grass and broadleaf species although higher rates and multiple applications might be required for improved control of nutseed species, annual morningglory species, and perennial weeds (Swann and Wilson 2001; York and Culpepper 2001).

MSMA may be applied POST to 8- to 15-cm cotton for common cocklebur control and yellow and purple nutseed suppression, although injury may occur. MSMA or DSMA (disodium methanearsonate) may be POSD to cotton taller than 8 cm (York and Culpepper 2001). Both MSMA and DSMA are organic arsenicals causing rapid dessication of plant tissue (Ahrens 1994).

Cyanazine, a triazine herbicide, inhibits photosynthesis in the same manner as bromoxynil and fluometuron (Ahrens 1994). It may be applied POSD in cotton until December 31, 2002, although production of the compound has ceased (Jones 2000). Cyanazine was the standard POSD treatment in cotton for many years and is effective in controlling many broadleaf weeds (Swann and Wilson 2001).
Lactofen ((±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate) and oxyflurofen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) are diphenylether herbicides that inhibit the protoporphyrinogen oxidase enzyme (E.C.1.3.3.4) (Ahrens 1994). They may be applied POSD to cotton at least 15 cm tall. When applied with MSMA, control or suppression of many broadleaf weeds can be obtained. Two applications of oxyflurofen may be made each year while only one application of lactofen may be made (Swann and Wilson 2001). Contact of spray solution with foliage will cause severe leaf burn.

Prometryn (N,N'-bis(1-methylethyl)-6-(methylothio)-1,3,5-triazine-2,4-diamine) is a photosynthesis inhibitor in the triazine family and became commercially available in 1964 (Ahrens 1994). It may be POSD to cotton taller than 15 cm for control of many broadleaf weeds (Swann and Wilson 2001). Dimethipin (2,3-dihydro-5,6-dimethyl-1,4-dithiin 1,1,4,4-tetraoxide) also may be POSD to cotton at least 25 cm tall for control of several broadleaf weeds (Swann and Wilson 2001).

Five graminicides may be applied POST for annual and perennial grass control: clethodim (E,E)-(±)-2-[1-[[3-chloro-2-propenyl]oxy]-imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one), sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one), fluazifop-p (R)-2-[4-[[5(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid), fluazifop-p plus fenoxaprop-p ((±)-2-[(6-chloro-2-benzoazolyl)oxy]phenoxy]propanoic acid), and quizalofop (R)-2-[4-[(6-chloro-2-quinoxaliny]oxy]phenoxy]propanoic acid). These herbicides are usually effective on many annual grass species, but two applications are usually required for control of johnsongrass [Sorghum halepense (L.) Pers.] or bermudagrass [Cynodon dactylon (L.) Pers.] (Swann and Wilson 2001). Graminicides function by inhibiting the acetyl-CoA-carboxylase enzyme that catalyzes the biosynthesis of fatty acids (Ahrens 1994). Clethodim was the most used cotton graminicide in 2000, but was applied to only 3% of cotton acreage (Anonymous 2001b).

ALS-inhibiting herbicides. The first patent for an ALS-inhibiting herbicide was issued in 1966 to a sulfonylurea (SU) (Hay 1990). While the next patent was not issued until 1977, work in the
area of SUs increased dramatically in the 1980s (Beyer et al. 1988). By 1987, 230 U. S. patents had been issued for SUs (Beyer et al. 1988). Extremely low use rates, low mammalian toxicity, and numerous possible structural variations made SUs a major focus of research in the agricultural chemical industry (Beyer et al. 1988). Five chemical families are known to inhibit ALS: SU (Chaleff and Muvais 1984), imidazolinone (Shaner et al. 1984), pyrimidinylthiobenzoate (Stidham 1991), triazolopyrimidine sulfonanalide (Gerwick et al. 1990), and sulfonylaminocarbonyltriazolinone (Santel et al. 1999). Today, ALS-inhibiting herbicides are used in every major crop and multiple minor crops. Around 40 different ALS-inhibiting herbicides are currently used with more in development. The structure of a general SU molecule is shown in Figure 1.1.B.

ALS is an effective target site for herbicidal action, as it catalyzes the formation of acetolactate or acetohydroxybutyrate from condensation reactions involving one molecule of pyruvate plus 2-ketobutyrate or two molecules of pyruvate, respectively (Subramanian et al. 1990). This reaction is the initial step in the synthesis of the branched-chain amino acids leucine, valine, and isoleucine in plants and microbes (Umbarger 1978). These amino acids are formed in the chloroplast and are essential for protein biosynthesis (Stidham 1991).

