KIMBERLY HUTCHISON LOHMEYER
Use of precision insecticide placement and cultural control methods to reduce chemical requirements for insect management in agricultural systems
(Under the Direction of JOHN ALL)

Field tests were conducted between 1999 and 2001 to evaluate the efficacy of precision placement of at planting insecticides and cultural control methods for the management of soil pests of corn and tobacco thrips in cotton in comparison to standard in-furrow rates. Precision placed insecticides were placed alongside the seed at planting with no insecticide along the furrow between the seeds. Efficacy evaluations in cotton showed that precision placement rates of aldicarb were as effective in reducing tobacco thrips, *Frankliniella fusca* (Hinds), populations as the standard in-furrow rate, but at significantly reduced amounts of product per ha. Analysis of treated cotton plants showed that significantly higher amounts of aldicarb and aldicarb metabolites were found in precision placement treated plants. The use of precision placed aldicarb in combination with conservation tillage was found to significantly reduce thrips populations. Ultra-narrow row planting practices did not appear to significantly enhance thrips infestations. Tests in field corn evaluated the efficacy of precision placed and in-furrow rates of soil insecticides for the management of the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), the southern corn billbug, *Sphenophorus callosus* (Olivier), the corn wireworm, *Melantotus communis* (Gyllenhal), and the sugarcane beetle *Eutheola rugiceps* (LeConte). There was indication that precision placement of soil insecticides provided superior control in mixed infestations of southern corn billbug and lesser cornstalk borer at reduced insecticide rates when compared to conventional in-furrow applications. Mean percent damage due to southern corn billbug was significantly higher and yields were significantly decreased in conservation tillage as compared with conventional tillage. Southern corn billbug damage was increased in conservation tillage but lesser cornstalk borer infestations were reduced when compared to conventionally tilled corn.

INDEX WORDS: Cotton, Corn, Conservation Tillage, Aldicarb, Precision placement, Soil insecticides, *Frankliniella fusca* (Hinds), *Elasmopalpus lignosellus* (Zeller), *Sphenophorus callosus* (Olivier) *Melantotus communis* (Gyllenhal), *Eutheola rugiceps* (LeConte)

# USE OF PRECISION INSECTICIDE PLACEMENT AND CULTURAL CONTROL METHODS TO REDUCE CHEMICAL REQUIREMENTS FOR INSECT MANAGEMENT IN AGRICULTURAL SYSTEMS

by

KIMBERLY HUTCHISON LOHMEYER

B.S., King College, 1993

M.S., University of Tennessee, 1995

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2002

# USE OF PRECISION INSECTICIDE PLACEMENT AND CULTURAL CONTROL METHODS TO REDUCE CHEMICAL REQUIREMENTS FOR INSECT MANAGEMENT IN AGRICULTURAL SYSTEMS

by

KIMBERLY HUTCHISON LOHMEYER

Approved:

| | |
|---|---|
| Major Professor: | John All |
| Committee: | Paul Guillebeau |
| | Robert McPherson |
| | Phillip Roberts |
| | John Ruberson |

Electronic Version Approved:

Gordan L. Patel
Dean of the Graduate School
The University of Georgia
May 2002

DEDICATION

This dissertation is dedicated with love to my husband, Robert F. Lohmeyer. His support and encouragement have been the foundation on which I have completed my education.

## ACKNOWLEDGEMENTS

I express sincere gratitude to my major professor, Dr. John All, for the guidance and support he has shown me throughout this study and for pointing me in a new direction. I also thank Dr. Phillip Roberts, Dr. John Ruberson, Dr. Paul Guillebeau, and Dr. Bob McPherson, committee members, for their support and advice throughout my studies and field work. I am grateful for financial support provided by the Department of Entomology at the University of Georgia. I thank Kurk Lance for all his help, advice, and field assistance and Patrick McPherson and Dean Kemp for field help. Many thanks go to Susan Watkins, Nancy Jordan, Detsy Bridges, and the late Ann Fowler for all their assistance throughout my degree process. Thanks to Terry All for all her help with my many questions. Special thanks and love go to my parents, Dan and Jane Hutchison, for all their encouragement, advice, and support. They instilled in me a love of science and knowledge and taught me that there is always something new to learn.

TABLE OF CONTENTS

# CHAPTER I

# INTRODUCTION AND LITERATURE REVIEW

Cotton and field corn, *Gossypium hirstum* L. and *Zea mays* L., respectively, are two of the most important crops produced in the southeastern United States. Over 200,000 hectares of field corn were harvested in Georgia in 1997 and over 539,500 hectares of cotton were harvested in 2000 (Hudson and All 1997a, Hardee 2001). Both cotton and corn are susceptible to damage by an array of insect pest species, several of which may cause millions of dollars in damage losses and control costs. Losses to insect damage and control costs average over $11,000,000 dollars in field corn and over $88,000,000 in cotton each year in Georgia (Hudson and All 1997a, Williams 2001).

Some of the most costly pests to control in field corn are soil insects (Hudson and All 1997a). On average, over $2,000,000 is spent each year in Georgia to manage these pests (Hudson and All 1997a). These insects typically feed at or below the soil line and damage either the corn seed or the developing corn seedling (Steffey et al. 1999, Tippins 1982, Luginbill and Ainslie 1917, Metcalf 1917). Infestations are often sporadic, making them even more difficult to anticipate and manage (Steffey et al. 1999, All and Jellum 1977, Luginbill and Ainslie 1917). Several soil insects of particular interest that damage field corn in the southeastern United States are the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), the southern corn billbug, *Sphenophorus callosus* (Olivier) the corn wireworm, *Melantotus communis* (Gyllenhal), and the sugarcane beetle, *Eutheola rugiceps* (LeConte) (Morgan and Beckham 1960, Tippins 1982, Riley 1986, Hudson and All 1997a).

The lesser cornstalk borer is a polyphagous feeder. The larval stage attacks corn particularly during dry weather and/or late planting (Dupree 1965). Larvae burrow into corn seedlings in the 2-10 leaf stage causing severe damage (Lynch 1999, Riley 1882).

Larvae can usually be found under the soil surface in silken tubes (Luginbill and Ainslie 1917). As the host plant dies, the feeding larva may move to other nearby plants, subsequently killing numerous plants within a stand (Isley and Miner 1944).

Southern corn billbug adults migrate into corn fields from nearby weedy and wooded areas and cause extensive damage, particularly in fields planted early in the growing season (Morgan and Beckham 1960). The adult beetle chews into the base of the corn seedling, deforming or killing the plant (Van Duyn and Wright 1999, Durant 1975).

Wireworms are pests of corn and other small grains throughout the southeastern United States. Wireworms feed on corn seed preventing germination. Poor stands may also result from larvae feeding on roots or stems of germinating plants (Keaster and Riley 1999). Heavy infestations may cause damaged plants to lodge (Hudson and All 1997b). On average, wireworms cause over $2,000,000 worth of damage to corn in Georgia each year (McPherson and Douce 1993).

Another soil insect, the sugarcane beetle *Eutheola rugiceps* (Lec.), is an occasional pest of corn in the south. Adult beetles fly into corn fields from surrounding grassy pastures (All, 1999, Baerg 1942, Phillips and Fox 1926). Sugarcane beetles damage corn seedlings by chewing into the plant below the soil line, killing small plants and stunting larger ones (All, 1999, Phillips and Fox 1933, Riley 1986).

Conventional management tactics for soil pests in field corn utilize preventative planting-time application of insecticides (Steffey et al. 1999, Metcalf and Metcalf 1993, All and Jellum 1977, All et al. 1979, DuRant 1975). Insecticide formulations are placed with the corn seed in a continuous stream along the planting furrow. Insecticides such as terbufos (Counter®) or carbofuran (Furadan®) are typically used. Often rates as high as 0.56 kg of active ingredient per 1000 m of planted row and costs of $3.38 per 1000 m of planted row are necessary to prevent possible infestations, however even these amounts may fail to provide adequate control (Guillebeau 2001).

Carbofuran, a class II carbamate insecticide, and terbufos, a class I oraganophosphate insecticide, are commonly used for insect control in corn and are highly toxic to humans (Hayes 1982). Carbofuran is fairly toxic to humans by absorption through the skin and highly toxic by ingestation and inhalation (Ryan and Terry 1997, Hayes 1982, U.S. Environmental Protection Agency 1987). If ingested or inhaled, carbamates can affect nerve transmission by inhibiting cholinesterase (Kearney and Kaufmann 1975, Branch and Jacqz 1986). Symptoms include nausea, difficulty breathing, and high blood pressure. Death may result due to respiratory system failure (Tucker 1970). Terbufos is highly toxic to humans by both dermal and oral routes of exposure (Hayes 1982). Symptoms of terbufos exposure in humans include nausea, abdominal cramps, vomiting, and diarrhea. Absorption into the bloodstream may cause inhibition of cholinesterase. At high doses, death may result from respiratory failure (Tucker 1970).

Carbofuran and terbufos are both highly toxic to birds. Carbofuran is toxic in particular to chickens, songbirds, ducks, and quail (Martin et al.1991, Balcomb et al. 1984, Tucker 1970). In a test that applied granular carbofuran to 195 hectares of corn at-planting, Balcomb and co-workers observed seven bird deaths (Balcomb et al. 1984). This type of threat to birds resulted in an Environmental Protection Agency ban of granular carbofuran formulations in 1994. Currently there is no ban on liquid formulations of carbofuran (EXTOXNET 1997). Both carbofuran and terbufos are also highly toxic to fish such as rainbow trout and bluegill sunfish with LD50's as low as 0.24 mg/L (Kidd et al. 1991, Howard 1989, U.S. Environmental Protection Agency 1992).

