To the Graduate Council:

I am submitting herewith a dissertation written by Jimmy R. Summerlin, Jr. entitled "Selection and Performance of Weed Management Systems in Cotton (*Gossypium Hirsutum*) Utilizing Conventional and Herbicide Tolerant Crop Varieties." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Sciences.

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Selection and Performance of Weed Management Systems in Cotton (*Gossypium hirsutum*) Utilizing Conventional and Herbicide Tolerant Crop Varieties.

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Jimmy R. Summerlin, Jr.

December, 2000

DEDICATION

This dissertation is dedicated to my wife Jennifer,

for her love, encouragement, patience, and friendship in this venture.

With her by my side this and all future endeavors are possible.

Life is a journey we all must take.

Travelling with someone special more pleasant the journey doth make.

Each and every day I travel through this life,

I thank God that YOU are my wife.

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ABSTRACT

Field trials were conducted near Milan, TN in 1998 and 1999 to evaluate weed control, crop response, lint yield and quality, and net returns of standard, bromoxynil resistant, and glyphosate tolerant cotton (*Gossypium hirsutum*) management systems. Smooth pigweed (*Amaranthus hybridus*), common cocklebur (*Xanthium strumarium*), entireleaf morningglory (*Ipomoea hederacea var. integriuscula*), and large crabgrass (*Digitaria sanguinalis*) were controlled > 90 % by all weed control programs. Goosegrass (*Eleusine indica*) was controlled greater than 97 % with all programs that included a soil-applied herbicide (fluometuron and/or pendimethalin) or a late post-directed (PD) application of cyanazine + MSMA. Red sprangletop (*Leptochloa filiformis*) was controlled at least 93 % in all systems that included a soil-applied herbicide. The total postemergence (POST) treatment of glyphosate followed by (fb) glyphosate in glyphosate tolerant cotton controlled goosegrass and red sprangletop 80 to 82 % at 8 to 10 wk after planting. Red sprangletop control in the total POST system of glyphosate fb cyanazine + MSMA was poor (33 %).

Lint yields obtained from weed free checks were similar for the three varieties 'STV 474,' 'STV BXN47,' and 'Paymaster 1220RR.' With the exception of bromoxynil early POST fb cyanazine + MSMA, lint yields were similar for all systems that included soil-applied herbicide(s) or two applications of glyphosate. Lint yields in the glyphosate tolerant systems that included a soil-applied herbicide were 130 kg/ha greater than the bromoxynil system. Lint yield from the bromoxynil system was equivalent to both standard programs and the total POST programs in glyphosate tolerant cotton.

Net returns were highest for the pendimethalin fb glyphosate fb glyphosate program, but this program was not different from the total POST program of glyphosate fb glyphosate or pendimethalin + fluometuron fb glyphosate fb cyanazine + MSMA. The addition of soil-applied herbicides to the total POST glyphsate fb cyanazine + MSMA increased net return. However, no increase in net return was obtained by the addition of pendimethalin to the total POST glyphosate fb glyphosate program. Net returns following the pyrithiobac standard system and the bromoxynil system were significantly lower than those obtained from glyphosate systems.

A cotton variety decision aid model was created using weed control efficacy information reported on herbicide labels and in university extension publications. In fields with a history of weed problems that include weedy Amaranthus species (*Amaranthus hybridus, A. retroflexus, and A. palmeri,* respectively), spotted spurge (*Euphorbia maculata*), sicklepod (*Senna obtusifolia*), or purple and yellow nutsedges (*Cyperus rotundus and C. esculentus*), the model did not recommend bromoxynil resistant cotton varieties. Likewise, glyphosate tolerant varieties were not recommended for areas that have a history of weed problems including morningglories (*Ipomoea spp.*), hemp sesbania (*Sesbania exaltata*), Florida pusley (*Richardia scabra*), or spreading dayflower (*Commelina diffusa*). Fields with a history of weed problems that included a cross section of those weeds listed for bromoxynil resistant and glyphosate tolerant were recommended to be planted to conventional varieties. In addition, producers are advised not to use pyrithiobac in areas with a history of major weed problems resulting from spotted spurge, sicklepod, purple or yellow nutsedge, common lambsquarters (*Chenopodium album*), common ragweed (*Ambrosia artemisiifolia*), tall morningglory

(*Ipomoea purpurea*), or tropic croton (*Croton glandulosus var. septentrionalis*). Growers were also recommended not to use pyrithiobac in fields with a history of weeds resistant to acetolactate synthase (ALS) inhibiting herbicides. The decision aid presented utilizes a "decision tree" approach where the cotton variety is selected to optimize weed control, minimize herbicide resistance development, and maximize producer profitability.

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PART I

INTRODUCTION

BACKGROUND

The Malvaceae family of plants is a large family of herbs, shrubs, and trees (Radford et al. 1968). Included in this family are cultivated plants including cotton, okra, and hibiscus, and weedy plants such as velvetleaf, prickly and arrowleaf sida, and spurred anoda. Upland cotton (*Gossypium hirsutum* L.) is a perennial plant that is cultivated as an annual crop for fiber, feed, and oil production. Upland cotton originated in southern Mexico and was dispersed throughout Mexico, Central America and the Caribbean Islands (Smith 1995). Dispersal also brought cotton to parts of Florida and southern New Mexico. The oldest specimens of upland cotton (dated between 3400 and 2300 BC) were found at Tehuancan, Oaxaca, Mexico.

In the United States, upland cotton has been cultivated since 1621 (Smith 1995). However, large-scale production did not begin until 1794 when Eli Whitney invented the cotton gin (Metcalfe and Elkins 1980). Additional mechanization increased upland cotton production. Approximately 16.5 million bales of upland cotton were ginned in the United States in 1999 (Anonymous 1999a). Approximately 30 % of the United States upland cotton was produced in Texas, 9 % in California, and 3 % in Tennessee.

Upland cotton production acreage in Tennessee has remained steady over the past decade. Recent production in Tennessee was highest in 1994 when average yield was 813 kg lint/ha and 885,000 bales of cotton were ginned (Anonymous 1999b). Harvested cotton acreage hit a recent peak in 1995 when 267,000 ha of cotton were harvested. In 1998, Tennessee cotton producers harvested 180,000 ha of cotton that averaged 660 kg lint/ha and was valued at 193.5 million dollars (including cottonseed) (Anonymous 1999b).

GENERAL PRODUCTION PRACTICES

Soil Properties. Tennessee is located on the northern border of the United States cotton production belt. Thus, growers may experience cool temperatures in the early and late portions of the growing season (Shelby 1998a; Edmisten 1999a). Such growing conditions are less than ideal for cotton production and proper management is essential for producing a quality crop. Cotton may be grown utilizing both conventional tillage and no-till production methods. As with most agronomic crops cotton production begins with site selection and well-developed, well-drained soils are preferred (Shelby 1998a). In addition, cotton is sensitive to acid soils and performs best when soil pH levels range between 6.0 and 6.5 (Shelby 1998a; Hodges 1999). Highly acid soils (low pH) can be improved by liming to produce quality cotton crops.

Mineral nutrition. The major mineral nutrients required to produce quality cotton are nitrogen, phosphorus, potassium, and boron. Proper nitrogen management is essential in cotton production (Shelby 1998a; Hodges 1999). Nitrogen deficiency can result in stunted, slow growing plants and excessive nitrogen will result in excessive, uncontrolled vegetative growth. Nitrogen rates generally range between 50 and 90 kg/ha, depending on soil type and field history (Shelby 1998a). Highly productive soils require reduced nitrogen rates while less fertile soils may require increased nitrogen inputs. Adequate phosphorus and potassium levels are essential to maintain healthy, vigorous plants. However, management of these nutrients is not as critical as that of nitrogen. Maintaining proper phosphorus and potassium levels can be achieved through soil testing and timely fertilizer applications. Boron is essential for proper pollination, fruit set and development, new cell development, and regulation of carbohydrate metabolism (Tisdale et al. 1993). Boron deficiency symptoms include: shedding of young squares or bolls, death of terminal buds and shortened internodes, and small, deformed mature bolls (Shelby 1998a; Hodges 1999). Annual applications of boron should be made at approximately 1 kg/ha.

Variety Selection. Traditionally, variety selection has been based on yield performance history and growth characteristics. However, recent advances in genetic engineering have made selecting a cotton variety more difficult. Insect and weed control strategies must now be considered before selecting a cotton variety. This relatively new technology is the subject of this dissertation and will be discussed in more detail in the following sections.

Disease Management. In Tennessee, for the years 1993 to 1997, the average loss due to cotton diseases has been approximately 13 % (Newman 1998). Seedling diseases resulting from *Rhizoctonia solani*, *Pythium spp*., and *Fusarium spp*. have accounted for approximately 62 % of the disease losses. Other diseases include boll rots, *Verticillium* and other wilts, blights, nematodes, and leaf spots (Newman 1998).

Cotton disease management begins by utilizing proper cultural practices such as destroying crop residue, crop rotation, proper fertilization and liming, using bedded rows, timely planting, and variety selection (Koenning, 1999). Following these practices will reduce disease occurrence, but will not totally prevent problems. As stated, the seedling diseases are the major problems facing cotton production in Tennessee. Preventing seedling diseases begins at planting and incorporates a combined approach utilizing seed and soil fungicide treatments. Seed treatments are effective in controlling seed borne diseases that may cause seed-rot and provide some protection against pre-emergent damping-off (Newman 1998). Soil treatments are effective in providing control of post-emergent damping off and root-rot diseases and may be applied as a hopper-box, in-furrow spray, or in-furrow granule treatment (Newman 1998; Koenning 1999).

Utilizing proper cultural practices is the most effective method of controlling boll-rots and Verticillium wilt. Boll-rot diseases are most common in areas where rank cotton growth and high moisture and humidity coexist (Newman 1998). Reducing rank growth is essential for boll-rot control and can be achieved by proper nitrogen management in combination with growth regulators and defoliants. *Verticillium* wilt can be an important problem when cool, moist planting conditions are present (Newman 1998). Crop rotation and selecting varieties tolerant to *Verticillium* infection are effective practices that will reduce *Verticillium* occurrence. In addition, utilizing practices that enhance soil drying and increase soil temperature, such as bedding, will aid in reducing *Verticillium* losses (Newman 1998).

Insect Management. Most insect damage to cotton is caused by a small number of insect species. The predominate insect pests in Tennessee cotton production are thrips, aphids, the budworm/bollworm complex, boll weevils, stink bugs, and fall armyworms. In addition, other pests such as spider mites, cutworms, plant bugs, and whiteflies may cause damage under certain conditions or circumstances (Seward 1998). If these pests are not properly managed cotton yields may be reduced as much as 85 % (Bacheler 1999) depending on insect populations and environmental conditions.

Proper insect management begins before the cotton crop is planted. The utilization of sound cultural practices is beneficial in reducing insect damage. Such practices include selecting varieties based on soil type, timely planting, and nitrogen management (Bacheler 1999). In addition, other management practices, such as using plant growth regulators, may also be beneficial in reducing the susceptibility or attractiveness of the cotton plant to insect pests.

Two methods are commonly used for insect management in cotton. The first is a preventative approach used to inhibit the establishment of damaging pest populations. This prophylactic method, including seed treatments and in-furrow and surface-applied insecticides, is most commonly employed for control of early season pests such as thrips (Seward 1998; Bacheler 1999). After preventative measures are utilized, insect management shifts to a protective approach. Protective methods incorporate periodic scouting of the cotton crop for damaging and beneficial insect populations and comparing the scouting results to established economic thresholds to determine an "action" threshold for applying insecticidal sprays.

In addition to the use of insecticides for insect management, producers now have the option to utilize cotton varieties genetically engineered to express the delta endotoxin of *Bacillus thuringiensis* (BT) (Bacheler 1999). BT varieties are beneficial in controlling some of the caterpillar pests including the budworm/ bollworm complex and European corn borer. Other caterpillar (fall and beet armyworm) and non-caterpillar (aphids, stink bugs, boll weevils, plant bugs, etc) pests are not controlled by the *B.t.* endotoxin (Bacheler 1999). However, it should be noted that the absence of insecticidal sprays for controlling the budworm/bollworm complex may enhance populations of other pests, such as stink bugs. Thus, regular scouting and possible insecticide applications remain essential to maintain these pests at sub-economic populations (Bacheler 1999).

Weed Management. Weeds are unique among the pests that must be managed in cotton production, in that they generally do not cause direct damage to cotton plants but rather compete with cotton plants for light, moisture, nutrients, and space (Frans and Chandler 1989). Certain weed species directly impact cotton plants by allelopathic interactions. Weeds are diverse and vary significantly across the Cotton Belt (Frans and Chandler, 1989). Unlike disease and insect damage, the only predictable estimates of crop damage from weeds is reduction in yield and quality. Selectively controlling the growth of weedy plant species without inhibiting the growth of desired plants is often difficult. Whereas cotton insects and diseases may be managed with a wide variety of insecticides and fungicides, weed management requires the precise application of herbicides that can potentially injure the cotton plant. Compounding weed control efforts in cotton is the similarity of several key weed species to the cotton plant. Two of the most common and most troublesome weeds in Tennessee cotton are velvetleaf and prickly sida (Dowler 1998). As mentioned earlier, these two weeds are also members of the Malvaceae family (Radford et al. 1968) and are genetically similar to cultivated cotton. Due to these similarities, these weeds often respond similar to cotton to herbicide treatment and thus can be difficult to control.

Traditionally, weed management in cotton has incorporated the use of a preplant incorporated (PPI) or preemergence (PRE) herbicides for preventative weed control followed by tillage and post-directed (PD) herbicides. Until recently, over-the-top postemergence (POST) herbicides have generally been limited and such applications often injured cotton. Several relatively new weed control programs have been developed for cotton production in recent years. However, only one new herbicide active ingredient, pyrithiobac, has been developed for use in standard cotton varieties. Other advances in weed control have centered on genetically engineered crop varieties. Two weed control systems: glyphosate tolerant (Roundup Ready) and bromoxynil resistant (BXN) using genetically engineered varieties are now commonly used by growers and will be discussed further in the following sections.

Growth Management. Unlike other major agronomic row crops grown in the United States, cotton management does not end with controlling diseases, insects, and weeds. Due to the perennial nature of cotton, producing a high-yielding, high-quality cotton crop also requires managing cotton growth (Shelby 1998b). Efficient management of cotton growth accelerates crop maturity, reduces rank growth, aids in insect and disease management, promotes harvesting ease, and increases yields (Edmisten 1999b). Certain conditions facilitate excess growth and necessitate the use of plant growth regulators (PGRs). Such conditions include late planting, high plant population density, excess nitrogen, and organic soils. In addition, under favorable growing conditions large, indeterminate varieties will produce more vegetative growth than other varieties (Edmisten 1999b).

When conditions favor the use of PGRs in cotton, the recommended PGR is mepiquat chloride. Mepiquat chloride inhibits cell elongation in the stems of the cotton plant resulting in shorter, more compact plants. Mepiquat chloride may be applied in a single high rate application, dual high rate applications, or multiple low rate applications (Anonymous 1997a). Cotton should not be treated with mepiquat chloride during drought conditions (Anonymous 1997a) and previously treated cotton may exhibit slow growth and boll loading following drought conditions (Edmisten 1999b). The use of multiple low rate applications is recommended because mepiquat chloride applications may be discontinued during drought periods.

Harvest Aids. Due to the short growing season in many areas of the Cotton Belt and the perennial nature of cotton, natural defoliation rarely occurs to an extent that is conducive to mechanical harvesting. Therefore, it is often necessary to defoliate the cotton plant using synthetic compounds that enhance leaf abscission. The compounds that are generally used are referred to as defoliants. However, in some instances boll openers and desiccants may be applied as well.