Several ALS-inhibiting herbicides have been reported to have differential crop and weed response with varying environmental conditions. Application of sulfosulfuron (1-(4,6-dimethoxypyrimidin-2-yl)-3-[(2-ethanesulfonyl-imidazo[1,2-a]pyridine-3-yl)sulfonylurea) to jointed goatgrass (Aegilops cylindrica Host), downy brome (Bromus tectorum L.), and wild oat (Avena fatua L.) provided better control when soil moisture was at full field capacity than at one-third field capacity (Olsen et al. 1999). Harrison et al. (1996) conducted growth chamber experiments to evaluate both cotton and velvetleaf response to pyrithiobac. These researchers used three temperature regimes, three soil moisture regimes, and two pyrithiobac rates on each species. Control of velvetleaf decreased with soil moisture, but cotton response was not affected. The temperature regimes of 25/23 C (day/night), 30/28 C, and 35/33 C may not have been broad enough to influence cotton injury. Furthermore, Light et al. (1998) found pyrithiobac efficacy on palmer amaranth (Amaranthus palmeri S. Wats.) to be thermally dependent. The authors suggested a temperature range of 20 to 33 C to provide maximum efficacy and concluded that
inhibition kinetics could predict field efficacy. In a similar study by Jennings et al. (1999), cotton was grown at 31/24 C and exposed to 21/8 C for 5 d before, after, or before and after treatment. Length of exposure to low temperatures, but not exposure to cool temperatures before or after treatment, affected cotton injury.

The popularity of ALS-inhibiting herbicides has led to the development of herbicide resistance. The Herbicide Resistance Action Committee defines herbicide resistance as "the naturally-occurring inheritable ability of some weed biotypes within a given population to survive a herbicide treatment that should, under normal use conditions, effectively control that weed population." Since the introduction of the ALS-inhibiting herbicides, there have been at least 70 reported resistant species (Heap 2001) including ALS resistant smooth pigweed (Amaranthus hybridus L.) biotypes on the Delmarva Peninsula (Manley et al. 1998). These biotypes have differential tolerance levels by biotype to the various ALS-inhibitor families (Manley et al. 1998; Poston et al. 2000; Whaley and Wilson, unpublished data). At least one of these biotypes is cross-resistant to all ALS-inhibitor families (Whaley and Wilson, unpublished data).

Pyrithiobac. K-I Chemical Research Institute Co., Ltd. first synthesized pyrithiobac in 1987, leading to joint development of the compound by Kumiai Chemical Industry Co., Ltd. and E. I. du Pont de Nemours and Company (Nezu et al. 1999). The site of action of pyrithiobac is the ALS enzyme (Shimizu et al. 1994a), and the herbicide is classified in the pyrimidynlthiobenzoate family (Heap 2001). Like other ALS-inhibiting herbicides, pyrithiobac inhibits formation of the branched-chain amino acids valine, leucine, and isoleucine (Shimizu et al. 1994a). The pyrimidynylthiobenzoates have also been reported to slightly inhibit chlorophyll biosynthesis. This inhibition is most likely through an indirect route resulting from a lack of branched-chain amino acid precursors to form the enzymes in the chlorophyll biosynthesis pathway (Shimizu et al. 1994a). Pyrimidynylthiobenzoate inhibition of ALS is through mixed-type inhibition with respect to pyruvate (Shimizu et al. 1994b), contrary to noncompetitive and uncompetitive inhibition by SUs and imidazolinones, respectively (Durner et al. 1991).

POST applications of pyrithiobac generally cause no lasting effect to cotton. Jordan et al. (1993a) reported less than 11% injury from POST pyrithiobac treatments with no effect on
cotton yield or fiber characteristics. Likewise, other researchers have reported low initial injury from various POST treatments, also with no effects on fruiting characteristics, yield, or fiber quality (Jordan et al. 1993a; Keeling et al. 1993; Shankle et al. 1996; Culpepper and York 1997; Webster et al. 2000). However, injury has been commonly reported from pyrithiobac applied PRE or PPI (Keeling et al. 1993; Allen et al. 1997).