Carbofuran is soluble in water and has soil half-life of 3-60 days making it a high risk for groundwater contamination (Howard 1989). Low levels have been detected in aquifers in Wisconsin and New York (Holden 1986, U.S. Environmental Protection Agency 1992). Terbufos degrades quickly and is generally immobile in the soil, so it poses a low threat for ground water contamination. However, small amounts have been found in groundwater samples across the Unites States (Howard 1991, U.S. Environmental Protection Agency 1987).

Each year in Georgia approximately 93,750 bales of cotton are lost due to thrips damage (Williams 2001). In the southeastern Unites States, the majority of damage to cotton is caused by tobacco thrips, *Frankliniella fusca* (Hinds). Thrips overwinter as hibernating adults in sheltered areas, as larvae in plant debris, or as pupae in the soil. In the spring, winged adults fly in search of suitable host plants. Thrips damage plants by rasping young leaves and terminal buds with their mouthparts. They then feed on the escaping plant juices. Leaves may turn brown on the edges or become distorted and curl upwards (Hunt and Baker 1980). Uncontrolled thrips infestations may slow plant growth and delay fruiting, maturity, and harvest (Hawkins et al. 1966). Severe thrips injury can cause damage to terminal buds and may kill plants as well as cause significant reductions in yield (Gaines 1934, Watts 1937, Carter et al. 1982).

The application of aldicarb (Temik® 15G) at-planting has been shown to offer effective early season thrips control in cotton (Roberts 1994, All and Tanner 1995, All

1993). Like the insecticides used for controlling soil insects in corn, aldicarb is applied preventatively at-planting. Aldicarb granules are typically placed in a continuous stream along the entire furrow as cotton seed is planted. The standard rate for controlling tobacco thrips, in Georgia is 3.92 kg Temik® 15G product per ha (Guillebeau 2001). Approximately 650,000 kg of aldicarb are applied annually to cotton at planting in the United States (Williams 2000). Based on stakeholder estimates, approximately 75-85% of cotton planted in Georgia is treated with aldicarb.

Aldicarb, a class I carbamate pesticide, is an effective control measure for thrips in cotton, but it is both costly and acutely toxic to humans exposed by application or consumption of contaminated foods or water (Hayes 1982, Sofer and Shahak 1989, Journal of the American Medical Association 1986). Symptoms of aldicarb exposure by ingestion include nausea, diarrhea, salivation, vomiting, and blurred vision (Green et al. 1987). In 1985 and 1987, numerous cases of aldicarb poisonings were reported in Oregon and California as a result of consumption of contaminated watermelons (Jackson et al. 1986, Green et al. 1987). These and other incidents in recent years have raised public awareness of the risks of aldicarb use (Marshal 1985).

Aldicarb is extremely toxic to birds and moderately toxic to fish (Smith 1992, Kidd and James 1991). The LD50 for the red-winged blackbird is 1.78 mg/kg and for the bluegill sunfish is 1.5mg/L (Smith 1992). Since its discovery in wells in Long Island during 1979, the environmental fate and movement of aldicarb has been given much attention. Aldicarb is very soluble and is mobile in sandy loam soils making it a potential hazard for groundwater contamination (Hegg et al. 1988). Aldicarb has been found in wells in over 25 countries and 12 states in the United States in concentrations above the health advisory limit of 10 parts per billion (Howard 1991, National Library of Science 1992, U.S. Environmental Protection Agency 1992). The manufacturer of Temik®, Rhone-Poulenc Ag Company (now Bayer), announced a voluntary halt on the sales of aldicarb for use on potatoes in 1990 based on concerns of groundwater contamination (EXTOXNET 1997).

One aspect of insect pest management in cotton and corn is the utilization of cultural control practices such as conservation tillage or ultra-narrow row planting. Cultural control practices utilize preventative pest management by avoiding damaging pest populations instead of suppressive control of infestations (All 1999a and All 1989). Conservation tillage is defined as the practice of leaving at least 30% of prior crop residues remaining on the soil surface (Hammond and Stinner 1999). Conservation tillage is becoming increasingly popular worldwide. In the southern Unites Stated such systems have become increasingly popular and successful as growers take advantage of the extended growing season by utilizing multi-cropping systems. (Hammond and Stinner 1999, All 1994, All 1980).

Conservation tillage conserves soil moisture, reduces soil temperatures in summer, and prevents erosion (Blevins et al. 1971, Olson and Schoeberl 1970, Griffith et al 1973, Zing and Whitfield 1957). One concern that arises with this type of control practice is the potential for increased insect problems due to plant material remaining in the field or to the absence of insect pest mortality caused by conventional tillage (Hammond and Stinner 1999, Andow 1991). Tillage practices affect insect species populations differently and effects vary among crops. A survey conducted by Stinner and House of 45 studies of tillage in worldwide crops found that 28% of pest species and their damage increased in conservation tillage, 29% showed no change, and 43% decreased with conservation tillage (Stinner and House 1990). A good example of an insect suppressed by conventional tillage is the pink bollworm, *Pectinophora gossypiella* (Saunders), in the southwestern United States. Along with other cultural practices, conventional tillage by plowing is a good control tactic for managing this pest in cotton (El-Zik and Pimentel 1991). In the past, conservation tillage has also been criticized for increasing pesticide use (Little 1987).

In corn, the use of conservation tillage exerts varying influences on populations of insect pests (Hammond and Stinner 1999, All 1979). Significantly higher levels of southern corn billbug damage and lower yields occur in conservation tillage treatments when compared with conventional tillage treatments, however; lesser cornstalk borer feeding behavior is altered in conservation tillage causing less damage when compared with conventional tillage treatments (Roberts 1993, All 1996, Javid, et al. 1986, All and Gallaher 1977, Cheshire and All 1979, All 1980). Conservation tillage has also been shown to increase the abundance of southern corn rootworm, *Diabrotica undecimpunctata howardi* (Barber), and common stalk borer, *Papaipema nebris* (Guenee), in corn (Levine 1993, Buntin et al. 1994, House and Alzugaray 1989).

In cotton, conservation tillage has been shown to reduce thrips infestations. Previous research demonstrates that thrips populations are reduced significantly in cotton that has been planted after a cover crop such as wheat, clover, or canola (All et al. 1992, All 1995, All 1996, All et al. 1994).

Another type of cultural control practice, ultra-narrow row planting, has been shown to be a practical option for reducing cotton production costs while maintaining yield; however not much is known about its effects on pest insect infestations (Jost and Cothren 2000). Preliminary studies have demonstrated that ultra-narrow row planting may affect thrips populations. Harris et al. (1999) found that ultra-narrow row planting practices may increase the number of adult thrips found on cotton plants, while Earnest et al. (1999) found that ultra-narrow row planting with in-furrow application of insecticides achieved good thrips control.

Over the years, the definition of pest control has changed to suit the shifting needs of human population growth. The last several decades have led to the need for a more specific control concept, one that not only deals effectively with pest populations, but does so in a way that is economically and environmentally sound (Ruberson 1999). In corn and cotton agricultural systems, current farming technology allows for seeds to be placed at planting in specified intervals along the row. As previously mentioned, preventative insecticides used for insect management are applied at planting; however these insecticides are usually applied in a continuous stream "in-furrow" along the entire row. Pesticides used in this manner are applied to protect the seed and the seedling plant, but much of the pesticide ends up being deposited in the space between the seeds. Only a very small amount of the pesticide is placed directly with the seeds. The quantity of pesticide applied per ha could be reduced by as much as 50%, but the amount of pesticide adjacent to the seed would remain the same.

Placing the insecticide along with the seed in a specific location would be a more efficient method of applying planting time insecticides. This type of "precision placement" of insecticides would directly reduce risks to human health and the environment by reducing chemical needs. The incentive for growers to adopt this type of treatment practice would be high due to cost savings. Applying this system to aldicarb use in cotton and soil insecticide use in corn may be an effective solution for controlling pests while reducing grower costs and environmental hazards.

A method to further reduce control costs while enhancing control efficacy in cotton and corn may be the use of cultural control practices such as conservation tillage or ultra-narrow row planting in combination with precision placement. Pesticide application has been shown to impact invertebrates directly and indirectly in conservation tillage cropping systems. Specific pest species problems mitigate the need for further research to develop insecticide control measures in conservation tillage systems (All and Musick 1986).

To assess the potential control efficacy of precision placement of insecticides in cotton and corn as well as the efficacy of precision placement combined with cultural control practices, individual pest situations should be evaluated individually. Little is known about the effectiveness of precision-placed insecticide treatments on soil insect pests of field corn or thrips infestations in cotton. Additionally, much remains unclear about what influence precision placement of insecticides in combination with cultural control practices such as conservation tillage and ultra-narrow row planting practices may have on pest populations. Therefore, research was initiated to:

1. Evaluate the efficacy of precision-placed aldicarb treatments for controlling thrips populations in seedling cotton;
2. Evaluate the efficacy of precision-placed aldicarb treatments in combination with cultural control practices such as ultra-narrow row planting and conservation tillage for controlling thrips populations in seedling cotton;

3. Evaluate the efficacy of precision-placed soil insecticides for the control of southern corn billbug, lesser cornstalk borer, corn wireworms, and sugarcane beetle in field corn; and to determine the influence of conservation tillage practices in combination with precision-placed insecticide treatments on southern corn billbug and lesser cornstalk borer populations.