The primary purpose for applying defoliants is to remove the leaves from the plant to allow mechanical harvest (Shelby et al. 1998). However, several additional benefits are obtained through defoliation. Defoliation eliminates the primary source of trash and stain found in cotton harvest (Shelby et al. 1998; Edmisten 1999). In addition, leaf removal promotes boll opening and drying which reduces the moisture in harvested cotton. Moreover, defoliation promotes quicker drying of morning dew, which allows earlier harvest and reduces boll rot (Shelby et al. 1998; Edmisten 1999). Combinations of defoliants and boll openers are commonly used to accomplish three major objectives: defoliation, boll opening, and regrowth control. Boll opening is generally accelerated with ethephon. Ethephon releases ethylene which supplements endogenous ethylene (Hayes, 2000).

HERBICIDE CHARACTERISTICS

Glyphosate. Glyphosate (*N*-(phosphonomethyl)glycine) (Figure 1)[1] is a broad-spectrum, non-selective POST herbicide developed by Monsanto Agricultural Products in 1970 (Franz et al. 1997a). Glyphosate was introduced in agricultural markets in 1974 and today is one of the most widely used herbicides in the world. Glyphosate is registered for use in more than 100 crops and controls more than 300 weed species, including 74 of the world's worst weed species (Franz et al. 1997a). Glyphosate is a component of more than 90 herbicides and is sold under more than 150 trademarks including Roundup, Roundup Ultra, Roundup Ultra Max, Roundup Pro, Roundup Dry, and Rodeo.

Glyphosate is a potent inhibitor of the enzyme 5-enol-pyruvylshikimate-3-phosphate synthase (EPSPS, E.C. 2.5.1.19) (Devine et al. 1993; Franz et al 1997b). EPSPS is the catalyst for the production of 5-enol-pyruvylshikimate-3-phosphate (EPSP), a key intermediate in the synthesis of chorismate from erythrose-4-phosphate. Chorismate is an important precursor of several essential plant components including the aromatic amino acids tryptophan, tyrosine, and phenylalanine. Other downstream products of this and related pathways include auxin, lignin, ubiquinones, folic acid, vitamins K and E, and anthocyanin (Franz et al. 1997b). The termination of aromatic amino acid and other essential plant compound synthesis increases diversion of erythrose-4-phosphate from the Calvin cycle into the skikimic acid pathway (Geiger and Servaites 1994; Franz et al. 1997b). This increased diversion of erythrose-4-phosphate depletes ribulose bisphosphate (RuBP) levels, which slows the Calvin cycle and limits

[1] The figures and tables referenced in this dissertation are located in the appendices.

photosynthesis (Servaites et al. 1987; Shieh et al. 1991; Franz et al. 1997b). Therefore, inhibition of EPSPS by glyphosate decreases in protein synthesis, causes a cessation of growth, and plant starvation until death occurs.

In addition to its broad weed control spectrum, glyphosate is also one of the safest pesticides in use today. Acute toxicity assessments of glyphosate revealed oral toxicity levels greater than 4300 mg/kg (rat), dermal toxicity levels greater than 2 g/kg (rabbit), mild eye irritation, slight dermal irritation, and no skin sensitization (Anonymous 1993). Chronic toxicity studies have shown that glyphosate caused no effects in rats, mice, and dogs and glyphosate is considered a non-carcinogen by the Environmental Protection Agency (EPA) (Anonymous 1993). Moreover, glyphosate is non-toxic to fish, aquatic invertebrates, and honeybees and no more than slightly toxic to birds. Glyphosate is strongly adsorbed to soil where residues are immobile and rapidly degraded by microorganisms to aminomethyl phosphonic acid (AMPA) and further to carbon dioxide (Anonymous 1993).

Bromoxynil. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) (Figure 2) is a POST herbicide for dicot weed control in grass and other tolerant crops. In the United States, bromoxynil was first registered in 1965 for weed control in wheat and barley (Anonymous 1998). Bromoxynil is currently registered for use in several food, feed, and fiber crops including corn, sorghum, small grains, alfalfa, onions, garlic, mint, flax, and cotton (transgenic BXN varieties only) (Anonymous 1997b). Bromoxynil is also registered for use in sod production, grasses grown for seed, non-residential turfgrass, and on non-cropland and conservation reserve program lands. Bromoxynil is commercially available under the trade names Buctril and Moxy and is also sold in combination with other herbicides such as atrazine and MCPA in prepackaged mixtures.

Bromoxynil is a potent inhibitor of the photosystem II (PSII) complex, which is located in the thylakoid membranes of the chloroplast (Ahrens 1994). Bromoxynil acts by binding the Q_B binding site on the D1 protein. The binding of bromoxynil to the Q_B protein prevents normal electron flow through PSII and thus inhibits the system. This inhibition results in a cessation of CO_2 fixation and ATP and NADPH production, which inhibits other metabolic processes and leads to free radical formation, lipid and protein oxidation, loss of membrane integrity, and plant death (Ahrens 1994).

Bromoxynil toxicity is classified as category II for acute oral and dermal effects and Category III for acute inhalation effects by the EPA (Anonymous 1998). In addition, bromoxynil is classified as a possible human carcinogen and is considered to be a developmental toxin. Acute toxicity assessments of bromoxynil revealed oral toxicity levels of 238 mg/kg for females (F) and 400 mg/kg for males (M) (rat), dermal toxicity levels of 1310 mg/kg F and >2000 mg/kg M (rabbit), and inhalation toxicity levels of 0.72 and 0.81 mg/kg (rat), F and M, respectively (Anonymous 1998). Bromoxynil also causes eye irritation (rabbit), slight dermal irritation (rabbit), and was positive in skin sensitization studies (guinea pig). While the calculated risk level for mammals range from medium to high, the risk to birds, insects, aquatic vertebrates, and aquatic invertebrates is low to minimal (Anonymous 1998). Furthermore, bromoxynil is rapidly degraded to CO_2 in soil and water by abiotic hydrolysis and photolytic and microbial degradation. Thus, bromoxynil has a low potential for ground water contamination and is rapidly degraded in surface waters (half-life <12 hr).

GENETICALLY MODIFIED COTTON

Recent advances in plant genetics, molecular biology, and breeding have created an opportunity for the genetic manipulation of crop plants. The two strategies that have been employed in creating genetically modified (GM) crops are based on output and input traits. Output traits are generally those which are derived from the plant, including such things as increased nutritional value or production of medicinal compounds. Input traits are designed to decrease the cost of production, make production easier, and/or reduce risks to the producer and environment.

Glyphosate tolerant (GT) plants can be genetically engineered by two different methods. The first method is to promote overproduction of the EPSPS enzyme by inserting a strong constitutive promoter in front of the natural EPSPS gene (Shah et al. 1985). The second and most commonly used method is to produce GT EPSPS by an amino acid substitution in the EPSPS gene (Kishore and Shah 1988). The specific substitution occurs between positions 80 and 120 of a mature EPSPS sequence and involves replacing the second glycine residue of the sequence -L-G-N-A-G-T-A- with an alanine residue (Kishore and Shah 1988). The substitution results in a modified EPSPS enzyme with a lower affinity for glyphosate and normal catalytic activity in the production of EPSP.

Bromoxynil resistant (BR) plants express a nitrilase enzyme that rapidly detoxifies bromoxynil in the plant (Stewart 1991). Specifically, a gene isolated from resistant soil bacterium of *Klebsiella ozeanae* is inserted into the plant genome, which enables nitrilase production in the plant (Stalker 1987). The expression of the nitrilase enzyme in BR plants rapidly detoxifies bromoxynil by hydrolysis of the nitrile group (Stalker 1987).

RESEARCH OBJECTIVES

In 1999, approximately 14 million acres of cotton were planted in the United States (Anonymous 1999c). Glyphosate tolerant and bromoxynil resistant cotton varieties represented 25 and 10 %, respectively, of the total cotton acreage (including varieties stacked with *B.t.* traits) (Anonymous 1999d). Numerous studies have been conducted to evaluate the performance of GT and BR cotton varieties and the weed control obtained using these varieties (Choate et al. 1996; Isgrigg et al. 1996; Culpepper et al. 1996; Goldmon et al. 1996; Hayes et al. 1996; Keeling et al. 1996). However, little research has been conducted to evaluate the returns obtained from using these systems versus a conventional weed control program. In addition, little information is currently available to assist producers in selecting the proper weed management program based on specific, individual field situations.

The objectives of this study were: 1) to evaluate weed control in conventional, GT, and BR cotton cropping systems, 2) to determine cost effectiveness of weed control utilizing conventional, GT, and BR cotton cropping systems, and 3) to create a decision assistance model to aid producers in selecting cotton varieties and the subsequent weed management programs.

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PART II

COMPARISON OF WEED MANAGEMENT STRATEGIES IN NO-TILLAGE COTTON UTILIZING HERBICIDE TOLERANT AND CONVENTIONAL CROP VARIETIES

ABSTRACT

Field trials were conducted near Milan, TN in 1998 and 1999 to evaluate weed control, crop response, lint yield and quality, and net returns of standard, bromoxynil resistant, and glyphosate tolerant cotton management systems. Smooth pigweed, common cocklebur, entireleaf morningglory, and large crabgrass were controlled > 90 % by all weed control programs. Goosegrass was controlled greater than 97 % by all programs that included a soil-applied herbicide or a late post directed (PD) application of cyanazine + MSMA. Red sprangletop control was at least 93 % in all systems that included a soil-applied herbicide. The total postemergence (POST) treatment of glyphosate followed by (fb) glyphosate in glyphosate tolerant cotton controlled goosegrass and red sprangletop 80 to 82 % at 8 to 10 wk after planting . Red sprangletop control in the total POST system of glyphosate fb cyanazine + MSMA was poor (33 %). Lint yields obtained of each of the three varieties were similar in the weed free checks. With the exception of bromoxynil early POST fb cyanazine + MSMA, lint yields were similar for all systems that included soil-applied herbicide(s) or two applications of glyphosate. Lint yields in the glyphosate tolerant systems that included a soil-applied herbicide were 130 kg/ha greater than the bromoxynil system. Lint yield from the bromoxynil system was equivalent to both standard programs and the total POST programs in glyphosate tolerant cotton. Net returns were highest for the pendimethalin fb glyphosate fb glyphosate program, but this program was not different from the total POST program of glyphosate fb glyphosate or pendimethalin + fluometuron fb glyphosate fb cyanazine + MSMA. The addition of soil-applied herbicides to the total POST glyphsate fb cyanazine + MSMA increased net return. However, no increase in

net return was obtained by the addition of pendimethalin to the total POST glyphosate fb glyphosate program. Net returns following the pyrithiobac standard system and the bromoxynil system were significantly lower than those obtained from glyphosate systems.

Nomenclature: Bromoxynil, 3.5-dibromo-4-hydroxybenzonitrile; cyanazine, 2-[[4-chloro-6-(ethyl-amino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile; fluometuron, *N,N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea; glyphosate, *N*-(phosphonomethyl)glycine; MSMA, monosodium salt of methylarsonic acid; pendimethalin, *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; pyrithiobac, 2-chloro-6-[(4,6-dimethoxy-2-pyrimidinyl)thio]benzoic acid; common cocklebur, *Xanthium strumarium* L. #[1] XANST; entireleaf morningglory, *Ipomoea hederacea* var. *integriuscula* Gray # IPOHG; goosegrass, *Eleusine indica* (L.) Gaertn. # ELEIN; large crabgrass, *Digitaria sanguinalis* (L.) Scop. # DIGSA; red sprangletop, *Leptochloa filiformis* (Lam.) Beauv. # LEFFI; smooth pigweed, *Amaranthus hybridus* L. # AMACH; cotton, *Gossypium hirsutum* L. 'Stoneville 474,' 'Stoneville BXN 47,' 'Paymaster 1220RR.'

Additional Index Words: Genetically modified crops, bromoxynil resistant cotton, glyphosate tolerant cotton, weed control, cotton yield, cotton lint quality, AMACH, DIGSA, ELEIN, IPOHG, LEFFI, SIDSP, XANST.

Abbreviations: PRE, preemergence; POST, postemergence; PD, postemergence directed; EPSPS, 5-enol-pyruvylshikimate-3-phosphate synthase; EPSP, 5-enol-

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[1] Letters following this symbol are a WSSA approved computer code from *Composite List of Weeds*. Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

pyruvylshikimate-3-phosphate; GT, glyphosate tolerant; BR, bromoxynil resistant; STD, standard (non-transgenic); WAP, weeks after planting; fb, followed by; NIS, non-ionic surfactant.

INTRODUCTION

Weeds are unique among the pests that must be managed in cotton production, in that they generally do not cause direct damage to cotton plants but rather compete with cotton plants for light, moisture, nutrients, and space (Frans and Chandler 1989). Certain weed species directly impact cotton plants by allelopathic interactions. Weeds are diverse and vary significantly across the Cotton Belt (Frans and Chandler, 1989). Unlike disease and insect damage, the only predictable estimates of crop damage from weeds is reduction in yield and quality. Selectively controlling the growth of weedy plant species without inhibiting the growth of desired plants is often difficult. Whereas cotton insects and diseases may be managed with a wide variety of insecticides and fungicides, weed management requires the precise application of herbicides that can potentially injure the cotton plant. Compounding weed control efforts in cotton is the similarity of several key weed species to the cotton plant. Two of the most common and troublesome weeds in Tennessee cotton are velvetleaf and prickly sida (Dowler 1998). These two weeds are also members of the Malvaceae family (Radford et al. 1968) and are closely botanically related to cultivated cotton. Due to these similarities these weeds often respond to herbicides in a similar manner as the cotton crop and, thus, can be difficult to control.

Traditionally, weed management in cotton has incorporated the use of a preplant incorporated (PPI) or preemergence (PRE) herbicides for preventative weed control, followed by tillage and post-directed (PD) herbicide applications. Until recently, over-the-top postemergence (POST) herbicides have generally been limited and such applications often caused crop injury. Several relatively new weed control programs have been developed for cotton production in recent years. However, only one new herbicide active ingredient, pyrithiobac, has been developed for use in standard cotton varieties. Other advances in weed control have centered on genetically engineered crop varieties. Two weed control systems: glyphosate tolerant (Roundup Ready, GT) and bromoxynil resistant (BXN, BR) using genetically engineered varieties are now commonly used by growers.

Glyphosate (*N*-(phosphonomethyl)glycine) (Figure 1) is a broad-spectrum, nonselective POST herbicide developed by Monsanto Agricultural Products in 1970 (Franz et al. 1997a). Glyphosate was introduced in agricultural markets in 1974 and today is one of the most widely used herbicides in the world. Glyphosate is registered for use in more than 100 crops and controls more than 300 weed species, including 74 of the world's worst weed species (Franz et al. 1997a). Glyphosate is a component of more than 90 herbicide products and is sold under more than 150 trademarks.

Glyphosate is a potent inhibitor of the enzyme 5-enol-pyruvylshikimate-3-phosphate synthase (EPSPS, E.C. 2.5.1.19) (Devine et al. 1993; Franz et al 1997b). EPSPS is the catalyst for the production of 5-enol-pyruvylshikimate-3-phosphate (EPSP), a key intermediate in the synthesis of chorismate from erythrose-4-phosphate. Chorismate is an important precursor of several essential plant components including the aromatic amino acids tryptophan, tyrosine, and phenylalanine. Other downstream products of this and related pathways include auxin, lignin, ubiquinones, folic acid, vitamins K and E, and anthocyanin (Franz et al. 1997b). The termination of aromatic amino acid and other essential plant compound synthesis results in an increased diversion of erythrose-4-phosphate from the Calvin cycle into the skikimic acid pathway (Geiger and Servaites 1994; Franz et al. 1997b). This increased diversion of erythrose-4-phosphate depletes ribulose bisphosphate (RuBP) levels, which slows the Calvin cycle and limits photosynthesis (Servaites et al. 1987; Shieh et al. 1991; Franz et al. 1997b). Therefore, inhibition of EPSPS by glyphosate results in a decrease in protein synthesis, cessation of growth, and starvation until death occurs.

Glyphosate tolerant plants can be genetically engineered by two different methods. The first method is to promote overproduction of the EPSPS enzyme by inserting a strong constitutive promoter in front of the natural EPSPS gene (Shah et al. 1985). The second and most commonly used method is to produce GT EPSPS by an amino acid substitution in the EPSPS gene (Kishore and Shah 1988). The specific substitution occurs between positions 80 and 120 of a mature EPSPS sequence and involves replacing the second glycine residue of the sequence -L-G-N-A-G-T-A- with an alanine residue (Kishore and Shah 1988). The substitution results in a modified EPSPS enzyme with a lower affinity for glyphosate and normal catalytic activity in the production of EPSP.

Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) (Figure 2) is a POST herbicide for dicot weed control in grass and other tolerant crops. In the United States, bromoxynil was first registered in 1965 for weed control in wheat and barley (Anonymous 1998a). Bromoxynil is currently registered for use in several food, feed, and fiber crops including corn, sorghum, small grains, alfalfa, onions, garlic, mint, flax, and cotton (transgenic

(BXN) varieties only) (Anonymous 1997a). In addition, bromoxynil is registered for use in sod production, grasses grown for seed, non-residential turfgrass, and on non-crop and conservation reserve program lands. Bromoxynil is commercially available under the trade names Buctril and Moxy and is also sold in combination with other herbicides such as atrazine and MCPA in prepackaged mixtures.

Bromoxynil is a potent inhibitor of the photosystem II (PSII) complex, which is located in the thylakoid membranes of the chloroplast (Ahrens 1994). Bromoxynil acts by binding the Q_B binding site on the D1 protein. The binding of bromoxynil to the Q_B protein prevents normal electron flow through PSII and thus inhibits the system. This inhibition results in a cessation of CO_2 fixation and ATP and NADPH production, which inhibits other metabolic processes and leads to free radical formation, lipid and protein oxidation, loss of membrane integrity, and plant death (Ahrens 1994).

Bromoxynil resistant plants express a nitrilase enzyme that rapidly detoxifies bromoxynil in the plant (Stewart 1991). Specifically, a gene isolated from resistant soil bacterium of *Klebsiella ozeanae* is inserted into the plant genome, which enables nitililase production in the plant (Stalker 1987). The expression of the nitrilase enzyme in BR plants rapidly detoxifies bromoxynil by hydrolysis of the nitrile group on the bromoxynil compound (Stalker 1987).

Other researchers have previously documented the advantages of utilizing GT and BR cotton varieties. Culpepper and York (1999) observed that growers are most interested in the ease of application, crop safety, and weed control efficacy. In addition, the use of glyphosate and bromoxynil in cotton may be useful in managing weed species tolerant or resistant to conventional herbicides used in cotton and rotational crops (Byrd

1995; Shaw 1995). Moreover, the broad-spectrum weed control that can be obtained using glyphosate or bromoxynil alone or in combination with other POST herbicides may allow producers to exclude soil-applied herbicides from their weed control program (York and Culpepper 1999).

The weed control benefit from utilizing GT and BR cotton varieties has been clearly established. Nonetheless, many producers remain uncertain regarding the economic advantage of these varieties. Research, conducted in conventional tillage cotton, has shown that net returns obtained from utilizing GT and BR cotton with various weed management programs to be equivalent to that of non-transgenic cotton (Culpepper and York 1999). Similar results have been noted for BR cotton in no-tillage production (Culpepper and York, 1997). However, further analysis is needed to evaluate economic performance of GT, BR, and non-transgenic cotton weed management programs in various tillage systems, climatic conditions, soil types, and weed pressures. The objective of this research was to evaluate various weed management systems in no-tillage cotton production utilizing standard (STD), GT, and BR cotton varieties. Of particular interest were weed control, cotton yield and quality, and economic returns.

MATERIALS AND METHODS

Field trial establishment. Field studies were conducted in 1998 and 1999 at the Milan Experiment Station located near Milan, TN. The soil series was a Grenada Silt Loam (fine-silty, mixed, active, thermic, Glossic Fragiudalf) which has a surface of 4 % sand, 75 % silt, and 21 % clay. The surface soil contained 1.5 % organic matter and had a pH of 5.8. Field plot areas were established in 1997 utilizing a conventional tillage seedbed to smooth rough areas and prepare for no-tillage production. A no-tillage seedbed was established in the fall of 1997 using a winter wheat cover and maintained during the 1998 and 1999 experimental years. Weed management systems were applied to the same plot areas in each of the three years and data were collected in 1998 and 1999. Burndown treatments of paraquat were applied prior to planting. STD variety Stoneville 474, GT variety Paymaster 1220RR, and BR variety Stoneville BXN 47 were planted on May 14, 1998, and May 17, 1999 at a rate of 16.8 kg/ha and a depth of 1.9 cm. Plots consisted of four rows 9 m long and spaced 1 m apart and arranged in a randomized complete block design with four replications. Plots were maintained according to standard production practices for fertility, insect, disease, growth management, and harvest preparation.

Weed control programs are outlined in Table 1. Three weed management systems were evaluated in STD cotton, two in BR cotton, and five in GT cotton. All STD and BR treatments were treated with pendimethalin + fluometuron (0.84 kg ai/ha + 1.3 kg ai/ha) PRE. POST STD systems included hand hoeing, fluometuron + MSMA (1.1 kg ai/ha + 1.8 kg ai/ha) early postemergence directed (PD) fb cyanazine + MSMA (0.9 kg ai/ha + 2.2 kg ai/ha) late PD, and pyrithiobac + non-ionic surfactant (NIS) (0.071 kg ai/ha + 0.25 % v/v) early POST fb cyanazine + MSMA late PD. POST BR weed management systems were hand hoeing, and bromoxynil (0.56 kg ai/ha) early POST fb cyanazine + MSMA late PD. GT systems included glyphosate early POST fb cyanazine + MSMA late PD both with and without pendimethalin + fluometuron PRE, and glyphosate early POST fb glyphosate late PD both with and without pendimethalin PRE. An additional GT treatment included a pendimethalin + fluometuron fb hand hoeing. Glyphosate applications were made at 0.84 kg ai/ha.

PRE and early POST applications were made using a tractor-mounted CO_2 pressurized boom sprayer equipped with 80015 flat fan nozzles delivering 94 L/ha. Early and late PD applications were made using a post-directed to provide a uniform broadcast application under and between rows. The PD sprayer was equipped 8003 and 80015 flat fan nozzles and delivered 187 L/ha . PRE applications were made immediately following planting. Early POST and early PD applications were made 2 to 4 wk after planting (WAP) when cotton had 3 to 6 leaves and was 10 to 23 cm in height. Late PD applications were made 6 to 8 WAP when cotton was 38 to 46 cm tall.

Data collection and analysis. Weed control and crop injury were evaluated 2 wk after each POST application. Data were collected on a 0 to 100 scale where 0 represents no weed control or crop injury and 100 represents complete weed control or total crop destruction. Plots were harvested utilizing a spindle picker on 21 September and 9 October 1998, and 17 September and 6 October 1999. A grab sample of seed cotton was taken from each plot, ginned on a 20 saw gin with dual lint cleaners, and a 270 g lint sample was hand classed and evaluated using high-volume instrumentation for fiber quality, trash content, and lint content (Anonymous 1993).

Net returns to land, management and risk were assessed utilizing Tennessee cotton production budgets (Gerloff 2000) for no-till cotton. Cost of production was calculated exclusive of all weed management operations and included seed cost for the STD two-way treated cotton variety ($2.20/kg). Total production cost, exclusive of weed management operations, was $730.06/ha (Tables 2-3). Seed price increases for BR and GT cotton were +$1.10/kg and +$0.18/kg, respectively. In addition, a technology fee of $22.22/ha was assessed to GT seed prices. The cost of herbicide treatment per hectare were bromoxynil, \$35.65; cyanazine + MSMA, \$30.20; fluometuron, \$27.04; fluometuron + MSMA, \$34.35; glyphosate, \$19.09; pendimethalin, \$15.51; and pyrithiobac + NIS, \$66.17; (Rhodes and Breeden, 2000). Additional machinery and power inputs were based on costs reported in Tennessee cotton production budgets. Labor inputs were based on a salary of \$6.75/hr.

Treatment costs were calculated by the addition of inputs, as follows (Table 4):

$$C^{treat} = C^{seed} + C^{fee} + C^{herb} + C^{equip} + C^{labor}$$

Where C^{treat} is the cost of treatment, C^{seed} is the additional seed cost (ie. cost of STV BXN47 or Paymaster 1220RR seed less the cost of STV 474), C^{fee} is the technology fee, C^{herb} is the cost of herbicides and surfactants, C^{equip} is the cost related to machinery, and C^{labor} is labor expense for herbicide application or hand hoeing (Tables 5-14). Net returns were calculated by deducting production and treatment costs from the gross return, as follows (Larson et al. 1999):

$$NR = Y^{lint} \times (P^{base} + P^{diff}) - (C^{prod} + C^{treat})$$

Where NR is the net return and Y^{lint} is the lint yield. P^{base} is the average base price for October cotton in the production year and P^{diff} is any applicable premiums or discounts related to lint quality, as reported by the USDA Agricultural Marketing Service for the North Delta production region (Anonymous 1997b; Anonymous 1998b; Anonymous 1999). P^{base} for 1998 and 1999 were \$1.49/kg and \$1.12/kg, respectively. C^{prod} is the base cost of production and C^{treat} is the cost of the weed control treatment. Cotton seed produced is assumed to be exchanged for ginning fees and therefore, cotton seed yields and ginning fees are excluded from the return analysis.

All data were subjected to the appropriate ANOVA for the experimental design. When appropriate, data were combined over years. Means of significant treatment differences were separated using Fisher's protected LSD at P = 0.05. In addition, contrasts were performed when appropriate to compare selected treatments.

RESULTS AND DISCUSSION

Smooth pigweed, common cocklebur, entireleaf morningglory, large crabgrass, goosegrass, and red sprangletop were present in the test area in each of the two years. Other weeds present in the test area at low, random populations were bermudagrass, spotted spurge (*Euphorbia maculata* L.), prickly sida (*Sida spinosa* L.), and trumpetcreeper [*Campsis radicans* (L.) Seem. Ex Bureau]. Weed control following herbicide treatments was consistent in each of the three years and data were pooled over years. Due to dry growing conditions in 1999, goosegrass and red sprangletop did not germinate after early POST applications. Therefore, late season goosegrass and red sprangletop control is based on 1998 data only. Minor, insignificant crop injury was observed following some treatments (data not shown).

Broadleaf weed control. Mid-season (4 to 6 WAP, 2 wk after early POST) smooth pigweed control was greater than 96 % in all systems which contained pendimethalin + fluometuron PRE (Table 15). Smooth pigweed control following pendimethalin fb glyphosate was 94 %. The addition of pendimethalin + fluometuron to the GT total POST programs increased smooth pigweed control. However, the GT total POST program was not different from the GT program of pendimethalin fb glyphosate. Late season (8 to 10 WAP) smooth pigweed control was greater than 90 % for all treatments that included pendimethalin + fluometuron PRE (Table 16). Similar to previous research (Culpepper and York, 1999), no differences were observed among treatments. However, smooth pigweed control in programs that eliminated fluometuron or all soil-applied herbicides tended to be slightly lower.

Mid-season common cocklebur control was greater than 98 % for all hand-hoed treatments and pendimethalin + fluometuron fb either bromoxynil or glyphosate (Table 15). At 2 wk after early POST, common cocklebur control was 92 % following fluometuon + MSMA early PD and 95 % following pyrithiobac + NIS early POST. Reduced common cocklebur control was observed when fluometuron PRE was not included in the weed management systems. Common cocklebur control following one application of glyphosate and pendimethalin fb glyphosate was 93 to 94 %. All treatments controlled common cocklebur 97 to 99 % at 8 to 10 WAP except the total POST glyphosate fb glyphosate program which provided 91 % control (Table 16). As reported in previous research (Andersen et al. 1973), common cocklebur control with bromoxynil was excellent. Pendimethalin + fluometuron PRE did not increase common cocklebur control in the GT systems that contained glyphosate fb cyanazine + MSMA. However, a small decrease in common cocklebur control (6 %) was observed when a PRE was not used in the GT system consisting of glyphosate fb glyphosate.

Entireleaf morningglory control was excellent in all weed control systems at 4 to 6 WAP (Table 15). All treatments controlled entireleaf morningglory> 96 %. Entireleaf morningglory control in both GT total POST programs was similar to that of the STD programs which included either fluometuron + MSMA or pyrithiobac + NIS. Similar results have been reported previously (Webster and Baughman 1998). Including soil-applied herbicide(s) did not increase entireleaf morningglory control in the GT total POST programs. Due to excellent mid-season control, entireleaf morningglory was not present at late-season evaluations.

Annual grass control. Large crabgrass control in the hand-hoed checks, following pendimethalin + fluometuron fb fluometuron + MSMA, and following all glyphosate treaments was > 96 % at 4 to 6 WAP (Table 15). Mid-season large crabgrass control was significantly lower in systems which included pyrithiobac + NIS or bromoxynil (91 and 94 %, respectively). The elimination of soil-applied herbicides also reduced mid-season large crabgrass control. At least 93 % control of large crabgrass was obtained by each weed control system at 8 to 10 WAP (Table 16). Large crabgrass control was 99 % in the hand hoed checks, and 98 % in all GT systems except the total POST glyphosate fb cyanazine + MSMA which provided 95 % control. In contrast to previous research (Culpepper and York 1999), large crabgrass control following the STD treatment containing pyrithiobac + NIS was not equivalent to other programs. However, this research agrees with other previously reported results (Culpepper and York 1997). Culpepper and York (1999) also reported the addition of pendimethalin + fluometuron to GT total POST programs increased large crabgrass control when POST treatments were glyphosate fb glyphosate, but had no impact when POST treatments were glyphosate fb cyanazine + MSMA. Our research showed an increase in weed control did not occur with the addition of a soil-applied herbicide to the GT total POST glyphosate fb glyphosate program and the addition of pendimethalin + fluometuron to the GT total POST glyphosate fb cyanazine + MSMA increased large crabgrass control.

Goosegrass control 2 wk after early POST was 98 to 99 % for all treatments except glyphosate POST without a soil-applied herbicide (96 %) (Table 15). Late season goosegrass control was at least 97 % in all treatments except the GT total POST glyphosate fb glyphosate program (Table 16). An increase in goosegrass control was observed when soil-applied herbicides were added to the GT total POST glyphosate fb glyphosate program. Goosegrass control in the GT total POST glyphosate fb glyphosate system was 82 %. The addition of pendimethalin to the system increased goosegrass control to 99 %.

Mid-season red sprangletop control was 99 % in all systems that contained a soil applied herbicide (Table 15). Red sprangletop control following one application of glyphosate without a soil-applied herbicide was 67 %. Late season red sprangletop control in all hand hoed plots, the STD program pendimethalin + fluometuron fb fluometuron + MSMA fb cyanazine + MSMA, and the GT program DNA/fluometuron fb glyphosate fb cyanazine + MSMA was 99 % (Table 16). The pendimethalin fb glyphosate fb glyphosate system controlled red sprangletop 98 %. Only the GT total POST glyphosate fb cyanazine + MSMA program provided statistically lower control of red sprangletop. Greenhouse studies have shown that pendimethalin provides good to excellent control of red sprangletop up to 26 wk after treatment (McCarty et al. 1995). Similarly, the addition of pendimethalin to the both GT total POST programs increased late-season red sprangletop control.

Based on data from their research and that of previous researchers (Jordan et al. 1993) Culpepper and York (1997) theorized that large crabgrass and broadleaf signalgrass [*Brachiaria playtphylla* (Griseb.) Nash] may be less susceptible to pyrithiobac than goosegrass. In this research, annual grass control supported this hypothesis. Mid-season large crabgrass control following pyrithiobac treatment was 91 % while goosegrass was controlled 98 %.