Pyrithiobac controls many important weeds in cotton. POST applications can provide control of entireleaf morningglory \textit{[Ipomoea hederacea (L.) Jacq.]}, velvetleaf, hemp sesbania, pitted morningglory (\textit{I. lacunosa L.}), palmleaf morningglory (\textit{I. wrightii Gray}), palmer amaranth, smooth pigweed, jimsonweed, and spurred anoda (Jordan et al. 1993b; Jordan et al. 1993c; Smith et al 1996; Wilson et al. 2000). Pyrithiobac, however, cannot provide complete weed control in cotton. Sicklepod (\textit{Cassia obtusifolia L.}), tall morningglory \textit{[Ipomoea purpurea (L.) Roth]}, common ragweed, and common lambsquarters are generally tolerant to pyrithiobac (Jordan et al. 1993b; Wilson et al. 2000). In addition, pitted morningglory and palmleaf morningglory are controlled only when applications are made to weeds less than 5 cm tall (Jordan et al. 1993b). Yellow and purple nutsedge can be controlled with PPI applications of pyrithiobac, but control from POST applications is generally unacceptable (Wilcut 1998).

Graminicide antagonism is another feature that may limit pyrithiobac use. A common feature of ALS inhibitors, graminicide antagonism by pyrithiobac has been reported with johnsongrass, broadleaf signalgrass \textit{[Brachiaria platyphylla (Griseb.) Nash]}, and large crabgrass \textit{[Digitaria sanguinalis (L.) Scop.]} (Jordan 1993d; Ferreira and Coble 1994; Snipes and Allen 1996). Fluazifop-p, sethoxydim, quizalofop-P, and clethodim have all been antagonized by pyrithiobac (Jordan 1993d). Graminicide and pyrithiobac applications should be separated by 14-d to prevent antagonism.

\textit{CGA 362622.} CGA 362622 (N-\{(4,6-dimethoxy-2-pyrimidinyl)carbamoyl\}-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt) is an experimental sulfonylurea herbicide being developed by Syngenta Crop Protection, Inc. Like pyrithiobac, this molecule inhibits the ALS enzyme. CGA 362622 is reported to have low toxicological properties, a favorable environmental profile, and low use rates; CGA 362622 also controls many weeds (Hudetz et al.}
2000). It is being evaluated for weed control in cotton, sugarcane (*Saccharum officinarum* L.), and other crops (Hudetz et al. 2000). The chemical structure of CGA 362622 is shown in Figure 1.1.C.

POST applications of CGA 362622 generally result in transient cotton injury. Results of studies conducted in Louisiana demonstrate no visible cotton response to CGA 362622 (Vidrine and Miller 2001). However, reports of early crop injury are more common. Symptoms of chlorosis or stunting with rapid crop recovery and no effect on yield have been reported in multiple locations (Brecke et al. 2000; Faircloth et al. 2001). In North Carolina, injury up to 40% has been observed although symptoms were also transient (Wilcut et al. 2000).

In previous research, CGA 362622 POST controlled many weeds including common lambsquarters, sicklepod, palmer amaranth, slender amaranth (*Amaranthus gracilis* Desf.), smooth pigweed, entireleaf morningglory, pitted morningglory, and tall morningglory (Porterfield et al. 2000; Wilcut et al. 2000). In addition, CGA 362622 application may suppress other troublesome weeds such as purple nutsedge and johnsongrass (Hudetz et al. 2000). However, CGA 362622 will not control smallflower morningglory (*Jacquemontia tammifolia* (L.) Griseb.), prickly sida, or spurred anoda (Brecke et al. 2000; Faircloth et al. 2001).

**OBJECTIVES**

Virginia cotton growers need more weed control options. The primary objective of this research was to evaluate CGA 362622 for use in Virginia cotton weed management programs. Field, greenhouse, and laboratory studies were conducted to evaluate the specific objectives: 1) cotton response to CGA 362622 POST applications with selected adjuvants, 2) weed response to CGA 362622 and CGA 362622 combinations with bromoxynil, glyphosate, and pyrithiobac, 3) absorption, translocation, and metabolism of CGA 362622 in cotton, spurred anoda, and smooth pigweed.
LITERATURE CITED


Richardson, R. J. and H. P. Wilson. Unpublished data. Eastern Shore Agricultural Research and Extension Center, Painter, VA.


**Fig. 1.1.A.** Chemical structure of pyrithiobac.

**Fig. 1.1.B.** Structure and functional groups of a general sulfonylurea molecule.

**Fig. 1.1.C.** Chemical structure of CGA 362622.