## References

**All, J. N. 1979.** Insect relationships in no-till cropping. Agrichem. Age 23: 22-23.

**All, J. N. 1980.** Pest management decisions in no-tillage agriculture. *In* Proceedings of the Third Annual No-Tillage Systems Conference. Univ. of FL. pp. 1-6.

**All, J. N. 1989.** Importance of designating prevention and suppression control strategies for insect pest management programs in conservation tillage. *In* Conservation Tillage Farming, Integrated Pest Management. I. O. Teare, E. Brown, and C. A. Trimble (eds.). Proceedings of the Southern Conservation Tillage Conference. University of Florida Press. Spec. Bull. pp. 1-5.

**All, J. N. 1993.** Impact of selected rates of Thimet and Temik on control of thrips and production of cotton. 1993 GA Cotton Res. Ext. Rep. 208p.

**All, J. N. 1994.** Interaction of cultivar, tillage practice, and aldicarb on thrips populations in seedling cotton. *In* Annual Plant Resistance to Insects Newsletter. E. E. Ortman, and R. H. Ratcliffe, eds. W. Lafayette, Indiana: Purdue University Press. pp. 15-19.

**All, J. N. 1995.** Insect pest management in conservation tillage for the southeastern United States. Conservation Tillage Workshop. *In* Proceedings Beltwide Cotton Conferences. National Cotton Council of America. p. 78.

**All, J. N. 1996.** Insect population shifts from conventional to conservation tillage: What to expect and how to control. *In* Doublecropping/Conservation Tillage Workshop Proceedings. Univ. of GA Coop. Ext. Serv. pp.12-14.

**All, J. N. 1999a.** Cultural approaches to managing arthropod pests. *In* Handbook of Pest Management. J. R. Ruberson (ed.). Marcel and Dekker, Inc. New York. pp. 395-415.

**All, J. N. 1999b.** Sugarcane beetle. *In* Handbook of Corn Insects. K. L. Steffey, M. E. Rice, J. N. All, D. A. Andow, M. E. Gray, and J. W. Van Duyn. (eds.) Entomol. Soc. America. Lanham MD. pp. 109-110.

**All, J. N. and R. N. Gallaher. 1977**. Detrimental impact of no-tillage corn cropping systems involving insecticides, hybrids, and irrigation on lesser cornstalk borer (*Elasmopalpus lignosellus*) infestations. J. Econ. Entomol. 70: 361-365.

**All, J. N. and M. D. Jellum. 1977.** Efficacy of insecticide-nematicides on *Sphenophorus callosus* and phytophagous nematodes in field corn. J. GA Entomol. Soc. 12; 291-297.

**All, J. N., and J. N. Musick. 1986.** Management of vertebrate and invertebrate pests. *In* No-tillage and surface-tillage agriculture: the tillage revolution. M. A. Sprague and G. B. Triplett (eds.). Wiley. New York.

**All, J. N., and B. H. Tanner. 1995.** Thrips control in cotton with planting time insecticides. *In* 1995 Georgia Cotton Res. Ext. Rep. pp. 133-134.

**All, J. N. , R. N. Gallaher, and M. D. Jellum. 1979.** Influence of planting date, preplanting weed control, irrigation, and conservation tillage practices on efficacy of planting time insecticide application for control of lesser cornstalk borer *Elasmopalpus lignosellus* in field corn. J. Econ. Entomol. 72: 265-268.

**All J. N., B. H. Tanner, and P. M. Roberts. 1992.** Influence of no-tillage practices on tobacco thrips infestations in cotton. *In* Proceedings 1992 Southern Conservation Tillage Conferences. Univ. of TN. pp.77-78.

**All, J. N., W. K. Vencill, and W. Langdale. 1994.** Five-year study on influence of cultural practices on thrips in seedling cotton. *In* 1994 Georgia Cotton Research-Extension Report. Univ. of GA. pp. 140-144.

**Andow, D. A. 1983.** Yield loss to arthropods in vegetationally diverse agroecosystems. Environ. Entomol. 20: 1228-1235.

**Baerg, W. J. 1942.** Rough-headed corn stalk beetle. Arkansas Agric. Exp. Sta. Bull. 415.

**Balcomb, R., C.A. Bowen, D. Wright, and M. Law. 1984.** Effects on wildlife of at-planting corn applications of granular carbofuran. J. Wildl. Manage. 48: 1353-1359.

**Blevins, R. L., D. Cook, S. H. Phillips, and R. E. Phillips. 1971.** Influence of no-tillage on soil moisture. Agron. J. 63: 593-596.

**Branch, R. A. and E. Jacqz. 1986.** Subacute neurotoxicity following long-term exposure to carbaryl. Am. J. Med. 80: 659-664.

**Buntin, G. D., J. N. All, D. V. McCracken, and W. L. Hargrove.** 1994. Cover crop and nitrogen fertility effects on southern corn rootworm (Coleoptera: Chrysomelidae) damage in corn. J. of Econ. Entomol. 87:1683-1688.

**Carter, C. C., T. N. Hunt, D. L. Kline, T. E. Reagan, and W. P. Barney. 1982.** Insect and related pests of cover crop, tillage, and insecticide on thrips populations in seedling cotton. *In* Proceedings Beltwide Cotton Conferences 1982. National Cotton Council. pp. 1066-1067.

**Cheshire, J. M., and J. N. All. 1979.** Feeding behavior of lesser cornstalk borer larvae in simulations of no-tillage, mulched conventional tillage, and conventional tillage corn cropping systems. Environ. Entomol. 8: 261-264.

**DuRant, J. A. 1975.** Southern corn billbug [*Sphenophorus callosus*] (Coleoptera:Curculionidae): control on corn in South Carolina. J. GA Entomol. Soc. 10: 287-291.

**Dupree, M. 1965.** Observation on the life history of the lesser cornstalk borer. J. Econ. Entomol. 58:1156-1157.

**Earnest, L., C. T. Allen, M. Kharboutli, and C. Capps. 1999.** Thrips control in conventional and ultra-narrow row cotton. *In* Proceedings Beltwide Cotton Conferences 1999. National Cotton Council. pp. 1193-1195.

**El-Zik, K. M. and R. E. Frisbie. 1991.** Integrated crop management systems for pest control. *In* Handbook of Pest Management in Agriculture. 2nd Ed. D. Pimentel, ed. Boca Raton, Florida. CRC Press, pp. 3-104.

**EXTOXNET. Extension Toxicology Network. 1997.** Pesticide Information Profile. http://ace.orst.edu/cgi-bin/mfs/01/pips/aldicarb.htm, http://ace.ace.orst.edu/info/extonet/pips/carbofur.htm, and http://ace.ace.orst.edu/info/extoxnet/pips/terbufos.htm.

**Gaines, J. C. 1934.** A preliminary study of thrips on seedling cotton with special reference to population, migration, and injury. J. Econ. Entomol. 27: 740-743.

**Green, M. A., M. A. Heumann, H. M. Wehr, L. R. Foster, L. P. Williams, Jr., J. A. Polder, C. L. Morgan, S. L. Wagner, L. A. Wanke, and J. M. Witt. 1987.** An outbreak of watermelon-borne pesticide toxicity. American Journal of Public Health. 77:1431-1434.

**Griffith, D. R., J. V. Mannering, H. M. Galloway, S. D. Parsons, and C. B. Richey. 1973.** Effect of eight tillage-planting systems on soil temperature, percent stand, plant growth, and yield of corn on five Indiana soils. Agron. J. 65: 321-326.

**Guillebeau, P. ed. 2001.** Georgia Pest Control Handbook. Commercial Edition. Sp. Bull. 28. 629 p.

**Hammond, R. B. and B. R. Stinner. 1999.** Impact of tillage systems on pest management. *In* Handbook of Pest Management. J. R. Ruberson (ed.). Marcel and Dekker, Inc. New York. pp. 693-712.

**Hardee, D. D. 2001.** 54$^{th}$ Annual conference report on cotton insect research and control. Proceedings Beltwide Cotton Conferences. National Cotton Council. pp. 741-773.

**Harris, H. M., W. K. Vencill, and J. N. All. 1999.** Influence of row spacing and tillage upon western flower thrips and tobacco thrips in cotton. Proceedings Beltwide Cotton Conference. National Cotton Council. pp. 974-975.

**Hawkins, B. S. , H. A. Peacock, and T. E. Steele. 1966.** Thrips injury to upland cotton (*Gossypium hirsutum* L.) varieties. Crop Sci. 6: 256-258.

**Hayes, W. 1982.** Pesticide Studies in Man. Baltimore. Williams and Wilkins.

**Hegg, R. O. W. H. Shelley, R. L. Jones, and R. R. Romine. 1988.** Movement and degradation of aldicarb residues in South Carolina loamy sand soil. Agriculture, Ecosystems, and Environment. 20: 303-305.

**Holden, P. W. 1986.** Pesticides and groundwater quality: issues and problems in four states. National Academy Press. Washington, D.C.

**House , G. J., and M. D. R. Alzugaray. 1989.** Influence of cover cropping and no-tillage practices on community composition of soil arthropods in a North Carolina agroecosystem. Environ. Entomol. 18: 302-307.