Lint yield and quality. Lint yields in 1998 were greater than those obtained in 1999 due to better growing conditions during fruit set and ripening. However, the year by treatment interaction was not significant and yields were combined over years. No differences in lint yield were observed among cotton varieties (Table 17). The highest lint yield was obtained by hand hoeing Paymaster 1220RR. This yield was not different than hand hoed treatment in Stoneville 474 or Stoneville BXN 47. These varieties have performed similarly in Tennessee variety trials over the same time period (Gwathmey et al. 1999; Gwathmey et al. 2000). Lint yields across STD, BR, and GT herbicide programs were lower than the yield of the respective hand hoed treatment. A yield increase was obtained by the addition of pendimethalin + fluometuron to the GT total POST glyphosate fb cyanazine + MSMA, however, no yield response was observed for the addition of pendimethalin to GT total POST glyphosate fb glyphosate. Similar to previous research (Culpepper and York 1999), lint yields in the GT total POST program glyphosate fb cyanazine + MSMA were 141 kg/ha lower than the same GT system which included pendimethalin + fluometuron. This reduction in yield is likely a result of early season weed competition similar to that observed by Culpepper and York (1999).

Fiber quality (Table 18) and the associated price discounts (Table 19) varied in each of the two years, but no differences were noted between treatments (data not shown). Fiber length varied with year and variety. Fiber length in 1998 and 1999 was greatest with Paymaster 1220RR (28.7 and 27.5 mm, respectively) and shortest with

Stoneville 474 (27.9 and 26.9 mm, respectively). However, premiums or discounts associated with fiber length were not different with respect to variety within years.

Premiums, based on color grade, leaf grade, and fiber length, were paid in each of the two years for Paymaster 1220RR and ranged from $0.007/kg (1998) to $0.0031/kg (1999) (Table 19). Discounts were assessed for both Stoneville varieties in each year and were primarily a result of higher leaf grade (increased trash content). Discounts for Stoneville 474 were $0.13, and 0.055/kg (1998 and 1999 respectively). Stoneville BXN 47 received discounts of $0.074 and 0.011/kg for the respective years.

Fiber fineness (micronaire) and fiber strength varied with year and variety. Micronaire ranged from 41 to 49 for Paymaster 1220RR, 43 to 46 for Stoneville 474 and 41 to 46 for Stoneville BXN 47 (Table 18). Paymaster 1220RR was assessed a discount for micronaire of $0.059/kg in 1999 (Table 19). No other premiums or discounts were assessed based on micronaire. In 1998 fiber strengths for the two Stoneville varieties were 29.60 g/tex (474) and 29.98 g/tex (BXN 47) and received premiums of $0.0040 and 0.0043/kg, respectively (Tables 18-19). Paymaster 1220RR fiber strength was 30.66 g/tex in 1998 and received a premium of $0.0052/kg. In 1999 fiber strengths for Stoneville BXN 47 and Paymaster 1220RR were 30.51 and 32.93 g/tex, respectively, and received premiums of $0.0040 and 0.0044/kg while Stoneville 474 received a premium of $0.0031/kg for a fiber strength of 30.40 g/tex.

Extraneous matter content was not significant among treatments or varieties (Table 18). In 1998, the highest discount ($0.055/kg) was received by Stoneville BXN 47 and the lowest ($0.014/kg) by Stoneville 474 (Table 19). In 1999, Stoneville BXN 47 was not discounted for extraneous matter. Paymaster 1220RR was docked $0.009/kg and Stoneville 474 received a $0.029/kg discount.

Economics of weed control. Due to higher yields and lint prices, net returns in 1998 were higher than those obtained in 1999. However, the year by treatment interaction was not significant and net returns were averaged over years. Exclusive of the hand-hoed checks, net returns ranged from $277 to $581/ha (Table 17). The highest net returns were obtained with Paymaster 1220RR and the GT programs pendimethalin fb glyphosate fb glyphosate ($581/ha), pendimethalin + fluometuron fb glyphosate fb cyanazine + MSMA ($555/ha), and the total POST glyphosate fb glyphosate program ($520/ha). Net return following the GT total POST glyphosate fb cyanazine + MSMA ($345/ha) were significantly lower than the same POST program with pendimethalin + fluometuron PRE. The addition of pendimethalin to the GT total POST glyphosate fb glyphosate program did not increase net return. Net returns following the two STD programs and the BR-bromoxynil programs were significantly lower than those obtained with pendimethalin fb glyphosate fb glyphosate in GT cotton. However, pendimethalin + fluometuron fb fluometuron + MSMA fb cyanazine + MSMA was not different from other GT programs. Exclusive of the hand hoed checks, net returns were lowest when the pyrithiobac and bromoxynil systems were used ($282 and 277/ha, respectively). Similar research in conventional tillage cotton has shown no differences in net returns following these weed management programs in STD, BR, and GT cotton (Culpepper and York 1999).

The findings of this research have shown the use of genetically modified cotton varieties and the related herbicide programs to be effective alternatives for weed control in cotton. The results of this and previous research (Culpepper and York, 1999) have shown broadleaf and grass weed control utilizing BR and GT cotton varieties is comparable to that obtained with STD varieties and conventional herbicides. BR varieties offer growers the opportunity for POST over-the-top applications for control of some important broadleaf weeds. Bromoxynil will not control annual and perennial grasses, sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby], or Palmer amaranth (*Amaranthus palmeri* S. Wats.) and thus must be used in conjunction with other herbicides. The non-selective nature of glyphosate can provide effective and economical control of most annual and perennial weeds. When used in GT cotton varieties, glyphosate has the potential to offer growers the option of eliminating soil-applied herbicides (York and Culpepper 1999). However, previous research (Culpepper and York 1999) demonstrates high weed densities necessitate proper timing of POST applications. In this research, no significant benefit was obtained from adding soil-applied herbicides to a total POST glyphosate fb glyphosate program. In farm scale production the inclusion of soil-applied herbicides will permit a larger window for glyphosate application and may offer substantial benefit in fields where weed species tolerant to glyphosate are found (York and Culpepper 1999).

Yields were similar for BR and GT cotton systems and both were comparable to that of conventional practices in STD varieties. Yields, lint prices, and thus net returns will fluctuate across production areas and from year to year. Thus, the net returns obtained from utilizing a particular weed management system are subject to significant variation.

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PART III

DECISION ASSISTANCE MODEL FOR SELECTING COTTON VARIETIES BASED ON WEED MANAGEMENT STRATEGIES

ABSTRACT

Recent advances in genetic engineering have made selecting a cotton variety more complex. Due to the increased seed and technology costs of GT and BR varieties, weed control strategies must now be considered before a cotton variety is selected. Thus, understanding a field's history and the potential weaknesses of a herbicide program can make this decision easier. A cotton variety decision aid model was created using weed control efficacy information reported on herbicide labels and in university extension publications. In fields with a history of weed problems that include pigweed species, spotted spurge, sicklepod, or purple and yellow nutsedges, bromoxynil resistant cotton varieties were not recommended. Glyphosate tolerant varieties were not recommended for fields that have a history of weed problems including morningglory species, hemp sesbania, Florida pusley, or spreading dayflower. Fields with a history of weed problems that included a cross section of those weeds listed for bromoxynil resistant and glyphosate tolerant were recommended to be planted to conventional varieties. In addition, producers are advised not to use pyrithiobac in areas with a history of major weed problems resulting from spotted spurge, sicklepod, purple or yellow nutsedge, common lambsquarters, common ragweed, tall morningglory, or tropic croton. Growers are also advised not to use pyrithobac where acetolactate synthase (ALS) resistant weeds are present, and where carryover to sensitive crops is a concern. The decision aid presented utilizes a "decision tree" approach where the cotton variety is selected to optimize weed control, minimize herbicide resistance development, and maximize farmer profitability.

Nomenclature: Bromoxynil, 3.5-dibromo-4-hydroxybenzonitrile; glyphosate, *N*-(phosphonomethyl)glycine; pyrithiobac, 2-chloro-6-[(4,6-dimethoxy-2-pyrimid-inyl)thio]benzoic acid, sodium salt; smooth pigweed, *Amaranthus hybridus* L. #[1] AMACH; redroot pigweed, *Amaranthus retroflexus* L. # AMARE; Palmer amaranth, *Amaranthus palmeri* S. Wats. # AMAPA; sicklepod, *Senna obtusifolia* (L.) Irwin and Barneby # CASOB; spotted spurge, *Euphorbia maculata* L. # EPHMA; purple nutsedge, *Cyperus rotundus* L. # CYPRO; yellow nutsedge, *Cyperus esculentus* L. # CYPES; morningglory spp., *Ipomoea spp.*; hemp sesbania, *Sesbania exaltata* (Raf.) Rydb. *ex* A.E. Hill # SEBEX; spreading dayflower, *Commelina diffusa* Burm. f. # COMDI; Florida pusley, *Richardia scabra* L. # RCHSC; common lambsquarters, *Chenopodium album* L. # CHEAL; tall morningglory, *Ipomoea purpurea* L. (Roth) # PHBPU; common ragweed, *Ambrosia artemisiifolia* L. # AMBEL; tropic croton, *Croton glandulosus var. septentrionalis* Muell.-Arg. # CVNGS; cotton, *Gossypium hirsutum* L.

Additional Index Words: Genetically modified crops, bromoxynil resistant cotton, glyphosate tolerant cotton, weed control, variety selection, AMACH, AMARE, AMAPA, CASOB, EPHMA, CYPRO, CYPES, SEBEX, COMDI, RCHSC, CHEAL, PHBPU, AMBEL, CVNGS.

Abbreviations: BR, bromoxynil resistant; GT, glyphosate tolerant; PPI, preplant incorporated; PRE, preemergent; PD, postemergence directed; POST, postemergence.

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[1] Letters following this symbol are a WSSA approved computer code from *Composite List of Weeds*. Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

INTRODUCTION

Weed management strategies in cotton have traditionally incorporated the use of preplant incorporated (PPI) or preemergence (PRE) herbicides for preventative weed control followed by tillage and/or post-directed (PD) herbicides for late season weed control. Over-the-top postemergent (POST) applications have previously been limited to crop salvage situations because such applications often injured cotton. Several new weed control programs have been developed for cotton production in recent years. However, only one new herbicide active ingredient, pyrithiobac, has been developed for use in cotton. Other advances in cotton weed control have centered on genetically engineered varieties. Two weed control systems using genetically engineered varieties [glyphosate tolerant (Roundup Ready, GT) and bromoxynil resistant (BXN, BR)] are now available for use by growers.

Pyrithiobac (2-chloro-6-[(4,6-dimethoxy-2-pyrimidinyl)thio]benzoic acid, sodium salt) (Figure 3) is a selective herbicide for broadleaf weed control in cotton. Pyrithiobac may be used PRE at a rate of 36 to 48 g ai/ha alone or in combination with diuron, fluometuron, or prometryn (Anonymous 2000c). POST applications of pyrithiobac may be applied at a rate of 71 g ai/ha. Pyrithiobac may be applied in combination with glyphosate, MSMA or DSMA, or quizalofop-P when used POST (Anonymous 2000c). Pyrithiobac does not control annual or perennial grasses. In addition, pyrithiobac does not adequately control several important broadleaf weeds and sedges (Rhodes and Breeden 2000; York 1999; Jordan et al. 1993).

Glyphosate (*N*-(phosphonomethyl)glycine) is a non-selective herbicide that may be applied POST over-the-top to GT cotton until the four leaf stage. After cotton has reached the four leaf growth stage glyphosate must be applied as a directed spray (Anonymous 2000b). Glyphosate applied POST in conjunction with GT cotton varieties has been shown previously to be effective for weed control in both conventional and no-tillage cotton (Culpepper and York 1999; Summerlin 2000). However, like pyrithiobac, glyphosate does not provide complete control of every weed species (Rhodes and Breeden 2000; York and Culpepper 1999; Culpepper and York 1999).

Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) is a selective POST herbicide for broadleaf weed control in BR cotton. Bromoxynil may be applied over-the-top of BR cotton at rates of 43 to 56 g ai/ha from emergence until 75 d before harvest (Anonymous 2000a). Bromoxynil does not control annual or perennial grasses and does not provide complete control of certain broadleaf weeds (Rhodes and Breeden 2000; York 1999; Wilcut et al. 1995).

Traditionally, cotton variety selection has been based on adaptation, yield performance history, fiber quality, and growth characteristics. However, the recent advances in genetic engineering have made selecting a cotton variety more complex. Due to the increased seed and technology costs of GT and BR varieties, weed control strategies must now be considered before a cotton variety is selected. Understanding a field's history and the potential weaknesses of a herbicide program can make this decision easier. While many producers would prefer to plant their entire acreage to Roundup Ready® cotton, it is generally not recommended to plant an entire cotton crop to one variety. In addition, seed supply limitations commonly occur and limit the acreage a grower may plant to a particular variety. Therefore, the purpose of this paper is to provide a decision assistance model to aid producers in selecting the most appropriate cotton varieties from a weed control perspective.

MATERIALS AND METHODS

A series of questions was created to provide producers with a variety selection guideline based on rotational crop restrictions, and weed control efficacy data provided on herbicide specimen labels (Anonymous 2000a; Anonymous 2000b; Anonymous 2000c) in conjunction with efficacy evaluations provided in university extension publications (Rhodes and Breeden 2000; York 1999).

Crop rotation restrictions were obtained from the labels of herbicides approved for use in cotton. These restrictions were used to inform and remind producers of possible plantback restrictions that may occur following the use of selected herbicides. Crop rotation restrictions alone cannot exclude the use of conventional, BR, or GT varieties, and are used only as additional information.

The cotton variety decision aid model was created by an exclusion method. The weed control deficiencies of each weed management program associated with the genetically modified varieties were used to eliminate possible variety options. The weaknesses associated with bromoxynil used in a BR system were: weedy Amaranthus species (palmeri, hybridus, and retroflexus), sicklepod, spotted spurge, and purple and yellow nutsedges (Rhodes and Breeden 2000; York 1999). The weaknesses associated with glyphosate use in a GT system were: morningglory species, hemp sesbania, spreading dayflower, and Florida pusley (Rhodes and Breeden 2000; York and Culpepper 1999; Culpepper and York 1999).

In addition, the weed control weaknesses of pyrithiobac were included to provide producers information regarding which areas should not be treated with pyrithiobac, but were not used to eliminate the use of any variety. The weaknesses associated with pyrithiobac were common lambsquarters, tall morningglory, common ragweed, sicklepod, spotted spurge, tropic croton, and purple and yellow nutsedges (Rhodes and Breeden 2000; York 1999).

A simple cost analysis budget was prepared utilizing recommended herbicide rates and 1999 herbicide cost for each of the herbicides labeled for use in cotton. Sample weed management programs were presented as a model for using the table and are for example only. A weed management program should be selected based on the strengths and deficiencies of particular herbicides in conjunction with information regarding the weed populations present in an individual field. The use of brand or trade names is for clarity of information and does not imply approval of the product to the exclusion of other similar products.

RESULTS AND DISCUSSION

The decision assistance model for selecting cotton varieties based on weed management strategies is presented below with explanatory text following the instrument. The instrument is also located in Appendix C in a version using herbicide trade names and without explanatory text.

PART I. Rotational crops and field history

1. Do you intend to plant wheat or other small grain crops in this field after harvesting this years cotton crop?

   YES-go to #2 NO-go to #4

2. Do you intend to harvest the wheat or other small grain crop to be planted this fall for grain or hay?

   YES-go to #3 NO-go to #4

3. You are still eligible to select standard, BXN, or Roundup Ready cotton varieties. However, your intent to harvest wheat or other small grain crops eliminates your ability to use certain herbicides and makes the timing of application of other herbicides critical. Please note the restrictions outlined in Table 1.

   Proceed to #4

4. Have you applied more than one of the following herbicides in this field during the past two years, have you made multiple applications of one of these herbicides in the past year, or have you applied one of the following herbicides in each of the past two years? NOTE: Rotation restrictions for some of the herbicides listed below do not permit cotton to be planted the following year. Consult herbicide labels for rotation restrictions.

Accent	Accent Gold	Ally	Backdraft
Basis	Basis Gold	Beacon	Canopy
Canopy XL	Broadstrike SF + Dual	Broadstrike SF + Treflan	Celebrity B+G
Classic	Contour	Detail	Exceed

Expert	Extreme	FirstRate	Frontrow
Gemini	Harmony Extra	Hornet	Peak
Permit	Pinnacle	Pursuit	Pursuit Plus
Python	Raptor	Resolve	Scepter
Scepter-OT	Scorpion III	Squadron	Staple
Staple Plus	Steel	Strongarm	Synchrony
TriScept			

YES-go to #5 NO-go to #6

5. It is generally not recommended that herbicides with the same mode of action not be used on a field in more than two consecutive years due to selection pressures and the possibility of resistance development. If you answered YES to question 4 do not use Staple for weed control in this field.