**Howard, P. H**. **1991.** Handbook of environmental fate and exposure data for organic Chemicals: Pesticides, Lewis Publishers, Chelsea, MI.

**Hudson, R. D., and J. N. All. 1997a.** Summary of losses from insect damage and costs of control in Georgia: field corn insects. ww.bugwood.org/s197/fieldcorn97.htm.

**Hudson, R. D. and J. N. All. 1997b.** Management of wireworms affecting corn and small grains. *In* Wireworms Affecting Agriculture in Georgia. S. L. Brown (ed). GA Agric. Exp. Sta. Res. Bull. 432. 27p.

**Hunt, T. N. and J. R. Baker. 1980.** Insect and related pests of field crops. North Carolina Ag. Ext. Serv. Raleigh, NC. 214 p.

**Isley, D. and F. D. Miner. 1944.** The lesser cornstalk borer, a pest of fall beans. J. Kan. Entomol. Soc. 17: 51-57.

**Jackson, R. J., J. W. Stratton, L. R. Goldman, D. F. Smith, E. M. Pond, D. Epstein, R. R. Neutra, A. Kelter, and K. W. Kizer. 1986.** Aldicarb food poisoning from contaminated melons- California. Journal of the American Medical Association. 256: 175-176.

**Javid, A. M., J. N. All, and J. S. Laisa, 1986.** The influence of cultural treatments on feeding damage of southern corn billbug (Coleoptera: Curculionidae) to corn. J. Entomol. Sci. 21: 276-282.

**Jost, P. H., and J. T. Cothren. 2000.** Growth and yield comparisons of cotton planted in conventional and ultra-narrow row spacings. Crop Science. 40: 430-435.

**Kearney, P. C. and D. D. Kaufman (eds.) 1975.** Herbicides: chemistry, degradation, and mode of action. 2nd Ed. Vol. 1 and 2. New York. M. Dekker.

**Keaster A. J. , and T. J. Riley. 1999.** Wireworms. *In* Handbook of Corn Insects. K. L. Steffey, M. E. Rice, J. N. All, D. A. Andow, M. E. Gray, and J. W. Van Duyn. (eds.).Entomol. Soc. America. Lanham MD. p. 117-118.

**Kidd, H. and D. R. James. (eds.) 1991.** The Agrochemicals Handbook, Third Ed. Royal Society of Chemistry Information Sevices, Cambridge, UK. pp. 3-11.

**Levine, E. 1993.** Effect of tillage practices and weed management on survival of stalk borer (Lepidopetera:Noctuidae) eggs and larvae. J. Econ. Entomol. 86: 924-928.

**Little, C. E. 1987.** Green fields forever. Washington D.C. Island Press.

**Luginbill, P., and G. G. Ainslie. 1917.** The lesser cornstalk borer. USDA Agric. Bull. 539. pp. 1-27.

**Lynch, R. 1999.** Lesser cornstalk borer. *In* Handbook of Corn Insects. Steffey, K. L., M.E. Rice, J. N. All, D. A. Andow, M.E. Gray, and J. W. Van Duyn. (eds.).Entomol. Soc. America. Lanham MD. p. 94.

**McPherson, R. M. and G. K. Douce (eds). 1993.** Summary of losses from insect damage and cost of control in Georgia. 1992. GA Agric. Exp. Sta. Pub. 83. 55p.

**Marshal, E. 1985.** The rise and fall of Temik. Science: 229: 1369-1370.

**Martin, P.A., K. R. Solomon, and H. J. Boermans. 1991.** Effects of carbofuran ingestion on mallard ducks. J. Wildl. Manage. 55: 103-111.

**Metcalf, R. L., and R. A. Metcalf. 1993.** Destructive and useful insects; their habits and control. 5th ed. Mc-Graw Hill, New York.

**Metcalf, Z. P. 1917.** Biological investigations of *Sphenophorus callosus* Olivier. N.C. Agr. Exp Sta.Tech. Bull. 13. 123p.

**Morgan, L.W. and C. M. Beckham. 1960.** Investigations on control of the southern corn billbug, GA Agr. Exp. Stn. Mimeo. Series N.S. 93. 9p.

**National Library of Science. 1992.** Hazardous substances databank. Medlars Management Section, Bethesda, MD.

**Olson, T. R., and L. S. Schoeberl. 1976.** Corn yields, soil temperature and water use with four tillage methods in the western corn belt. Agron. J. 66: 229-231.

**Phillips, W. J. and H. Fox. 1933.** The rough-headed corn stalk beetle in the southern states and its control. USDA Farmers Bull. 875. Washington D. C.

**Riley, C. V. 1882.** The smaller cornstalk borer. (*Pempelia lignosella* Zeller). USDA Report. 1881: 142-145.

**Riley, T. J. 1986.** Greenhouse and field evaluations of granular soil insecticides for control of sugarcane beetle, *Eutheola rugiceps* (Coleoptera: Scarbaeidae) in field corn. Florida Entomologist. 69: 390-394.

**Roberts, P. M. 1993.** Risk Assessment of Southern Corn Billbug, Lesser Cornstalk Borer and Fall Armyworm Infestations in Field Crops Using Sustainable Agricultural Practices. PhD dissertation, University of Georgia, Athens, Georgia.

**Roberts, P. M. 1994.** Control of thrips on seedling cotton with in-furrow insecticides. *In* Proceedings 1994 Beltwide Cotton Conferences. National Cotton Council. pp. 845-846.

**Ruberson, J. R. (ed). 1999.** Handbook of pest management. New York. M. Dekker. 842 p.

**Ryan, R. P. and C. E. Terry. (eds.) 1997.** Toxicology Desk Reference. Taylor and Francis pp.585-596.

**Smith, J. G. 1992.** Toxicology and Pesticide Use in Relation to Wildlife: Organophosphate and Carbamate Compounds. Smoley, Boca Raton FL. pp 3-18.

**Sofer, S. and E. Shahak. 1989.** Carbamate and organophophate poisoning in early childhood. Pediatr. Emerg. Care 5: 222-225.

**Steffey, K. L., M. E. Rice, J. N. All, D. A. Andow, M. E. Gray, and J. W. Van Duyn. (eds) 1999.** Handbook of Corn Insects. Entomol. Soc. America. Lanham MD. pp. 164.

**Stinner, B. R. and G. J. House. 1990.** Arthropods and other invertebrates in conservation tillage systems. Ann. Rev. of Entomol. 35: 299-318.

**Tippins, H. H. 1982.** A review of information on the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller). UGA/College of Ag. Experiment Stations. Special Pub. No. 17.

**Tucker, R. 1970.** Handbook of toxicity of pesticides to wildlife. USDA Fish and Wildlife Service.

**United States Environmental Protection Agency. 1987.** Health Advisories for for 50 Pesticides. Office of Drinking Water, Washington, D.C. pp. 3-16.

**United States Environmental Protection Agency. 1992.** Pesticides in Ground Water Data Base. 1988. Interim Report. Washington, D.C. pp. 5-43.

**Van Duyn, J. W. and R. Wright. 1999.** Billbugs. *In* Handbook of Corn Insects. K. L. Steffey, M. E. Rice, J. N. All, D. A. Andow, M. E. Gray, and J. W. Van Duyn. (eds.).Entomol. Soc. America. Lanham MD. pp. 53-54.

**Watts, J. G. 1937.** Reduction of cotton yields by thrips. J. Econ. Entomol. 30: 806-813.

**Williams, M. R. 2001.** Cotton insect loss estimates - 2000. *In* Proceedings Beltwide Cotton Conferences. National Cotton Council. pp. 774-776.

**Zing, A. W., and C. J. Whitfield. 1957.** Stubble-mulch farming in the Western states. USDA Tech. Bull. 1166: 27 p.

# CHAPTER II

# PRECISION APPLICATION OF ALDICARB TO ENHANCE EFFICIENCY OF THRIPS (THYSANOPTERA: THRIPIDAE) MANAGEMENT IN COTTON[1]

---

[1]Lohmeyer, K. H., J. N. All, and P. M. Roberts. To be submitted to Journal of Economic Entomology.

**ABSTRACT** Thrips are a major pest of early season cotton throughout much of the United States. Growers rely heavily on aldicarb (Temik® 15G) placed preventatively in a continuous stream at planting for thrips control even though it is expensive and represents a toxicity hazard for non-target animals and the environment. Recently, vacuum induced planters that allow for precision placement of seed or "hills" of multiple seeds at desirable intervals have become available. This research was initiated to simulate technology for "precision placement" of aldicarb only on seed hills and not in the furrow between the hills. Field experiments investigated the efficacy of precision-placed rates of aldicarb compared with standard in-furrow treatments on tobacco thrips, *Frankliniella fusca* (Hinds), at two sites in Georgia from 1999-2001. Precision-placed aldicarb at rates per ha of one half or less of standard in-furrow rates controlled thrips during seedling stages of cotton with no significant differences in yield. Residual analysis of plants showed that precision placement plots had as much or more aldicarb and aldicarb metabolites present within the plant when compared to the higher rates of in-furrow treatments. Results indicate that precision placement of aldicarb at planting may be an efficient and cost effective method of managing thrips populations in cotton.

KEY WORDS: Cotton, aldicarb, Temik®, *Frankliniella fusca*, precision placement.

**Introduction**

Cotton is the most utilized textile fiber in the world (Martin and Leonard 1967). In 2000, over five million ha of cotton were harvested in the United States alone with a value of $450 million (Hardee 2001). Insect pests significantly reduce cotton yields each year and millions of dollars in insecticide treatments are required to suppress pest populations. One of the most challenging and important concerns facing contemporary agriculture is the struggle to control pests in a manner that is both effective and environmentally sound.

Tobacco thrips, *Frankliniella fusca* (Hinds), cause damage to seedling cotton by using rasping/sucking mouthparts to feed on plant juices. Feeding damage causes yellowing, stunting, and overall plant decline (Davidson et al. 1979). In 2000, 85% of the cotton grown in the United States was infested with thrips, resulting in an estimated loss of 172,160 bales. Over three million ha were treated to control thrips at a cost of $81 million (Williams 2001).

Current management approaches for thrips in cotton include utilizing granular aldicarb (Temik® 15G) in planting-time applications. Aldicarb is a systemic insecticide that is an effective control measure for thrips in cotton, but is costly and may be hazardous to use. In the United States during 1999, growers spent on average $10 per acre to control thrips, with approximately 75% of that being spent on aldicarb (Williams 2000). Based on stakeholder estimates, approximately 75-85% of the ha planted in Georgia are treated with aldicarb. Approximately 680,389 kg of aldicarb is applied annually to cotton at planting in the United States (Williams 2000). In addition to being expensive, aldicarb is among the most acutely toxic systemic pesticides available for use, with substantial risks for both human health and as an environmental pollutant (EXTOXNET 1997). Aldicarb easily leaches to groundwater from the soil in quantities that are high enough to potentially result in human health effects (EXTOXNET 1997). Aldicarb has been found in wells in twelve states in concentrations above the health advisory limit of 10 parts per billion (Howard 1991). The manufacturer of Temik® 15G, Rhone-Poulenc Ag Company (now Bayer), voluntarily halted the sale of aldicarb for use on potatoes in 1990, based on concerns of groundwater contamination (EXTOXNET 1997). The primary routes of human exposure to aldicarb are consumption of contaminated food or water, and occupational exposure from handling and application.

In cotton and several other cropping systems, current planting technology allows for seeds to be placed in specified intervals along the row. Pesticides applied at planting, however, are usually applied in a continuous stream "in-furrow" along the row. Pesticides utilized in this manner are applied to protect the seed and the seedling plant, but much of the pesticide ends up being deposited in the space between the seeds. It may be possible to eliminate the pesticide that is applied between the seeds without a significant effect on control efficacy. The quantity of pesticide applied per acre could be reduced, by 50% or more, but the amount of pesticide adjacent to the seed would remain the same.

Placing the insecticide along with the seed in a specific location would be a more efficient method of applying planting-time insecticides. This type of "precision placement" of insecticide would directly reduce risks to the environment. The incentive for growers to adopt would be high due to cost savings. Applying this system to aldicarb use in cotton may be an effective solution for controlling thrips while reducing grower costs and environmental hazards.

Relevant to understanding the control potential of precision-placed insecticides is the knowledge of what is happening to the insecticide in the plant throughout the growing season. Residual analysis of aldicarb and aldicarb metabolites reveals how much of the insecticide reaches the growing plant and also shows how long it remains in the plant. In an effort to evaluate the efficacy of precision-placed aldicarb compared with traditional in-furrow treatments and to determine residual levels of Temik® present within cotton at specific points during the growing season, the following study was conducted.

## Materials and Methods

Experiments were conducted at the University of Georgia's Plant Sciences Farm (PSF), in Oconee County, near Watkinsville, Georgia during 1999, 2000, and 2001. The PSF is located in the southern piedmont region of Georgia. The soil types in test sites were Cecil coarse sandy loam. Tests were also conducted in 2000 and 2001 at the University of Georgia's Coastal Plain Experiment Station (CPES), Lang Farm, in Tift County, near Tifton, Georgia. The station is within the coastal plain region and has Tifton loamy sand soil. Varying rates of aldicarb were applied to 4 row plots in a randomized complete block design with four replications. One untreated check was included in each replication.

For CPES tests in 2000 and 2001, the two middle rows of 15 m long, four-row plots were treated. For the 1999 PSF test, the two middle rows of 7.6 m long, four-row plots were treated. For the 2000 and 2001 PSF tests, all four rows of 7.6 m long, four-row plots were treated.

For all tests, Bollgard™ NuCotn 33B cotton seed was planted in a hill method (seeds are grouped together in “hills” rather than planted individually along the row) using a two-row Monesem pneumatic planter. Hills were spaced 0.3 m apart in 1 m wide rows with three seeds per hill. Seed was planted on 4 May 2000 and 2 May 2001 for CPES tests and on 12 May 1999, 13 June 2000, and 8 May 2001 for PSF tests. Granular aldicarb was applied at planting using two methods. First, aldicarb was applied in-furrow within the entire row using a tractor-mounted Gandy® mechanical granular applicator. After applying the granules the furrow was closed with the packer-wheel device that is standard with Monesem planters. The second method, precision placement, used the same planter but the furrow closure apparatus was disengaged so that the planted seed was exposed. Insecticide granules were then placed directly on top of the seed with a “bazooka” type applicator that was constructed to place calibrated quantities of insecticide onto the top of seed by a trap release system (Wiseman et al. 1980). The open furrows were then closed with a hoe. All insecticide rates were specified as kg per ha based on 1 m wide rows.

Plots were irrigated and fertilized as needed during the growing season. No other insecticide treatments were applied to test plots.

**Thrips Sampling.** For the 2000 CPES test, cotton plants were sampled for thrips on 15 May, 24 May, and 5 June. For the 2001 CPES test, plants were sampled on 14 May, 22 May, and 1 June. For the 1999 PSF test, plants were sampled on 24 May, 3 June, and 14 June. The 2000 PSF test was sampled on 23 June, 5 July, 14 July and 3 August. The 2001 PSF test was sampled on 17 and 29 May, and 6 and 18 June.

Plants were sampled by randomly selecting 10 plants from the treated rows of each plot. Whole plants were immersed in a 120 ml specimen cup containing 60 ml of 70% EtOH. For later sampling dates, when plants were larger, only the upper portion of the plant was used. Samples were then brought back to the laboratory where thrips were identified and adults and immature stages were counted using a dissecting scope. Voucher specimens were deposited at the University of Georgia's Natural History Museum.

**Thrips Damage Rating.** CPES test plots were evaluated for thrips damage on 24 May 2000 and 22 May 2001. All of the treated plants within the plots were visually assessed for thrips damage and each plot was assigned a mean damage rating: 1 = no damage; 2 = slight leaf curl; 3 = moderate leaf curl and stunting; 4 = heavy leaf distortion; 5 = severe damage and stunting, missing seedlings.

**Plant Heights.** For all tests, ten plants were randomly selected from each plot and measured in centimeters to determine plant height. Plants were measured from the soil line, using the terminal bud as the upper measurement point. Plant height assessments were taken at approximately the same number of days after planting as the last thrips sample. Plant heights for CPES tests were taken on 19 June 2000 and 21 June 2001. Plant heights for PSF tests were taken on 30 June 1999 and 25 June 2001.

**Phytotoxicity Rating.** Due to the varying rates of aldicarb applied in this test, a phytotoxicity rating was taken to assess any plant effects that higher rates of aldicarb may cause. Plants from CPES test plots were evaluated for possible phytotoxic effects from aldicarb treatments on 15 May 2000 and 14 May 2001. Plants from treated rows were visually assessed for insecticide phytotoxicity. Each plot was assigned a rating: 0 = no aldicarb effect; 1 = slight leaf chlorosis; 2 = minor chlorosis of leaves and slight stunting; 3 = moderate chlorosis, some browning and stunting; 4 = heavy browning of foliage and stunting to plants.

**Yield**. CPES tests were harvested mechanically on 3 October 2000 and 16 October 2001. Tests at the PSF were harvested mechanically on 29 October 1999, 1 November 2000, and 1 November 2001. Seed cotton was weighed in the field to determine yield.

**Residual Analysis.** Aldicarb is absorbed by the growing cotton seedling very quickly upon germination. The growing plant metabolizes aldicarb into two byproducts: rapidly to a sulfone form and then more slowly to a sulfoxide metabolite (Coppedge et al. 1967). These metabolites are all responsible for the insecticidal properties of aldicarb (Montgomery 1993). Analysis of aldicarb residues was conducted for the PSF 1999 and the CPES 2000 test. Plants to be used for residual analysis were collected on the same days as the thrips sampling was conducted. Ten whole plants were randomly selected from treated rows, bagged, and frozen until analysis. Approximately 20 g samples of plants from each plot were extracted and run on a gas chromatograph against analytical standards for aldicarb and aldicarb metabolites (sulfone and sulfoxide) to determine the amount of insecticide residue present in the sampled plants from each plot.

**Statistical Analysis.** Thrips sampling data were square root transformed and analyzed using ANOVA. Treatment means were separated using Tukey's Studentized Range Test, with $P<0.05$ (SAS Institute 2000). Plant heights, damage ratings, phytotoxicity ratings, seed cotton yield, and residual levels of aldicarb and aldicarb metabolites were analyzed using ANOVA. Treatment means were separated using Tukey's Studentized Range Test, with $P<0.05$ (SAS Institute 2000).

## Results

**Thrips Sampling.** For all tests, over 95% of the adult thrips sampled and counted were tobacco thrips, *F. fusca* (Hinds). A few western flower thrips, *F. occidentalis* (Pergrande) were also present.