Proceed to #6

6. Have you experienced failure to control common cocklebur or pigweeds following applications of any of the herbicides listed in question 4, or does this field have confirmed ALS resistant common cocklebur or Palmer amaranth?

Yes-go to #7 NO-go to #8a

7. Failure to control common cocklebur or pigweeds with ALS inhibiting herbicides (those listed in question 4) may indicate the presence of ALS resistant biotypes of these weeds. If resistant weeds are present adequate control will not be achieved with Staple. Do not use Staple for control of these weeds.

Proceed to #8a

8a. Were Roundup Ready soybeans or Roundup Ready cotton planted in this field during the previous growing season?

YES-go to #9a NO-go to #8b

8b. Was BXN cotton planted in this field during the previous growing season?

YES-go to #9b NO-go to #16

9a. It is generally not recommended that the same herbicides be used on a field in consecutive years due to selection pressures and the possibility of resistance development. However, certain situations may benefit from the use of Roundup Ready cotton varieties. Do still wish to evaluate Roundup Ready cotton as an option?

YES-go to #16 NO-go to #10

9b. It is generally not recommended that the same herbicides be used on a field in consecutive years due to selection pressures and the possibility of resistance development. However, certain situations may benefit from the use of BXN cotton varieties. Do still wish to evaluate BXN cotton as an option?

YES-go to #16 NO-go to #13

PART II. Weed management

10. Are pigweeds (smooth or Palmer) a major problem in this field?

NO-go to #11 YES-go to #25

11. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #12 YES-go to #27

12. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #28 YES-go to #29

13. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #14 YES-go to #25

14. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #15 YES-go to #30

15. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #34 YES-go to #30

16. Are pigweeds (smooth or Palmer) a major problem in this field?

NO-go to #17 YES-go to #20

17. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #18 YES-go to #23

18. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #19 YES-go to #30

19. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #31 YES-go to #32

20. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #21 YES-go to #25

21. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #22 YES-go to #30

22. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #34 YES-go to #30

23. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #24 YES-go to #27

24. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #28 YES-go to #29

25. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #26 YES-go to #27

26. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #33 YES-go to #27

27. The weed pressures you have described are not likely to be effectively controlled by Staple, Buctril or Roundup Ultra (or you have chosen not to evaluate either Roundup Ready or BXN programs). Consider using a high yielding standard variety with a sound weed management system that does not include Staple. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

28. Because of the weed pressure you have described, Roundup Ready varieties should not be used in this field (or you have chosen not to evaluate Roundup Ready programs). Select a high yielding standard or BXN variety for this field. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

29. The weed pressures you have described are not likely to be effectively controlled by Staple or Roundup Ultra (or you have chosen not to evaluate Roundup Ready programs). Consider using a high yielding standard or BXN variety with a sound

weed management system that does not include Staple. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

30. Buctril will not provide good control of pigweeds (or you have chosen not to evaluate BXN programs). Buctril and Staple typically will not provide good control of sicklepod, nutsedge, or spotted spurge. Staple will not adequately control common lambsquarters, common ragweed, or tropic croton. Lack of control will often promote additional herbicide applications and increase production costs. Do not plant this field to BXN cotton varieties. Select a high yielding standard or Roundup Ready variety for this field. Do not use Staple for weed management in this field. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.
31. Because of the weed pressure you have described this field may be planted to standard, BXN, or Roundup Ready varieties. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.
32. Staple herbicide typically will not provide good control of the weeds present in this field. Select a high yielding standard, BXN, or Roundup Ready variety for this field. Do not use Staple in the weed management program. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

33. The weed pressures you have described are not likely to be effectively controlled by Buctril or Roundup Ultra (or you have chosen not to evaluate either Roundup Ready or BXN programs). Consider using a high yielding standard variety with a sound weed management system. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.
34. Buctril typically will not provide good control of pigweeds (or you have chosen not to evaluate BXN programs). Lack of control will often promote additional herbicide applications and increase production costs. Do not plant this field to BXN cotton varieties. Select a high yielding standard or Roundup Ready variety for this field. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

Rotational crops. The rotational crop restrictions used to develop this instrument are provided in Table 20. Rotational crop restrictions alone do not necessitate the exclusion of certain cotton varieties. However, the rotation restrictions associated with certain herbicides may necessitate removal of one or more herbicides from a potential weed management program. The use of the same herbicide or herbicides of a similar mode of action in the same field in consecutive years is generally not recommended. Such continuous applications increase selection pressures which increase the possibility of herbicide resistance and weed population shifts. Therefore, the instrument was developed to allow growers to decide if certain varieties (and their related herbicide programs) should be considered.

Weed Management. The emphasis of this decision assistance model is weed management systems and is based on the previously described weaknesses of the three POST herbicides (bromoxynil, pyrithiobac, and glyphosate). It is generally not recommended that the grower plant a BR cotton variety if pigweed spp. is a major weed problem. Planting BR cotton varieties would likely only increase production costs and reduce possible returns. Likewise, if hemp sesbania, morningglories, Florida pusley, and/or spreading dayflower are major weed problems in the grower's field it is not recommended to plant GT cotton varieties. Common ragweed, common lambsquarters, and/or tropic croton as major weed problems and the presence of ALS resistant weeds would exclude pyrithiobac as a viable herbicide option, but would not exclude using conventional (non-transgenic) varieties. The presence of sicklepod, nutsedge, or spotted spurge as major weed species present in a field excludes both pyrithiobac and bromoxynil as viable herbicide options. Therefore, GT or non-transgenic cotton varieties are recommended and pyrthiobac should not be used.

Certain weed management programs are not addressed in this instrument because of economic feasibility. For example, a situation could occur in which a grower's field has pigweed species., common ragweed, and common lambsquarters as major weed problems. In this circumstance, an efficacious weed management option could be to apply bromoxynil for common ragweed and lambsquarters control tank mixed with a reduced rate of pyrithiobac for pigweed spp. control. However, due to the high cost of the treatment and the great likelihood of an added application for POST grass control, it is highly likely that an alternative weed management program can provide more economical weed control. Therefore, the grower is recommended to plant GT or conventional cotton varieties and not use pyrithiobac in the weed management system.

Weed control cost. As the cost of seed, technology fees, and herbicides changes so to do the cost of weed management. The information outlined in Table 21 is to be used as a rough guideline for cost comparison and does not take into account any reduction in yield or quality that may result from a herbicide treatment. The information in Table 21 is not a recommendation, but should be used for comparison purposes only.

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APPENDICES

APPENDIX A

FIGURES

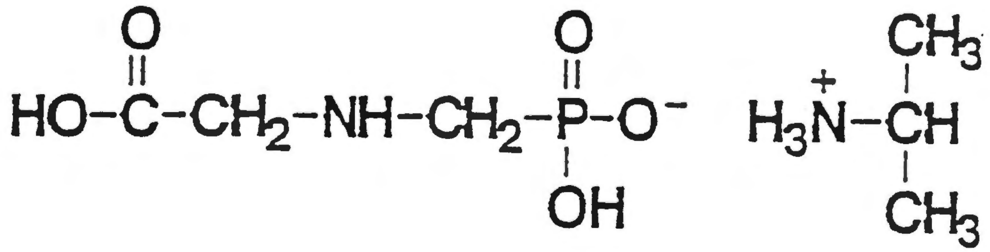

Figure 1. Chemical structure of the isopropylamine salt of glyphosate [*N*-(phosphonomethyl)glycine].

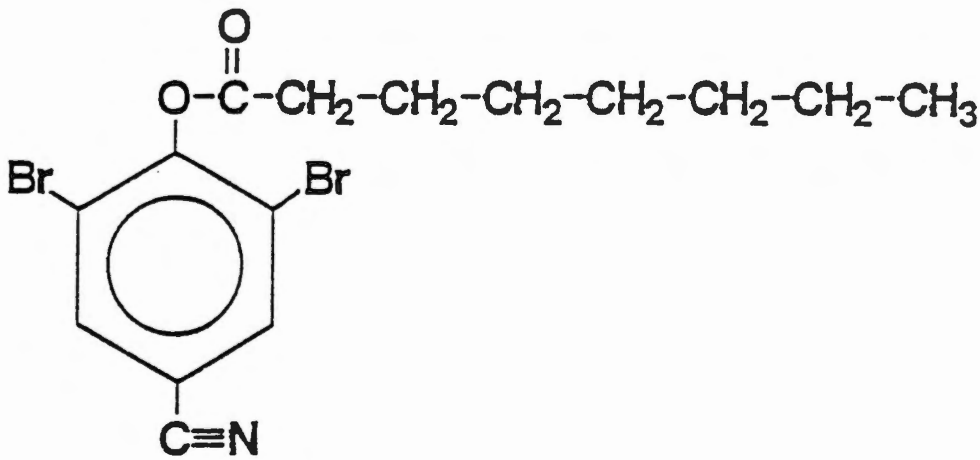

Figure 2. Chemical structure of the octanoate ester of bromoxynil (3,5-dibromo-4-hydroxybenzonitrile).

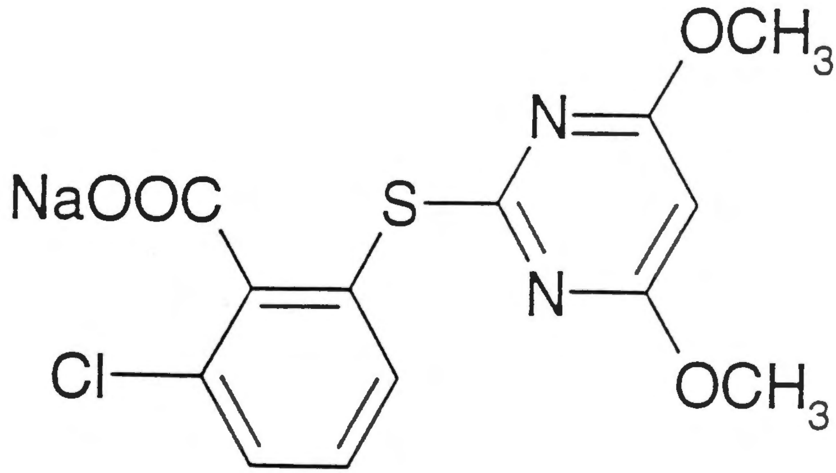

Figure 3. Chemical structure of pyrithiobac (2-chloro-6-[(4,6-dimethoxy-2-pyrimid-inyl)thio]benzoic acid, sodium salt).

APPENDIX B

TABLES

Table 1. Herbicide treatments evaluated in comparison of standard, bromoxynil resistant, and glyphosate tolerant cotton cultivars[a].

	Herbicides[b,c]			
Cultivar	PRE	Early POST	Early PD	Late PD
Stonville 474	Pendimethalin + Fluometuron	Hand hoeing	Hand hoeing	Hand hoeing
	Pendimethalin + Fluometuron	None	Fluometuron + MSMA	Cyanazine + MSMA
	Pendimethalin + Fluometuron	Pyrithiobac + NIS	None	Cyanazine + MSMA
Stoneville BXN 47	Pendimethalin + Fluometuron	Hand hoeing	Hand hoeing	Hand hoeing
	Pendimethalin + Fluometuron	Bromoxynil	None	Cyanazine + MSMA
Paymaster 1220RR	Pendimethalin + Fluometuron	Hand hoeing	Hand hoeing	Hand hoeing
	Pendimethalin + Fluometuron	Glyphosate	None	Cyanazine + MSMA
	Pendimethalin	Glyphosate	None	Glyphosate
	None	Glyphosate	None	Cyanazine + MSMA
	None	Glyphosate	None	Glyphosate

[a]Abbreviations: NIS, non-ionic surfactant; PRE, preemergence; POST, postemergence; PD, postemergence directed.

[b]PRE applications made immediately following planting. Early POST and early PD applications made 2 to 4 wk after planting (WAP). Late PD appliactions made 6 to 8 WAP.

[c]Pendimethalin + fluometuron applied PRE at 0.84 kg ai/ha + 1.3 kg ai/ha. Bromoxynil and pyrithiobac + NIS applied early POST at 0.56 kg ai/ha and 0.071 kg ai/ha + 0.25 % v/v. Glyphosate applied early and late PD at 0.84 kg ai/ha, fluometuron + MSMA applied early PD at 1.1 kg ai/ha + 1.8 kg ai/ha. Cyanazine + MSMA applied late PD at 0.9 kg ai/ha + 2.2 kg ai/ha.

Table 2. Estimated production expenses per hectare for no tillage standard cotton, exclusive of treatment related weed control operations.[a,b]

Item	Description	Unit	Quantity	Price	Amount
				dollars	
Seed	STD, acid delinted	KG	13.44	2.20	29.57
Fungicide	Terrachlor super X	KG	11.20	4.83	54.07
Insecticide					
In-furrow	Temik	KG	3.92	7.32	28.69
Pinhead square (1st)	Methyl parathion	L	0.58	7.77	4.54
Pinhead square (2nd)	Vydate	L	0.58	16.21	9.47
In-season insecticides		HA	1.00	98.77	98.77
Boll worm spray					
Boll weevil spray					
Secondary spray					
Fertilizer	N (NH_4NO_3)	KG	89.60	0.49	43.46
	P_2O_5	KG	67.20	0.42	28.15
	K_20	KG	100.80	0.29	28.89
Boron		KG	0.56	6.61	3.70
Lime		mTON	1.25	17.72	22.22
Burndown	Roundup Ultra	L	2.34	9.37	21.91
Preemerge	Gramoxone Extra	L	1.17	7.09	8.29
Growth regulator	Pix	L	1.17	24.53	28.67
Scouting		HA	1.00	11.85	11.85
Defoliant	Defoliant	L	0.88	10.13	8.88
Boll opener	Prep	L	1.75	12.50	21.91
Machinery repair		HA	1.00	66.57	66.57
Machinery fuel		HA	1.00	20.09	20.09
Operating capital	6 months	HA	616.57	0.09	27.75
Machinery depreciation		HA	1.00	84.49	84.49
Interest expense		HA	1.00	48.79	48.79
Labor		HR	4.35	6.75	29.33
				Total	730.06

[a]Modified for use from Gerloff (2000).

[b]Machinery and labor costs based on the use of 8-row equipment.

Table 3. Estimated labor, power, and machinery inputs per hectare for no tillage cotton, exclusive of treatment related weed control operations.[a,b]

Month	Operation	Equipment	Hours Machine	Hours Labor
Nov.-Dec.	Chop stalks	Rotary mower, 15'	0.25	0.30
Apr.-May	Apply Roundup Ultra	S.P. sprayer	0.12	0.17
	Spread fertilizer	125 hp tractor	0.17	0.20
	Plant/apply Temik	Sod planter, 8 row	0.22	0.27
	Apply Gramoxone Extra	S.P. sprayer	0.12	0.17
May-Jun.	Apply Methyl parathion	S.P. sprayer	0.12	0.17
	Apply Vydate	S.P. sprayer	0.12	0.17
	Boll worm spray	S.P. sprayer	0.12	0.17
Jul.-Aug.	Boll weevil spray	S.P. sprayer	0.12	0.17
	Secondary spray	S.P. sprayer	0.12	0.17
	Apply Pix	S.P. sprayer	0.12	0.17
	Apply defoliant/boll opener	S.P. sprayer	0.12	0.17
Sept.-Oct.	Harvest	S.P. picker, 4 row	0.64	0.81
	Haul	125 hp tractor	0.64	0.81
Nov.-Dec.	Harvest	S.P. picker, 4 row	0.17	0.20
	Haul	125 hp tractor	0.17	0.20
		TOTAL		4.35

Machine	Hours	Interest cost Per hour	Interest cost Per hectare	Cost per hour Fixed	Cost per hour Variable	Cost per hectare Fixed	Cost per hectare Repair	Cost per hectare Fuel	Cost per hectare Variable
		dollars							
Tractor, 125 hp	1.53	3.72	5.68	4.66	11.47	7.14	7.01	10.54	17.56
Picker, 4 row	0.81	28.20	22.79	60.37	59.37	48.79	40.52	7.48	48.00
Sprayer	1.11	13.50	15.01	19.52	13.74	21.60	13.04	2.07	15.26
Planter	0.32	11.25	3.53	17.82	12.50	5.58	3.93	0.00	3.93
Mower	0.25	7.31	1.78	5.71	8.53	1.38	2.07	0.00	2.07
TOTAL			48.79			84.49	66.57	20.09	86.81

[a]Modified for use from Gerloff (2000). Machinery and labor costs based on use of 8-row equipment.