**PSF 1999.** On 24 May, cotyledon stage plants were infested with low populations of adult and larval thrips (Table 2.1). No significant reductions in larval, adult, or total thrips populations were found for any of the treatments when compared with the untreated check (larvae: $F = 1.00$; df = 11, 33; $P = 0.4671$; adults: $F = 1.80$; df = 11, 33; $P = 0.0950$; total: $F = 1.51$; df = 11, 33; $P = 0.1743$). All precision-placed treatments were as effective in reducing in adult, larval, and total thrips populations as the standard in-furrow 3.92 kg product per ha.

Plants in the 2-leaf stage on 3 June were predominantly infested with larval thrips (Table 2.2). All precision-placed treatments significantly reduced larval thrips numbers when compared to the untreated check ($F = 5.29$; df = 11, 33; $P < 0.0001$). All precision-placed aldicarb treatments were as effective in reducing larval thrips infestations as the standard in-furrow 3.92 kg product per ha rate. All precision-placed treatments significantly reduced adult thrips numbers when compared to the untreated check except the 0.18 and 2.15 kg product per ha ($F = 7.65$; df = 11, 33; $P < 0.0001$). All precision-placed aldicarb treatments were as effective at reducing adult thrips infestations as the standard 3.92 kg product per ha rate. Precision-placed aldicarb at a rate of 1.44 kg product per ha showed the greatest reduction of adult thrips in comparison with the untreated check. All treatments significantly reduced total thrips numbers when compared with the untreated check except the in-furrow rates of 0.28 and 1.12 kg product per ha ($F = 7.20$; df = 11, 33; $P < 0.0001$). All precision-placed treatments were as effective in reducing total thrips as the standard in-furrow rate of 3.92 kg product ha.

On 14 June, plants had four leaves and were infested with adult and larval thrips (Table 2.3). All precision placement treatments showed significant reductions in larval thrips when compared with the untreated check except for the two lowest rates of 0.18 and 0.71 kg product per ha ($F = 9.09$; df = 11, 33; $P < 0.0001$). All precision-placed treatments were as efficient in reducing larval thrips populations as the standard in-furrow 3.92 kg product per ha rate. All of the precision placement treatments showed significant reductions in adult thrips when compared with the untreated check except the two lowest rates of 0.18 and 0.71 kg product per ha ($F = 7.86$; df = 11, 33; $P < 0.0001$). All precision-placed treatments showed as significant reduction in adult thrips as the standard in-furrow 3.92 kg product per ha rate. As with the adult and larval thrips, all precision-placed treatments significantly reduced total thrips when compared with the untreated check except the two lowest rates of 0.18 and 0.71 kg product per ha ($F = 12.81$; df = 11, 33; $P < 0.0001$). All precision-placed treatments were as effective in reducing total thrips as the standard in-furrow 3.92 kg product per ha rate.

**CPES 2000.** On 15 May, cotyledon stage plants were predominantly infested with adult thrips (Table 2.4). Very few larval thrips were observed. No significant differences were found for any of the treatments when compared with the untreated check for larval thrips ($F = 2.20$; df = 9, 27; $P = 0.0545$). All precision-placed treatments significantly reduced adult thrips infestations when compared to the untreated check except for the lowest rate of 0.18 kg product per ha ($F = 7.91$; df = 9, 27; $P < 0.0001$). All precision-placed treatments were as effective in reducing adult thrips populations as the standard in-furrow rate of 3.92 kg product per ha rate. Significantly reduced numbers of total thrips were observed for all treatments except precision-placed aldicarb at 0.18 kg product per ha and in-furrow aldicarb at 0.28 and 0.56 kg product per ha ($F = 8.34$; df = 9, 27; $P < 0.0001$). All precision-placed treatments except the lowest rate of 0.18 kg product per ha were as effective in reducing total thrips populations as the standard in-furrow rate of 3.92 kg product per ha.

Plants were in the 2-leaf stage on 24 May and were predominantly infested with larval thrips (Table 2.5). All but the two lowest rates of precision-placed treatments significantly reduced larval thrips populations in comparison with the untreated check ($F = 3.28$; df = 9, 27; $P = 0.0080$). All precision-placed treatments were as effective in reducing larval thrips populations as the standard in-furrow rate. As populations were low, no significant differences in adult thrips populations were observed for any treatment in comparison with the untreated check ($F = 0.89$; df = 9, 27; $P = 0.5474$). As with larval thrips, significantly reduced numbers of total thrips were observed for precision-placed aldicarb at 1.44, 2.87, and 5.74 kg product per ha when compared with the untreated check ($F = 2.81$; df = 9, 27; $P = 0.0182$). All precision-placed treatments were as effective in reducing total thrips populations as the standard in-furrow rate of 3.92 kg product per ha.

On 5 June, the cotton plants had four leaves and were predominantly infested with larval thrips (Table 2.6). However, infestations of all thrips stages had dropped since the previous sampling date. All precision placement treatments were as effective in reducing larval thrips as the standard in-furrow 3.92 kg product per ha rate ($F = 3.56$; df = 9, 27;

*P*=0.0050). No significant differences in adult thrips populations were observed for adult for any of the treatments when compared with the untreated check ($F$ = 0.64 df = 9, 27; $P$ = 0.7552). All precision placement treatments were as effective in reducing total thrips as the standard in-furrow 3.92 kg product per ha rate ($F$ = 2.12; df = 9, 27; $P$ = 0.0063).

**CPES 2001.** On 14 May, cotyledon stage plants were predominantly infested with adult thrips (Table 2.7). Very few larval thrips were observed. All treatments significantly reduced adult thrips when compared to the untreated check ($F$ = 10.76; df = 9, 27; $P$ < 0.0001). All precision-placed treatments were as effective in reducing adult thrips populations as the standard in-furrow rate of 3.92 kg per ha. No significant differences in larval thrips populations were observed for any treatment in comparison with the untreated check ($F$ = 1.43; df = 9, 27; $P$ = 0.2262). As with adult thrips populations, significantly reduced numbers of total thrips were observed for all treatments when compared with the untreated check ($F$ = 10.60; df = 9, 27; $P$ < 0.0001). All the precision-placed treatments showed as significant a reduction in total thrips as the standard in-furrow 3.92 kg product per ha rate.

The cotton plants were in the 2-leaf stage on 22 May and were predominantly infested with populations of larval thrips (Table 2.8). All treatments significantly reduced larval thrips in comparison with the untreated check ($F$ = 21.87; df = 9, 27; $P$ < 0.0001). All precision-placed treatments except for 0.71 kg product per ha were as effective in reducing larval thrips populations as the standard in-furrow rate. All treatments significantly reduced adult thrips infestations in comparison with the untreated check except precision-placed 0.71 kg product per ha and in-furrow 0.56 kg product per ha ($F$ = 5.46; df = 9, 27; $P$ = 0.0003). All precision-placed treatments were as effective in reducing adult thrips populations as the standard in-furrow rate. All treatments significantly reduced numbers of total thrips when compared with the untreated check with in-furrow aldicarb at a rate of 3.92 kg product per ha and precision-placed aldicarb at a rate of 5.74 kg product per ha showing the greatest reductions ($F = 20.88$; df = 9, 27; $P < 0.0001$). All precision-placed treatments except for 0.71 kg product per ha were as effective in reducing total thrips numbers as the standard in-furrow rate of 3.92 kg product per ha.

On 1 June, the cotton plants had four leaves and were predominantly infested with larval thrips (Table 2.9). Only precision-placed aldicarb at a rate of 5.74 kg product per ha showed a significant reduction in larval thrips populations in comparison with the untreated check ($F = 3.60$; df = 9, 27; $P = 0.0047$). All the precision-placed treatments were as effective in reducing larval thrips as the standard in-furrow 3.92 kg product per ha rate. No significant differences in adult thrips populations were observed for any treatment in comparison with the untreated check ($F = 1.97$; df = 9, 27; $P = 0.0832$). As with larval thrips populations, only precision-placed aldicarb at a rate of 5.74 kg product per ha showed a significant reduction in total thrips populations in comparison with the untreated check ($F = 3.46$; df = 9, 27; $P = 0.0059$). All precision-placed treatments were as effective in reducing total thrips populations as the standard in-furrow rate of 3.92 kg product per ha.

**PSF 2001.** On 17 May, cotyledon stage plants in the field were predominantly infested with adult thrips (Table 2.10). Very few larval thrips were observed. All precision-placed treatments significantly reduced adult thrips populations in comparison with the untreated check and were as effective in reducing adult thrips populations as the standard in-furrow rate ($F$ = 19.62; df = 9, 27; $P$ < 0.0001). As populations were low, no significant differences in larval thrips numbers were observed for any treatment in comparison with the untreated check ($F$ = 1.21; df = 9, 27; $P$ = 0.3304). All precision-placed treatments significantly reduced total thrips populations in comparison with the untreated check ($F$ = 19.82; df = 9, 27; $P$ < 0.0001). All the precision-placed treatments showed as significant a reduction in total thrips as the standard in-furrow 3.92 kg product per ha rate.

Plants in the 2-leaf stage on 29 May were predominantly infested with larval thrips (Table 2.11). All treatments significantly reduced larval thrips in comparison with the untreated check except for the in-furrow aldicarb treatments of 0.28, 0.56, and 1.12 kg product per ha ($F$ = 20.62; df = 9, 27; $P$ < 0.0001). All the precision-placed treatments showed as significant a reduction in larval thrips as the standard in-furrow 3.92 kg product per ha rate. All treatments showed a significant reduction in adult thrips when compared to the untreated check except the lower rates of in-furrow aldicarb at 0.28, 0.56, and 1.12 kg product per ha ($F$ = 8.93; df = 9, 27; $P$ < 0.0001). Precision-placed aldicarb at 2.87 kg product per ha showed the most significant reduction in adult thrips in comparison with the untreated check. All precision-placed treatments were as effective in reducing adult thrips infestations as the standard in-furrow rate of 3.92 kg product per ha. All precision-placed treatments significantly reduced total thrips populations in comparison with the untreated check ($F$ = 12.02; df = 9, 27; $P$ < 0.0001). Precision-placed aldicarb at 2.87 kg product per ha showed the most significant reduction in total thrips in comparison with the untreated check. All precision-placed treatments were as effective in reducing total thrips as the standard in-furrow rate.

On 6 June, the plants had four leaves and were predominantly infested with larval thrips (Table 2.12). All precision-placed treatments had significantly reduced numbers of larval thrips when compared to the untreated check except for 0.71 kg product per ha ($F = 15.25$; df = 9, 27; $P < 0.0001$). All of the precision-placed treatments were as effective in reducing larval thrips populations as the standard in-furrow 3.92 kg product per ha rate. No significant reductions in adult thrips were observed for any treatment in comparison with the untreated check ($F = 1.71$; df = 9, 27; $P = 0.1347$). As with larval thrips populations, all precision-placed treatments had significantly reduced numbers of total thrips when compared to the untreated check except for 0.71 kg product per ha ($F = 12.66$; df = 9, 27; $P < 0.0001$). All of the precision-placed treatments were as effective in reducing total thrips populations as the standard in-furrow 3.92 kg product per ha rate.

On 18 June the plants had 8+ leaves and were infested with both larval and adult thrips (Table 2.13). Precision-placed aldicarb at rates of 2.87 and 5.74 kg product per ha showed the greatest reduction in larval thrips counts in comparison with the untreated check ($F = 6.40$; df = 9, 27; $P < 0.0001$). All precision-placed treatments were as effective in reducing larval thrips infestations as the standard in-furrow rate of 3.92 kg product per ha. No significant reductions in adult thrips were observed for any treatment in comparison with the untreated check ($F = 1.98$; df = 9, 27; $P = 0.0822$). Precision-placed aldicarb at a rate of 2.87 kg product per ha showed the greatest reduction in total thrips infestations in comparison with the untreated check ($F = 6.52$; df = 9, 27; $P < 0.0001$). All precision-placed treatments were as effective in reducing total thrips infestations as the standard in-furrow rate of 3.92 kg product per ha.

**Thrips Damage Rating.** On 24 May 2000, all the precision-placed aldicarb treatments had significantly limited thrips damage when compared to the untreated check except for the lowest rate of 0.18 kg product per ha (Table 2.14) ($F = 14.09$; df = 9, 27; $P = 0.0001$). On 22 May 2001 precision-placed aldicarb at 0.18, 1.44, 2.87, and 5.74 kg product per ha and in-furrow aldicarb at 1.12 and 3.92 kg product per ha had significantly limited thrips plant damage when compared to the untreated check (Table 2.14) ($F = 7.20$; df = 9, 27; $P = 0.0001$).

**Plant Heights.** For the 1999 PSF test, the plants that were measured in plots treated with precision-placed aldicarb at 0.71, 1.44 and 2.15 kg product per ha were significantly taller than plants from the untreated check and were as tall or taller than the plants measured in plots treated with the standard in-furrow rate of 3.92 kg product per ha (Table 2.15) ($F = 2.46$; df = 11, 33; $P = 0.0227$). No significant differences were observed in plant heights for all the treatments from the 2001 PSF test (Table 2.16) ($F = 0.78$; df = 9, 27; $P = 0.6393$). There were also no significant differences in plant heights for any treatments for the CPES 2000 test (Table 2.16) ($F = 1.96$; df = 9, 27; $P = 0.0851$). For the 2001 CPES test, the plants measured from plots treated with precision-placed aldicarb at 0.71 and 1.44 kg product per ha and the plants from treatments of in-furrow 0.56, 1.12, and 3.92 kg product per ha were significantly taller than plants from the untreated check and were similar in height to plants from plots treated with the standard 3.92 kg product per ha rate (Table 2.16) ($F = 3.29$; df = 9, 27; $P = 0.0078$).

**Phytotoxicity Rating.** For the 2000 CPES test, the precision-placed aldicarb treatments at rates of 1.44, 2.87, and 5.74 kg product per ha had significantly higher phytotoxicity ratings when compared with the untreated check plants and the plot treated with the standard in-furrow 3.92 kg product per ha rate (Table 2.17) ($F = 18.88$; df = 9, 27; $P = 0.0001$). In the 2001 CPES test the precision-placed aldicarb treatments at rates of 1.44, 2.87, and 5.74 kg product per ha again showed significantly greater phytotoxicity ratings when compared with plants in the untreated check plots and the standard in-furrow 3.92 kg per ha treatments ($F = 22.87$; df = 9, 27; $P = 0.0001$).

**Yield.** No significant differences in seed cotton yield were observed for any of the aldicarb treatments when compared with the untreated check for the PSF 1999 test (Table 2.18) or for the CPES 2000 test (Table 1.19) (PSF 1999: $F = 1.00$; df = 11, 33; $P = 0.4693$; CPES 2000: $F = 0.74$; df = 9, 27; $P = 0.6711$). For the CPES 2001 test, all precision placement-treated plots had significantly higher yields when compared to the untreated check except for the lowest rate of 0.18 kg product per ha (Table 2.19) ($F = 3.22$; df = 9, 27; $P = 0.0088$). All precision placement treated plots had yields that were as high as those from plots treated with the standard in-furrow rate of 3.92 kg product per ha. For the PSF 2001 test, significantly more seed cotton was produced from plots that had been treated by precision placement at a rate of 0.18 kg product per ha when compared with the untreated check (Table 2.19) ($F = 3.70$; df = 9, 27, $P = 0.0039$). Yield from all but the lowest rate of precision-placed treated plots was as high as the yield from plots treated with the standard in-furrow treatment of 3.92 kg product per ha.

**Residual Analysis. PSF 1999.**

Residual samples were taken at approximately 10 and 30 days after planting from selected treatments. In the 10-day sample the cotton seedlings treated by precision placement at a rate of 2.87 kg product per ha had significantly more aldicarb residue present than any of the other treatments (Table 2.20) ($F$ = 13.56; df = 5, 11; $P$ < 0.0001). All the precision placement treated plants had as much or more aldicarb present as compared to the standard in-furrow 3.92 kg product per ha rate. Significantly more sulfone residue was found in plants in the 2.87 and 1.44 kg product per ha precision placement treatments when compared with the untreated check and the standard in-furrow rate of 3.92 kg product per ha rate ($F$ = 11.55; df = 5, 11; $P$=0.0001). Significantly more sulfoxide residue was found in plants treated by precision placement at a rate 1.44 and 2.87 kg product per ha when compared with the untreated check and the standard in-furrow 3.92 kg product per ha rate ($F$ = 25.10; df = 5, 11; $P$<0.0001).

After 30 days the cotton plants treated by precision placement at a rate of 0.71 kg per ha had significantly higher amounts of aldicarb residue present than any of the other treatments (Table 2.21) ($F$ = 7.44; df = 5, 11; $P$ = 0.0037). Significantly more sulfone residue was found in plants treated by precision placement at rates of 0.71 and 2.87 kg product per ha when compared to the untreated check ($F$ = 6.33; df = 5, 11; $P$ = 0.0067). No significant differences in sulfoxide residues were observed for any treatments ($F$ = 2.09; df = 5, 11; $P$ = 0.1400).

**CPES 2000.** Residual samples were taken at approximately 10, 20, 30, and 50 days after planting from all treatments. At 10 days after planting, significantly more aldicarb residue was found in plants treated by precision placement at a rate of 5.74 kg product per ha when compared to the untreated check (Table 2.22) ($F$ = 2.62; df = 9, 27; $P$ = 0.0254). Plants from all the precision placement treatments contained as much or more aldicarb residue as did plants from the standard in-furrow treatment of 3.92 kg product per ha. Significantly more sulfone residue was found in plants treated by precision placement at rates of 2.87 and 5.74 kg product per ha when compared to the untreated check and the standard in-furrow 3.92 kg product per ha rate ($F = 10.55$; df = 9, 27; $P < 0.0001$). Significantly more sulfoxide residue was found in plants treated by precision placement at a rate of 5.74 kg product per ha when compared to the untreated check and the standard in-furrow 3.92 kg product per acre rate ($F = 4.02$; df = 9, 27; $P = 0.0024$).

At 20 days after planting significantly more aldicarb residue was present in plants treated by precision placement at a rate of 5.74 kg product per ha when relative to the untreated check (Table 2.23) ($F = 3.72$; df = 9, 27; $P = 0.0038$). All the precision-placed rates had as much aldicarb present as the standard in-furrow 3.92 kg product per ha rate. Precision placement rates of 1.44, 2.87, and 5.74 kg product per ha had significantly higher amounts of sulfone residue present when compared with the untreated check ($F = 6.67$; df = 9, 27; $P < 0.0001$). When compared to the untreated check, significantly higher sulfoxide residue levels were observed for all the precision-placed treatments ($F = 9.21$, df = 9, 27; $P < 0.0001$). The precision-placed aldicarb at treatments of 0.71, 1.44, and 5.74 kg product per ha had the highest sulfoxide residue levels in comparison with the check.