[b]Abbreviation: S.P., self-propelled

Table 4. Cost of selected herbicide treatments for conventional and transgenic cotton varieties.[a]

Cultivar	Herbicides[b] PRE	Herbicides[b] Early POST	Herbicides[b] Late POST	Seed price + technology fee[c]	Total herbicide costs[d]	Machinery + labor costs[e]	Total treatment expenses
				$/ha			
Stoneville 474	Pend/Fluo	Hand hoed	Hand hoed	0	42.55	1166.67	1209.21
	Pend/Fluo	Fluo + MSMA	Cyan + MSMA	0	107.10	13.47	120.57
	Pend/Fluo	Pyrithiobac + NIS	Cyan + MSMA	0	138.92	13.47	152.39
Stoneville BXN 47	Pend/Fluo	Hand hoed	Hand hoed	14.78	42.55	1166.67	1223.99
	Pend/Fluo	Bromoxynil	Cyan + MSMA	14.78	108.40	13.47	136.55
Paymaster 1220RR	Pend/Fluo	Hand hoed	Hand hoed	24.64	42.55	1166.67	1233.85
	Pend/Fluo	Glyphosate	Cyan + MSMA	24.64	91.84	13.47	129.95
	Pend	Glyphosate	Glyphosate	24.64	53.69	13.47	91.80
	None	Glyphosate	Cyan + MSMA	24.64	49.29	13.47	87.40
	None	Glyphosate	Glyphosate	24.64	31.80	13.47	69.91

[a]Abbreviations: Pend, pendimethalin; Fluo, fluometuron; Cyan, cyanazine; NIS, non-ionic surfactant; PRE, preemergence; POST, postemergence; PD, postemergence directed.

[b]Pendimethalin applied PRE at 0.84 kg ai/ha. Fluometuron applied PRE at 1.3 kg ai/ha. Bromoxynil and pyrithiobac + NIS applied early POST at 0.56 kg

ai/ha and 0.071 kg ai/ha + 0.25 % v/v. Glyphosate applied early POST and late PD at 0.84 kg ai/ha. Fluometuron + MSMA applied early PD at 1.1 kg ai/ha + 1.8 kg ai/ha. Cyanazine + MSMA applied late PD at 0.9 kg ai/ha + 2.2 kg ai/ha.

[c]Seed prices are calculated as the increase in seed cost over the standard cotton variety. Seed prices were $2.20/kg, 3.30/kg, and 2.38/kg for Stoneville 474, Stoneville BXN 47, and Paymaster 1220RR. Seed cost increases were $1.10/kg for Stoneville BXN 47 and $0.18/kg for Paymaster 1220RR. A technology fee was assessed at $22.22/ha for Paymaster 1220RR.

[d]The cost of herbicide treatment per hectare were: bromoxynil, $35.65; cyanazine + MSMA, $30.20; fluometuron, $27.04; fluometuron + MSMA, $34.35; glyphosate, $19.09; pendimethalin, $15.51; and pyrithiobac + NIS, $66.17.

[e]Machinery and labor inputs calculations based on cotton production budgets for Tennessee (Gerloff 2000). Hand hoed plots were hoed 3 to4 times and labor averaged 172 hr/ha. Cost of labor is based on a salary rate of $6.75/hr.

Table 5. Treatment based expenses worksheet: Stoneville 474, pendimethalin + fluometuron fb hand hoeing.

Variable	Cost/ha	Hours Machine	Hours Labor
Seed	0.00	0.00	0.00
Tech Fee	0.00	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Hoeing	0.00	0.00	172.84
Total	42.55		172.84

Machine	Hour/ha	Interest costs per hour	Interest costs per hectare	Cost per hour Fixed	Cost per hour Variable	Cost per hectare Fixed	Cost per hectare Repair	Cost per hectare Fuel	Cost per hectare Variable
Sprayer	0.00	13.50	0.00	19.52	13.74	0.00	0.00	0.00	0.00

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	0.00	0.00
Machinery fuel	HA	1.00	0.00	0.00
Machinery depreciation	HA	1.00	0.00	0.00
Interest expense	HA	1.00	0.00	0.00
Labor	HR	172.84	6.75	1166.67
Seed, Chemicals, and fees				42.55
Total expenses of all treatment operations				1209.21

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 6. Treatment based expenses worksheet: Stoneville BXN 47, pendimethalin + fluometuron fb hand hoeing.

Variable	Cost/ha	Hours Machine	Hours Labor
Seed	14.78	0.00	0.00
Tech Fee	0.00	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Hoeing	0.00	0.00	172.84
Total	57.33		172.84

Machine	Hour/ha	Interest costs per hour	Interest costs per hectare	Cost per hour Fixed	Cost per hour Variable	Cost per hectare Fixed	Cost per hectare Repair	Cost per hectare Fuel	Cost per hectare Variable
Sprayer	0.00	13.50	0.00	19.52	13.74	0.00	0.00	0.00	0.00

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	0.00	0.00
Machinery fuel	HA	1.00	0.00	0.00
Machinery depreciation	HA	1.00	0.00	0.00
Interest expense	HA	1.00	0.00	0.00
Labor	HR	172.84	6.75	1166.67
Seed, Chemicals, and fees				57.33
Total expenses of all treatment operations				1223.99

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 7. Treatment based expenses worksheet: Paymaster 1220RR, pendimethalin + fluometuron fb hand hoeing.

Variable	Cost/ha	Hours Machine	Hours Labor
Seed	2.42	0.00	0.00
Tech Fee	22.22	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Hoeing	0.00	0.00	172.84
Total	67.19		172.84

Machine	Hour/ha	Interest costs per hour	Interest costs per hectare	Cost per hour Fixed	Cost per hour Variable	Cost per hectare Fixed	Cost per hectare Repair	Cost per hectare Fuel	Cost per hectare Variable
Sprayer	0.00	13.50	0.00	19.52	13.74	0.00	0.00	0.00	0.00

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	0.00	0.00
Machinery fuel	HA	1.00	0.00	0.00
Machinery depreciation	HA	1.00	0.00	0.00
Interest expense	HA	1.00	0.00	0.00
Labor	HR	172.84	6.75	1166.67
Seed, Chemicals, and fees				67.19
Total expenses of all treatment operations				1233.85

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 8. Treatment based expenses worksheet: Stoneville 474, pendimethalin + fluometuron fb fluometuron + MSMA fb cyanazine + MSMA.

		Hours	
Variable	Cost/ha	Machine	Labor
Seed	0.00	0.00	0.00
Tech Fee	0.00	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Fluometuron + MSMA	34.35	0.12	0.17
Cyanazine + MSMA	30.20	0.12	0.17
Total	107.10		0.34

		Interest costs		Cost per hour		Cost per hectare			
Machine	Hour/ha	per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				107.10
Total expenses of all treatment operations				120.57

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 9. Treament based expenses worksheet: Stoneville 474, pendimethalin + fluometuron fb pyrithiobac + NIS fb cyanazine + MSMA.

		Hours	
Variable	Cost/ha	Machine	Labor
Seed	0.00	0.00	0.00
Tech Fee	0.00	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron[a]	27.04	0.00	0.00
Pyrithibac + NIS	66.17	0.12	0.17
Cyanazine + MSMA	30.20	0.12	0.17
Total	138.92		0.34

		Interest costs		Cost per hour		Cost per hectare			
Machine	Hour/ha	per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				138.92
Total expenses of all treatment operations				152.39

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 10. Treatment based expenses worksheet: Stoneville BXN 47, pendimethalin + fluometuron fb bromoxynil fb cyanazine + MSMA.

Variable	Cost/ha	Hours	
		Machine	Labor
Seed	14.78	0.00	0.00
Tech Fee	0.00	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Bromoxynil	35.65	0.12	0.17
Cyanazine + MSMA	30.20	0.12	0.17
Total	123.18		0.34

Machine	Hour/ha	Interest costs		Cost per hour		Cost per hectare			
		per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				123.18
Total expenses of all treatment operations				136.65

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 11. Treatment based expenses worksheet: Paymaster 1220RR, pendimethalin + fluometuron fb glyphosate fb cyanazine + MSMA.

		Hours	
Variable	Cost/ha	Machine	Labor
Seed	2.42	0.00	0.00
Tech Fee	22.22	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Fluometuron	27.04	0.00	0.00
Glyphosate	19.09	0.12	0.17
Cyanazine + MSMA	30.20	0.12	0.17
Total	116.48		0.34

		Interest costs		Cost per hour		Cost per hectare			
Machine	Hour/ha	per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				116.48
Total expenses of all treatment operations				129.95

[a]Pendimethalin and fluometuron applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 12. Treatment based expenses worksheet: Paymaster 1220RR, pendimethalin fb glyphosate fb glyphosate.

		Hours	
Variable	Cost/ha	Machine	Labor
Seed	2.42	0.00	0.00
Tech Fee	22.22	0.00	0.00
Pendimethalin[a]	15.51	0.00	0.00
Glyphosate	19.09	0.12	0.17
Glyphosate	19.09	0.12	0.17
Total	78.33		0.34

		Interest costs		Cost per hour		Cost per hectare			
Machine	Hour/ha	per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				78.33
Total expenses of all treatment operations				91.80

[a]Pendimethalin applied PRE in combination with paraquat burndown treatment. No extra application made. Application is included in base expenses and would have been incurred with or without pendimethalin application.

Table 13. Treatment based expenses worksheet: Paymaster 1220RR, glyphosate fb cyanazine + MSMA

Variable	Cost/ha	Hours Machine	Hours Labor
Seed	2.42	0.00	0.00
Tech Fee	22.22	0.00	0.00
Glyphosate	19.09	0.12	0.17
Cyanazine + MSMA	30.20	0.12	0.17
Total	73.93		0.34

		Interest costs		Cost per hour		Cost per hectare			
Machine	Hour/ha	per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				73.93
Total expenses of all treatment operations				87.40

Table 14. Treatment based expenses worksheet: Paymaster 1220RR, glyphosate fb glyphosate.

Variable	Cost/ha	Hours	
		Machine	Labor
Seed	2.42	0.00	0.00
Tech Fee	22.22	0.00	0.00
Glyphosate	12.71	0.12	0.17
Glyphosate	19.09	0.12	0.17
Total	56.44		0.34

Machine	Hour/ha	Interest costs		Cost per hour		Cost per hectare			
		per hour	per hectare	Fixed	Variable	Fixed	Repair	Fuel	Variable
Sprayer	0.24	13.50	3.24	19.52	13.74	4.68	2.81	0.45	3.30

Item	Unit	Quantiy	Price	Amount
Machinery repair	HA	1.00	2.81	2.81
Machinery fuel	HA	1.00	0.45	0.45
Machinery depreciation	HA	1.00	4.68	4.68
Interest expense	HA	1.00	3.24	3.24
Labor	HR	0.34	6.75	2.30
Seed, Chemicals, and fees				56.44
Total expenses of all treatment operations				69.91

Table 15. Mid-season broadleaf and grass weed control following selected herbicide treatments in conventional and transgenic cotton cultivars.[a,b]

Cultivar	Herbicides[c] PRE	Herbicides[c] Early POST	Smooth pigweed	Common cocklebur	Entireleaf morningglory	Large crabgrass	Goosegrass	Red sprangletop
			%					
Stoneville 474	Pend/Fluo	Hand hoed	98 ab	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Fluo + MSMA	96 ab	92 b	98 a	97 ab	99 a	99 a
	Pend/Fluo	Pyrithiobac + NIS	99 a	95 ab	99 a	91 c	98 a	99 a
Stoneville BXN 47	Pend/Fluo	Hand hoed	99 a	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Bromoxynil	97 ab	99 a	99 a	94 bc	99 a	99 a
Paymaster 1220RR	Pend/Fluo	Hand hoed	99 a	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Glyphosate	98 ab	98 a	99 a	99 a	99 a	99 a
	Pend	Glyphosate	94 bc	93 b	96 a	99 a	99 a	99 a
	None	Glyphosate	91 c	94 ab	97 a	96 ab	96 a	67 b

[a]Evaluations taken 4 to 6 wk after planting (2 wk after early postemergence (POST) herbicide application). Data pooled over test years 1998 and 1999. Means within a species followed by the same letter are not different according to Fisher's protected LSD test at P = 0.05.

[b]Abbreviations: Pend, pendimethalin; Fluo, fluometuron; Cyan, cyanazine; NIS, non-ionic surfactant; PRE, preemergence; PD, postemergence directed.

[c]Pendimethalin + fluometuron applied PRE at 0.84 kg ai/ha + 1.3 kg ai/ha. Bromoxynil and pyrithiobac + NIS applied early POST at 0.56 kg ai/ha and

0.071 kg ai/ha + 0.25 % v/v. Glyphosate applied early and late PD at 0.84 kg ai/ha, fluometuron + MSMA applied early PD at 1.1 kg ai/ha + 1.8 kg ai/ha. Cyanazine + MSMA applied late PD at 0.9 kg ai/ha + 2.2 kg ai/ha.

Table 16. Late-season broadleaf and grass weed control following selected herbicide treatments in conventional and transgenic cotton cultivars.[a,b]

	Herbicides[c]							
Cultivar	PRE	Early POST	Late POST	Smooth pigweed	Common cocklebur	Large crabgrass	Goosegrass[d]	Red sprangletop[d]
				%				
Stoneville 474	Pend/Fluo	Hand hoed	Hand hoed	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Fluo + MSMA	Cyan + MSMA	97 a	98 a	97 ab	99 a	99 a
	Pend/Fluo	Pyrithiobac + NIS	Cyan + MSMA	99 a	99 a	93 c	99 a	93 a
Stoneville BXN 47	Pend/Fluo	Hand hoed	Hand hoed	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Bromoxynil	Cyan + MSMA	96 a	99 a	97 ab	99 a	93 a
Paymaster 1220RR	Pend/Fluo	Hand hoed	Hand hoed	99 a	99 a	99 a	99 a	99 a
	Pend/Fluo	Glyphosate	Cyan + MSMA	98 a	99 a	98 a	97 a	99 a
	Pend	Glyphosate	Glyphosate	94 a	97 a	98 a	99 a	98 a
	None	Glyphosate	Cyan + MSMA	96 a	99 a	95 bc	98 a	33 b
	None	Glyphosate	Glyphosate	90 a	91 a	97 ab	82 b	80 a

[a]Evaluations taken 8 to 10 wk after planting (2 wk after late postemergence (POST) herbicide application). Data pooled over test years 1998 and 1999 for smooth pigweed, common cocklebur, and large crabgrass. Due to dry conditions, late season goosegrass and red sprangletop control is based on 1998 data only. Means within a species followed by the same letter are not different according to Fisher's protected LSD test at P = 0.05.

[b]Abbreviations: Pend, pendimethalin; Fluo, fluometuron; Cyan, cyanazine; NIS, non-ionic surfactant; PRE, preemergence; PD, postemergence directed.

[c]Pendimethalin + fluometuron applied PRE at 0.84 kg ai/ha + 1.3 kg ai/ha. Bromoxynil and pyrithiobac + NIS applied early POST at 0.56 kg ai/ha and 0.071 kg ai/ha + 0.25 % v/v. Roundup ultra applied early and late PD at 0.84 kg ai/ha, fluometuron + MSMA applied early PD at 1.1 kg ai/ha + 1.8 kg ai/ha. Cyanazine + MSMA applied late PD at 0.9 kg ai/ha + 2.2 kg ai/ha.

Table 17. Cotton yield and net returns in no-tillage cropping systems utilizing standard and transgenic cotton cultivars.[a,b]

	Herbicides[c]			Lint yield			Net returns		
Cultivar	PRE	Early POST	Late POST	1998	1999	Mean	1998	1999	Mean
					kg/ha			$/ha	
Stoneville 474	Pend/Fluo	Hand hoed	Hand hoed	1299 a	836 a	1067 ab	-116.60 c	-1060.71 d	-588.66 e
	Pend/Fluo	Fluo + MSMA	Cyan + MSMA	1196 a	768 a	982 bc	785.80 ab	-23.41 bc	381.21 bcd
	Pend/Fluo	Pyrithiobac + NIS	Cyan + MSMA	1172 a	818 a	995 bc	639.60 b	-74.80 c	282.39 d
Stoneville BXN 47	Pend/Fluo	Hand hoed	Hand hoed	1243 a	848 a	1045 abc	-144.50 c	-1001.10 d	-572.81 e
	Pend/Fluo	Bromoxynil	Cyan + MSMA	1142 a	750 a	946 c	595.90 b	-41.04 bc	277.45 d
Paymaster 1220RR	Pend/Fluo	Hand hoed	Hand hoed	1364 a	911 a	1138 a	93.30 c	-976.27 d	-441.49 e
	Pend/Fluo	Glyphosate	Cyan + MSMA	1270 a	883 a	1076 ab	1053.20 a	57.81 abc	555.48 ab
	Pend	Glyphosate	Glyphosate	1261 a	891 a	1076 ab	1048.00 a	114.05 ab	581.03 a
	None	Glyphosate	Cyan + MSMA	1039 a	832 a	935 c	645.60 b	43.93 abc	344.76 cd
	None	Glyphosate	Glyphosate	1123 a	914 a	1019 bc	852.10 ab	188.26 a	520.18 abc

[a]Cotton yields are based on lint yields taken by twice over harvesting. Seed yields are assumed to be exchanged for ginning fees. Ginning fees and seed yields are not included in net returns calculations. Means within a column followed by the same letter are not different according to Fisher's protected LSD at P = 0.05.

[b]Abbreviations: Pend, pendimethalin; Fluo, fluometuron; Cyan, cyanazine; NIS, non-ionic surfactant; PRE, preemergence; POST, postemergence; PD, postemergence directed.

[c]Pendimethalin + fluometuron applied PRE at 0.84 kg ai/ha + 1.3 kg ai/ha. Bromoxynil and pyrithiobac + NIS applied early POST at 0.56 kg ai/ha and 0.071 kg ai/ha + 0.25 % v/v. Glyphosate applied early and late PD at 0.84 kg ai/ha. Fluometuron + MSMA applied early PD at 1.1 kg ai/ha + 1.8 kg ai/ha. Cyanazine + MSMA applied late PD at 0.9 kg ai/ha + 2.2 kg ai/ha.

Table 18. Stoneville 474, Stoneville BXN 47, and Paymaster 1220RR fiber quality characteristics as measured by high volume instrumentation (HVI) classing, pooled over treatments.[a]

	Fiber quality characteristic					
	Length		Fineness		Strength	
Cultivar	1998	1999	1998	1999	1998	1999
	mm		micronaire		g/tex	
Stoneville 474	27.91 b	26.92 b	43 a	46 b	29.60 b	30.40 b
Stoneville BXN 47	28.48 a	27.19 ab	41 b	46 b	29.98 b	30.51 b
Paymaster 1220RR	28.73 a	27.54 a	41 b	49 a	30.66 a	32.93 a

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

Table 19. Price premiums and discounts received for Stoneville 474, Stoneville BXN 47, and Paymaster 1220RR.[a]

			Fiber quality characteristic premiums and discounts					
Year	Cultivar	Base price[b]	Grade[c]	Micronaire	Strength	Extraneous matter	Total discount	Final price
					$/kg			
1998	Stoneville 474	1.49	-0.130 c	0.000 a	0.0040 a	-0.014 a	-0.14	1.35
	Stoneville BXN 47	1.49	-0.074 b	0.000 a	0.0043 a	-0.055 a	-0.12	1.37
	Paymaster 1220RR	1.49	0.007 a	0.000 a	0.0052 a	-0.031 a	-0.02	1.47
1999	Stoneville 474	1.12	-0.055 b	0.000 a	0.0031 b	-0.029 a	-0.08	1.04
	Stoneville BXN 47	1.12	-0.011 a	0.000 a	0.0040 ab	0.000 a	-0.01	1.11
	Paymaster 1220RR	1.12	0.003 a	-0.059 b	0.0044 a	-0.009 a	-0.06	1.06

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

[b]The base price is that which was listed in the USDA-AMS Cotton price statistics bulletin for October of the respective year. Discounts based on quality characteristics are also calculated utilizing the same bulletin for the respective years.

[c]Grade discount is a combination of color grade, leaf grade, and staple.

Table 20. Crop rotation restrictions of herbicides used in cotton[a,b].

Herbicide		Rotational Crop					
Common name	Trade name	Corn	Cotton	Soybeans	Grain sorghum	Tobacco	Wheat
Bromoxynil	Buctril	30d	30d	30d	30d	30d	30d
Clethodim	Select	#	#	#	#	#	#
Clomazone	Command	9 m	w/ safener	#	9 m	#	12 m
Cyanazine	Bladex/Cypro	#	Spring	Spring	30 d	Spring	Fall
Diuron	Direx/Karmex	Spring	Spring	12 m	Spring	12 m	12 m
Fluazifop-P	Fusilade	60 d	#	#	60 d	#	60 d
Fluazifop-P + Fenoxaprop	Fusion	60 d	#	#	60 d	#	60 d
Fluometuron	Cotoran/Meturon	6 m	#	6 m	6 m	6 m	6 m
Glyphosate	Roundup Ultra	#	#	#	#	30 d	#
Lactofen	Cobra	#	#	#	#	#	#
Metolachlor + Benoxacor	Dual II/Dual II Magnum	#	#	#	#	Spring	4.5 m
MSMA/DSMA	Various	#	#	#	#	#	#
Norflurazon	Zorial	16 m	#	45 d	16 m	16 m	16 m
Oxyfluorfen	Goal	10 m	#	#	10 m	#	10 m
Pendimethalin	Prowl	#	#	#	FY	#	FY
Prometryn	Caparol/Cotton Pro	#	#	#	#	#	cover only
Pyrithiobac	Staple	9 m	#	10 m	DNP	10 m	4 m
Quizalofop-P	Assure II	120 d	#[c]	#	120 d	120 d	120 d
Sethoxydim	Poast/Poast Plus	#	#	#	#	#	#
Trifluralin	Treflan	#	#	#	12 m	#	#

[a]Refer to label for full crop rotation restriction guidelines.

[b]Abbreviations: d, days; m, months; FY, following year; DNP, do not plant the following year.

[c]Symbol: #, no restriction or no information on label.

Table 21. Simple cost analysis budget for weed management programs in cotton[a].

	Herbicide				Sample Weed Management Programs			Your Weed Management Program
	Name				Conventional	BXN	RR	
Application	Common	Trade	Rate[b]	Cost[c]	Varieties	Varieties	Varieties	
			lb ai/A	$/A				
PPI/PRE	pendimethalin	Prowl	0.5-1.5	4.02-12.06	6.70	6.70	6.70	
	trifluralin	Treflan	0.5-1.0	3.74-7.48	x	x	x	
	clomazone	Command	0.5	9.80	x	x	x	
	fluometuron	Cotoran/Meturon	1.0-2.0	9.13-18.25	13.70	13.70	13.70	
	metolachlor	Dual II	1.46-1.95	12.43-16.57	x	x	x	
	metolachlor	Dual II Magnum	0.63-1.27	8.84-17.82	x	x	x	
	norflurazon	Zorial	1.0-2.0	18.44-36.88	x	x	x	
POST OT	quizalofop-P	Assure II	0.034-0.069	5.09-10.18	x	x	x	
	bromoxynil[d]	Buctril	0.38-0.5	10.83-14.44	x	10.83	x	
	fluazifop-P	Fusilade	0.094-0.188	6.02-12.05	x	x	x	
	fluazifop-P + fenoxaprop	Fusion	0.16-0.24	8.78-13.17	x	x	x	
	sethoxydim	Poast	0.19	8.34	x	x	x	
	sethoxydim	Poast Plus	0.19	9.41	x	x	x	
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	7.73	
	clethodim	Select	0.094-0.125	8.26-11.02	x	11.02	x	
	pyrithiobac	Staple	0.0625	26.64	x	x	x	
EPD	fluometuron	Cotoran/Meturon	1.0	9.13	9.13	x	x	
	MSMA	Various	2.0	5.99	5.99	x	x	
	DSMA	Various	3.6	7.50	x	x	x	
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	x	
LPD	cyanazine	Bladex/Cypro	0.6-1.0	4.68-7.80	7.80	7.80	x	
	lactofen	Cobra	0.2	12.21	x	x	x	
	oxyfluorfen	Goal	0.25-0.5	13.38-26.75	x	x	x	

	prometryn	Caporal/Cotton Pro	0.5-0.65	3.85-5.01	x	x	x	______
	diuron	Direx/Karmex	0.2-0.4	1.05-2.10	x	x	x	______
	MSMA	Various	2.0	5.99	5.99	5.99	x	______
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	7.73	______
Misc.	Additional Seed Cost	Roundup Ready		0.96	x	x	0.96	______
		BXN		6.00	x	6.00	x	______
	Technology Fee	Roundup Ready		9.00	x	x	9.00	______
Total Herbicide Cost, Seed Cost, and Technology Fees					49.31	62.04	45.82	______

[a]Abbreviations: BXN, bromoxynil resistant; RR, Roundup Ready; PPI, preplant incorporated; PRE, preemergence; POST OT, postemergence over-the-top; EPD, early postemergence directed; LPD, late postemergence directed.

[b]Herbicide rates vary depending on soil type and application timing. Consult herbicide labels for specific rate information.

[c]Herbicide costs vary depending of rate used. Herbicide costs are likely to change from year to year and region to region.

[d]For use on BXN varieties only.

[e]For use on Roundup Ready varieties only.

APPENDIX C

VARIETY DECISION ASSITANCE MODEL

While many producers would prefer to plant their entire acreage to Roundup Ready cotton, it is generally not recommended to plant an entire cotton crop to one variety. In addition, seed supply limitations commonly occur and limit the acreage a grower may plant to a particular variety. Therefore, this decision aid was created to aid producers in selecting field areas in which standard or BXN cotton varieties may be more beneficial.

PART I. Rotational crops and field history

1. Do you intend to plant wheat or other small grain crops in this field after harvesting this years cotton crop?

   YES-go to #2 NO-go to #4

2. Do you intend to harvest the wheat or other small grain crop to be planted this fall for grain or hay?

   YES-go to #3 NO-go to #4

3. You are still eligible to select standard, BXN, or Roundup Ready cotton varieties. However, your intent to harvest wheat or other small grain crops eliminates your ability to use certain herbicides and makes the timing of application of other herbicides critical. Please note the restrictions outlined in Table 1.

   Proceed to #4

4. Have you applied more than one of the following herbicides in this field during the past two years, have you made multiple applications of one of these herbicides in the past year, or have you applied one of the following herbicides in each of the past two years? NOTE: Rotation restrictions for some of the herbicides listed below do not permit cotton to be planted the following year. Consult herbicide labels for rotation restrictions.

Accent	Accent Gold	Ally	Backdraft
Basis	Basis Gold	Beacon	Canopy
Canopy XL	Broadstrike SF + Dual	Broadstrike SF + Treflan	Celebrity B+G
Classic	Contour	Detail	Exceed
Expert	Extreme	FirstRate	Frontrow
Gemini	Harmony Extra	Hornet	Peak
Permit	Pinnacle	Pursuit	Pursuit Plus
Python	Raptor	Resolve	Scepter
Scepter-OT	Scorpion III	Squadron	Staple
Staple Plus	Steel	Strongarm	Synchrony
TriScept			

   YES-go to #5 NO-go to #6

5. It is generally not recommended that herbicides with the same mode of action not be used on a field in more than two consecutive years due to selection pressures and the possibility of resistance development. If you answered YES to question 4 do not use Staple for weed control in this field.

   Proceed to #6

6. Have you experienced failure to control common cocklebur or pigweeds following applications of any of the herbicides listed in question 4, or does this field have confirmed ALS resistant common cocklebur or Palmer amaranth?

   Yes-go to #7 NO-go to #8a

7. Failure to control common cocklebur or pigweeds with ALS inhibiting herbicides (those listed in question 4) may indicate the presence of ALS resistant biotypes of these weeds. If resistant weeds are present adequate control will not be achieved with Staple. Do not use Staple for control of these weeds.

Proceed to #8a

8a. Were Roundup Ready soybeans or Roundup Ready cotton planted in this field during the previous growing season?

YES-go to #9a NO-go to #8b

8b. Was BXN cotton planted in this field during the previous growing season?

YES-go to #9b NO-go to #16

9a. It is generally not recommended that the same herbicides be used on a field in consecutive years due to selection pressures and the possibility of resistance development. However, certain situations may benefit from the use of Roundup Ready cotton varieties. Do still wish to evaluate Roundup Ready cotton as an option?

YES-go to #16 NO-go to #10

9b. It is generally not recommended that the same herbicides be used on a field in consecutive years due to selection pressures and the possibility of resistance development. However, certain situations may benefit from the use of BXN cotton varieties. Do still wish to evaluate BXN cotton as an option?

YES-go to #16 NO-go to #13

PART II. Weed management

10. Are pigweeds (smooth or Palmer) a major problem in this field?

NO-go to #11 YES-go to #25

11. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #12 YES-go to #27

12. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #28 YES-go to #29

13. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #14 YES-go to #25

14. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #15 YES-go to #30

15. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #34 YES-go to #30

16. Are pigweeds (smooth or Palmer) a major problem in this field?

NO-go to #17 YES-go to #20

17. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #18 YES-go to #23

18. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #19 YES-go to #30

19. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #31 YES-go to #32

20. Are hemp sesbania (coffeeweed), morningglories, Florida pusley or spreading dayflower major problems in this field?

NO-go to #21 YES-go to #25

21. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #22 YES-go to #30

22. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #34 YES-go to #30

23. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #24 YES-go to #27

24. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #28 YES-go to #29

25. Are sicklepod, nutsedge, or spotted spurge a major problem in this field?

NO-go to #26 YES-go to #27

26. Are ragweed, lambsquarters, or tropic croton a major problem in this field?

NO-go to #33 YES-go to #27

27. The weed pressures you have described are not likely to be effectively controlled by Staple, Buctril or Roundup Ultra (or you have chosen not to evaluate either Roundup Ready or BXN programs). Consider using a high yielding standard variety with a sound weed management system that does not include Staple. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

28. Because of the weed pressure you have described, Roundup Ready varieties should not be used in this field (or you have chosen not to evaluate Roundup Ready programs). Select a high yielding standard or BXN variety for this field. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table

2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

29. The weed pressures you have described are not likely to be effectively controlled by Staple or Roundup Ultra (or you have chosen not to evaluate Roundup Ready programs). Consider using a high yielding standard or BXN variety with a sound weed management system that does not include Staple. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

30. Buctril will not provide good control of pigweeds (or you have chosen not to evaluate BXN programs). Buctril and Staple typically will not provide good control of sicklepod, nutsedge, or spotted spurge. Staple will not adequately control common lambsquarters, common ragweed, or tropic croton. Lack of control will often promote additional herbicide applications and increase production costs. Do not plant this field to BXN cotton varieties. Select a high yielding standard or Roundup Ready variety for this field. Do not use Staple for weed management in this field. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

31. Because of the weed pressure you have described this field may be planted to standard, BXN, or Roundup Ready varieties. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

32. Staple herbicide typically will not provide good control of the weeds present in this field. Select a high yielding standard, BXN, or Roundup Ready variety for this field. Do not use Staple in the weed management program. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

33. The weed pressures you have described are not likely to be effectively controlled by Buctril or Roundup Ultra (or you have chosen not to evaluate either Roundup Ready or BXN programs). Consider using a high yielding standard variety with a sound weed management system. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

34. Buctril typically will not provide good control of pigweeds (or you have chosen not to evaluate BXN programs). Lack of control will often promote additional herbicide applications and increase production costs. Do not plant this field to BXN cotton varieties. Select a high yielding standard or Roundup Ready variety for this field. Do not use Staple if you answered YES to questions 4 or 6. Refer to Table 2 for the rotational restrictions for selected herbicides. Please use the attached budget sheet to evaluate the cost of different weed control options.

Table 1. Crop rotation restrictions of herbicides used in cotton[a,b].

Herbicide		Rotational Crop					
Common name	Trade name	Corn	Cotton	Soybeans	Grain sorghum	Tobacco	Wheat
Bromoxynil	Buctril	30d	30d	30d	30d	30d	30d
Clethodim	Select	#	#	#	#	#	#
Clomazone	Command	9 m	w/ safener	#	9 m	#	12 m
Cyanazine	Bladex/Cypro	#	Spring	Spring	30 d	Spring	Fall
Diuron	Direx/Karmex	Spring	Spring	12 m	Spring	12 m	12 m
Fluazifop-P	Fusilade	60 d	#	#	60 d	#	60 d
Fluazifop-P + Fenoxaprop	Fusion	60 d	#	#	60 d	#	60 d
Fluometuron	Cotoran/Meturon	6 m	#	6 m	6 m	6 m	6 m
Glyphosate	Roundup Ultra	#	#	#	#	30 d	#
Lactofen	Cobra	#	#	#	#	#	#
Metolachlor + Benoxacor	Dual II/Dual II Magnum	#	#	#	#	Spring	4.5 m
MSMA/DSMA	Various	#	#	#	#	#	#
Norflurazon	Zorial	16 m	#	45 d	16 m	16 m	16 m
Oxyfluorfen	Goal	10 m	#	#	10 m	#	10 m
Pendimethalin	Prowl	#	#	#	FY	#	FY
Prometryn	Caparol/Cotton Pro	#	#	#	#	#	cover only
Pyrithiobac	Staple	9 m	#	10 m	DNP	10 m	4 m
Quizalofop-P	Assure II	120 d	#[c]	#	120 d	120 d	120 d
Sethoxydim	Poast/Poast Plus	#	#	#	#	#	#
Trifluralin	Treflan	#	#	#	12 m	#	#

[a]Refer to label for full crop rotation restriction guidelines.

[b]Abbreviations: d, days; m, months; FY, following year; DNP, do not plant the following year.

[c]Symbol: #, no restriction or no information on label.

Table 2. Simple cost analysis budget for weed management programs in cotton[a].

Application	Herbicide: Name: Common	Herbicide: Name: Trade	Rate[b]	Cost[c]	Sample Weed Management Programs: Conventional Varieties	BXN Varieties	RR Varieties	Your Weed Management Program
			lb ai/A	$/A				
PPI/PRE	pendimethalin	Prowl	0.5-1.5	4.02-12.06	6.70	6.70	6.70	______
	trifluralin	Treflan	0.5-1.0	3.74-7.48	x	x	x	______
	clomazone	Command	0.5	9.80	x	x	x	______
	fluometuron	Cotoran/Meturon	1.0-2.0	9.13-18.25	13.70	13.70	13.70	______
	metolachlor	Dual II	1.46-1.95	12.43-16.57	x	x	x	______
	metolachlor	Dual II Magnum	0.63-1.27	8.84-17.82	x	x	x	______
	norflurazon	Zorial	1.0-2.0	18.44-36.88	x	x	x	______
POST OT	quizalofop-P	Assure II	0.034-0.069	5.09-10.18	x	x	x	______
	bromoxynil[d]	Buctril	0.38-0.5	10.83-14.44	x	10.83	x	______
	fluazifop-P	Fusilade	0.094-0.188	6.02-12.05	x	x	x	______
	fluazifop-P + fenoxaprop	Fusion	0.16-0.24	8.78-13.17	x	x	x	______
	sethoxydim	Poast	0.19	8.34	x	x	x	______
	sethoxydim	Poast Plus	0.19	9.41	x	x	x	______
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	7.73	______
	clethodim	Select	0.094-0.125	8.26-11.02	x	11.02	x	______
	pyrithiobac	Staple	0.0625	26.64	x	x	x	______
EPD	fluometuron	Cotoran/Meturon	1.0	9.13	9.13	x	x	______
	MSMA	Various	2.0	5.99	5.99	x	x	______
	DSMA	Various	3.6	7.50	x	x	x	______
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	x	______
LPD	cyanazine	Bladex/Cypro	0.6-1.0	4.68-7.80	7.80	7.80	x	______
	lactofen	Cobra	0.2	12.21	x	x	x	______
	oxyfluorfen	Goal	0.25-0.5	13.38-26.75	x	x	x	______
	prometryn	Caporal/Cotton Pro	0.5-0.65	3.85-5.01	x	x	x	______
	diuron	Direx/Karmex	0.2-0.4	1.05-2.10	x	x	x	______
	MSMA	Various	2.0	5.99	5.99	5.99	x	______
	glyphosate[e]	Roundup Ultra	0.75-1.0	7.73-10.30	x	x	7.73	______
Misc.	Additional Seed Cost	Roundup Ready		0.96	x	x	0.96	______
		BXN		6.00	x	6.00	x	______
	Technology Fee	Roundup Ready		9.00	x	x	9.00	______
Total Herbicide Cost, Seed Cost, and Technology Fees					49.31	62.04	45.82	______

[a]Abbreviations: BXN, bromoxynil resistant; RR, Roundup Ready; PPI, preplant incorporated; PRE, preemergence; POST OT, postemergence over-the-top; EPD, early postemergence directed; LPD, late postemergence directed.

[b]Herbicide rates vary depending on soil type and application timing. Consult herbicide labels for specific rate information.

[c]Herbicide costs vary depending of rate used. Herbicide costs are likely to change from year to year and region to region.

[d]For use on BXN varieties only.

[e]For use on Roundup Ready varieties only.

APPENDIX D

STATISTICAL MODELS

Sample statistical program for computing cotton weed control efficacy.

```
Title 'Cotton weed control efficacy statistical analysis';
Data a;
Input year rep trmt var1 var2 var3 ...;
Cards;
/**************************************************************************/
Insert data set here
/**************************************************************************/
;
data b; set a;
proc sort; by year rep trmt;
proc glm; class year rep trmt;
model var1 var2 var3 ... = year rep(year) trmt year*trmt;
test h=trmt e=year*trmt;
contrast 'trmt 7 v 9' trmt 0 0 0 0 0 0 1 0 -1 0;
contrast 'trmt 8 v 10' trmt 0 0 0 0 0 0 0 1 0 -1;
means trmt/lsd;
run;
```

Sample statistical program for computing cotton yield, price, and returns.

```
title 'Cotton yield, price and net return statistical analysis';
title2 'Lint cotton only';
title3 'Seed exchanged for ginning';
title4 'Tech fee included in prod costs';
data a;
input year rep trt lintyld basprice color leaf staple gradedis micronr strength exmatter
    costprod costtrt;
/*costprod and costtrt are in $/hectare, all other data are english units*/
cards;
/*************************************************************************/
Insert data set here
/*************************************************************************/
;
data b; set a;
mike= (micronr*10);
/***************************1997 quality discounts*************************/
if year = '97' and mike >= 25 and mike <27 then mikedis = -0.1195;
else if year = '97' and mike >=27 and mike <30 then mikedis = -.0870;
else if year = '97' and mike >=30 and mike <33 then mikedis = -.0450;
else if year = '97' and mike >=33 and mike <35 then mikedis = -.0220;
else if year = '97' and mike >=35 and mike <37 then mikedis = 0;
```

```
else if year = '97' and mike >=37 and mike <43 then mikedis = 0;

else if year = '97' and mike >=43 and mike <50 then mikedis = 0;

else if year = '97' and mike >=50 and mike <53 then mikedis = -.0190;

else if year = '97' and mike >=53 then mikedis = -.0475;

if year = '97' and strength >= 20.5 and strength <21.5 then strdis = -.0100;

else if year = '97' and strength >=21.5 and strength < 22.5 then strdis = -.0075;

else if year = '97' and strength >=22.5 and strength < 23.5 then strdis = 0;

else if year = '97' and strength >=23.5 and strength < 25.5 then strdis = 0;

else if year = '97' and strength >=25.5 and strength < 26.5 then strdis = 0;

else if year = '97' and strength >=26.5 and strength < 27.5 then strdis = 0;

else if year = '97' and strength >=27.5 and strength < 28.5 then strdis = 0;

else if year = '97' and strength >=28.5 and strength < 29.5 then strdis = .0015;

else if year = '97' and strength >=29.5 and strength < 30.5 then strdis = .0020;

else if year = '97' and strength >=30.5 then strdis = .0025;

if year = '97' and exmatter='11' then exdis = -.0450;

else if year = '97' and exmatter = '21' then exdis = -.0800;

else if year = '97' and exmatter = '0' then exdis = 0;

/***************************1998 quality discounts*************************/

if year = '98' and mike >= 25 and mike <27 then mikedis = -0.1270;

else if year = '98' and mike >=27 and mike <30 then mikedis = -.0930;

else if year = '98' and mike >=30 and mike <33 then mikedis = -.0475;

else if year = '98' and mike >=33 and mike <35 then mikedis = -.0235;

else if year = '98' and mike >=35 and mike <37 then mikedis = 0;
```

```
else if year = '98' and mike >=37 and mike <43 then mikedis = 0;

else if year = '98' and mike >=43 and mike <50 then mikedis = 0;

else if year = '98' and mike >=50 and mike <53 then mikedis = -.0310;

else if year = '98' and mike >=53 then mikedis = -.0515;

if year = '98' and strength >= 20.5 and strength < 21.5 then strdis = -.0100;

else if year = '98' and strength >=21.5 and strength < 22.5 then strdis = -.0075;

else if year = '98' and strength >=22.5 and strength < 23.5 then strdis = 0;

else if year = '98' and strength >=23.5 and strength < 25.5 then strdis = 0;

else if year = '98' and strength >=25.5 and strength < 26.5 then strdis = 0;

else if year = '98' and strength >=26.5 and strength < 27.5 then strdis = 0;

else if year = '98' and strength >=27.5 and strength < 28.5 then strdis = 0;

else if year = '98' and strength >=28.5 and strength < 29.5 then strdis = .0015;

else if year = '98' and strength >=29.5 and strength < 30.5 then strdis = .0020;

else if year = '98' and strength >=30.5 then strdis = .0025;

if year = '98' and exmatter='11' then exdis = -.0435;

else if year = '98' and exmatter = '21' then exdis = -.0785;

else if year = '98' and exmatter = '0' then exdis = 0;

/***************************1999 quality discounts**************************/

if year = '99' and mike >= 25 and mike <27 then mikedis = -0.124;

else if year = '99' and mike >=27 and mike <30 then mikedis = -.0885;

else if year = '99' and mike >=30 and mike <33 then mikedis = -.0455;

else if year = '99' and mike >=33 and mike <35 then mikedis = -.0225;

else if year = '99' and mike >=35 and mike <37 then mikedis = 0;
```

```
else if year = '99' and mike >=37 and mike <43 then mikedis = 0;
else if year = '99' and mike >=43 and mike <50 then mikedis = 0;
else if year = '99' and mike >=50 and mike <53 then mikedis = -.0450;
else if year = '99' and mike >=53 then mikedis = -.0650;
if year = '99' and strength >= 20.5 and strength <21.5 then strdis = -.0100;
else if year = '99' and strength >=21.5 and strength < 22.5 then strdis = -.0075;
else if year = '99' and strength >=22.5 and strength < 23.5 then strdis = 0;
else if year = '99' and strength >=23.5 and strength < 25.5 then strdis = 0;
else if year = '99' and strength >=25.5 and strength < 26.5 then strdis = 0;
else if year = '99' and strength >=26.5 and strength < 27.5 then strdis = 0;
else if year = '99' and strength >=27.5 and strength < 28.5 then strdis = 0;
else if year = '99' and strength >=28.5 and strength < 29.5 then strdis = 0;
else if year = '99' and strength >=29.5 and strength < 30.5 then strdis = .0015;
else if year = '99' and strength >=30.5 then strdis = .0020;
if year = '99' and exmatter='11' then exdis = -.0435;
else if year = '99' and exmatter = '21' then exdis = -.0785;
else if year = '99' and exmatter = '0' then exdis = 0;
/***********************************************************************/
discLB = gradedis + mikedis + strdis + exdis;
disprice = basprice + totdis;
grossA = (lintyld*disprice);
KGlint = (lintyld*1.12);
discKG = (discLB/.454);
```

```
netHA= (grossA/0.405)-(costprod + costtrt);

proc sort; by year rep trt;

proc glm; class year rep trt;

model KGlint disKG netHA  = year rep(year) trt year*trt;

test h=trt e=year*trt;

contrast 'STD vs GT' KGlint 5 0 –3 5 5 0 –3 –3 –3 –3;

contrast 'STD vs BR' KGlint 2 –3 0 2 2 –3 0 0 0 0;

contrast 'GT vs BR' KGlint 0 5 –2 0 0 5 –2 –2 –2 –2;

contrast 'trmt 7 vs 9' KGlint 0 0 0 0 0 0 1 0 –1 0;

contrast 'trmt 8 vs 10' KGlint 0 0 0 0 0 0 0 1 0 –1;

contrast 'STD vs GT' disKG 5 0 –3 5 5 0 –3 –3 –3 –3;

contrast 'STD vs BR' disKG 2 –3 0 2 2 –3 0 0 0 0;

contrast 'GT vs BR' disKG 0 5 –2 0 0 5 –2 –2 –2 –2;

contrast 'trmt 7 vs 9' disKG 0 0 0 0 0 0 1 0 –1 0;

contrast 'trmt 8 vs 10' disKG 0 0 0 0 0 0 0 1 0 –1;

contrast 'STD vs GT' netKG 5 0 –3 5 5 0 –3 –3 –3 –3;

contrast 'STD vs BR' netKG 2 –3 0 2 2 –3 0 0 0 0;

contrast 'GT vs BR' netKG 0 5 –2 0 0 5 –2 –2 –2 –2;

contrast 'trmt 7 vs 9' netKG 0 0 0 0 0 0 1 0 –1 0;

contrast 'trmt 8 vs 10' netKG 0 0 0 0 0 0 0 1 0 –1;

means trt/lsd;

run;
```

VITA

Jimmy Summerlin was born on December 8, 1973 in Bethel, North Carolina. He was raised near Tarboro, North Carolina and graduated from SouthWest Edgecombe High School in 1991. Jimmy received his B.S. in Agronomy from N.C. State in 1995 and completed his M.S. in Crop Science at N.C. State under the direction of Dr. Harold Coble in 1998. While at N.C. State, Jimmy was active in several student organizations including the Agronomy Club (Treasurer), Alpha Zeta (Chronicler), and FarmHouse Fraternity. Upon completion of his M.S., Jimmy began the Ph.D. program in Plant and Soil Sciences at the University of Tennessee under the direction of Dr. Tom Mueller. In May 1998, the department employed Jimmy as a Research Associate in vegetable production under the supervision of Dr. David Coffey. While at Tennessee, he has presented research data to local and regional audiences and won first place in the SWSS and TAPA graduate student poster contests. Jimmy has been active in oral, written, and web-based extension activities. He is the author or co-author of several abstracts published in the proceedings of professional societies, several research reports, one refereed journal article, and recently completed the web version of the University of Tennessee Weed Control Manual. Jimmy has been inducted into Gamma Sigma Delta and Phi Kappa Phi and in the spring of 2000 he was awarded the Outstanding Ph.D. Student Award by the Tennessee Agricultural Production Association and the Gerald O. Mott Graduate Student Award in Crop Science by the Crop Science Society of America. Jimmy is happily married to the former Jennifer Wortman and completed his Ph.D. in August, 2000.