No significant differences in aldicarb residue levels at 30 days after planting were found for any treatment in comparison with the untreated check (Table 2.24) ($F = 1.00$; df = 9, 27; $P = 0.4635$). Significantly more sulfone residue was found in plants treated by precision placement at rates of 0.71, 1.44, 2.87, and 5.74 kg product per ha compared to untreated plants ($F = 11.68$; df = 9, 27; $P < 0.0001$). Significantly more sulfoxide residue was found in plants treated by precision placement at a rate of 2.87 and 5.74 kg product per ha ($F = 9.01$, df = 9, 27; $P < 0.0001$).

At 50 days after planting, plants from all treatments had comparable levels of aldicarb residues (Table 2.25) ($F = 3.01$; df = 9, 27; $P = 0.0128$). Significantly more sulfone residue was found in plants treated by precision placement at a rate of 5.74 kg product per ha ($F = 7.19$; df = 9, 27; $P < 0.0001$). No detectable levels of sulfoxide metabolite were found for any treatment.

## Discussion

The tests in this study evaluated the efficacy of various rates of precision-placed aldicarb treatments in comparison with in-furrow treatments for the control of tobacco thrips in seedling cotton. Residual analysis of treated plants was conducted to further validate the efficacy data obtained from sampling. Thrips counts indicated that precision-placed rates of aldicarb significantly reduced tobacco thrips relative to the untreated check. Furthermore, precision-placed rates were as effective in reducing tobacco thrips as the standard in-furrow rate of 3.92 kg product per ha, but at rates that were reduced by one half or more. Precision-placed rates as low as 0.18 and 0.71 kg Temik® were as effective in controlling thrips as the standard in-furrow rate of 3.92 kg Temik® per ha.

Plants receiving precisely placed aldicarb treatments had less thrips damage when compared to the untreated check. Damage to plants in precision placement treated plots was comparable to plants treated with the standard in-furrow rate of 3.92 kg product per ha. In general, plants treated with precision-placed treatments grew in a similar manner as in-furrow treated plants. However plants receiving higher precision placement rates had plants that demonstrated some symptoms of phytotoxic burn during the first 30 days of growth but seemed to recover with no significant differences in yield observed for any treatment.

In general, precision-placed aldicarb treatments appeared to have no adverse influence on yields. Precision placement treated plots produced yields that were as high as the yields obtained from plots treated with the standard in-furrow rate of 3.92 kg product per ha.

Analysis of aldicarb and aldicarb metabolite residues in cotton plants during the seedling stages showed that the insecticide quickly metabolizes into sulfone and is present in the plant at significant levels until 30 days after planting. Sulfone metabolizes into sulfoxide which is present in the plant until 30 days after planting. At 50 days after planting, only trace amounts of aldicarb metabolites remain in the plant. Comparison of residue levels showed that aldicarb metabolite levels were significantly higher in plants treated by precision placement compared to those receiving traditional in-furrow treatment.

Residual analysis verified that precision placement delivers more aldicarb to growing plants in comparison to in-furrow treatments. Thus, more aldicarb reaches the growing plant. The higher levels of aldicarb and aldicarb metabolites found in cotton seedlings during the first 30 days after planting/treatment appear to be the critical component for managing thrips infestations. Maximum residual levels during this 30-day period correspond with the peak thrips infestations found on cotton seedlings during the first 30 days after planting. When thrips populations are at their highest on small cotton plants, aldicarb residues are also at their peak levels. As the plant grows, thrips levels and aldicarb residues diminish.

The efficacy tests in these studies show that the development of the technology for precision placement of aldicarb with cotton seed during planting could be a valuable innovation for the management of thrips in cotton. Tests indicate that field rates of precision-placed aldicarb may be reduced by one half or more and still achieve similar thrips control as conventional in-furrow treatments.

The thrips counts and residual analysis of plants obtained from these studies is helping to develop a clearer picture of what is happening in the field during in-furrow and precision placement of Temik®. Precision placement of aldicarb at planting appears to significantly increase the amount of aldicarb that actually reaches the growing cotton seedling. The efficacy data as well as the information obtained through residual analysis in this study shows that precision placement may enhance the efficiency of using high-risk pesticides such as aldicarb at levels that are environmentally sound and significantly less costly for growers.

**Acknowledgements**

The author expresses appreciation to Kurk Lance, Patrick McPherson, Dean Kemp, and the University of Georgia's Agricultural Experiment Station and field crews for field assistance during this study, to Dr. Phillip Roberts and the late Dr. Gary Herzog for technical support, and to the Georgia Agricultural Commodity Commission for Cotton for funding.

**References:**

**Coppedge, J. R., D. A. Lindquist, D. L. Bull, and H. W. Dorough. 1967.** Fate of 2-methyl-2-((methylthio)priopionaldehyde ) *O*-(Methylcarbamoyl) oxime (Temik®) in cotton plants and soil. J. Agric. Food Chem. 15(5): 902-910.

**Davidson, R. H., L. M. Peairs, and W. F. Lyon. 1979.** Insect Pests of Farm, Garden, and Orchard. 7th ed.Wiley and Sons. New York.

**EXTOXNET. Extension Toxicology Network. 1997.** Pesticide Information Profile. http://ace.orst.edu/cgi-bin/mfs/01/pips/aldciarb.htm.

**Hardee, D. D. 2001.** 54th annual conference report on cotton insect research and control. *In* Proceedings of the Beltwide Cotton Conference. 2000. National Cotton Council. pp. 741-743.

**Howard, P. H. 1991.** Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume III. Lewis Publishers, Chelsea, MI.

**Martin, J. H. and W. H. Leonard. 1967.** Principles of Field Crop Production. The Macmillan Co., New York, NY. 1044 pp.

**Montgomery, J.H. 1993**. Agrochemicals desk reference. Environmental data. Lewis Publishers. Chelsea MI.

**SAS Institute. 2000.** SAS user's guide: statistics. Version 8.2. SAS Institute, Cary, NC.

**Williams, M. R. 2000.** Cotton Insect Loss Estimates - 1999. *In* Proceedings of the Beltwide Cotton Conference. 2000. National Cotton Council. pp. 884-887.

**Williams, M. R. 2001.** Cotton Insect Loss Estimates - 2000. *In* Proceedings of the Beltwide Cotton Conference. 2001. National Cotton Council. pp. 774-776.

**Wiseman, B. R., F. M. Davis, and J. E. Campbell. 1980.** Mechanical infestation device used in fall armyworm *Spodoptera frugiperda* plant resistance programs. Florida Entomol. 63: 424-232.

Table 2.1. Mean number of thrips sampled per plot from cotyledon stage plants on 24 May 1999, 12 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method kg product per ha | Mean # of Thrips per 10 plants[a] ± SE Larvae | Adults | Total (larvae + adults) |
|---|---|---|---|
| 0.18 precision placed | 0.5±0.3a | 1.3±1.0a | 1.8±1.1a |
| 0.71 precision placed | 0.0±0.0a | 2.0±0.9a | 2.0±0.8a |
| 1.44 precision placed | 0.5±0.3a | 1.3±0.8a | 1.8±0.9a |
| 2.15 precision placed | 0.8±0.3a | 1.2±0.5a | 2.0±0.8a |
| 2.87 precision placed | 1.2±0.3a | 0.8±0.5a | 2.0±1.1a |
| 5.74 precision placed | 0.0±0.0a | 3.8±1.5a | 3.8±1.5a |
| 0.28 in-furrow | 0.3±0.3a | 2.5±0.6a | 2.8±0.6a |
| 0.56 in-furrow | 0.0±0.0a | 2.0±0.4a | 2.0±0.4a |
| 1.12 in-furrow | 0.0±0.0a | 2.0±0.6a | 2.0±0.9a |
| 3.92 in-furrow | 0.0±0.0a | 0.8±0.5a | 0.8±0.5a |
| 7.85 in-furrow | 0.0±0.0a | 2.8±0.6a | 2.8±0.5a |
| check | 0.8±0.3a | 5.0±0.4a | 5.8±0.5a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.2. Mean number of thrips sampled per plot from 2-leaf stage plants on 3 June 1999, 22 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 1.3±0.9c | 3.5±0.9abc | 4.8±1.7c |
| 0.71 precision placed | 1.3±0.8c | 0.7±0.5cd | 2.0±0.4c |
| 1.44 precision placed | 2.3±0.9c | 0.0±0.0d | 2.3±0.9c |
| 2.15 precision placed | 4.0±3.3c | 3.8±1.0abc | 7.8±3.9bc |
| 2.87 precision placed | 7.5±7.2bc | 1.5±0.3bcd | 9.0±7.3c |
| 5.74 precision placed | 2.0±1.7c | 1.5±0.5bcd | 3.5±1.6c |
| 0.28 in-furrow | 20.3±7.8ab | 5.0±1.7ab | 25.3±6.9ab |
| 0.56 in-furrow | 6.5±4.3bc | 4.0±1.1abc | 0.5±5.0bc |
| 1.12 in-furrow | 7.8±5.3abc | 6.0±1.3ab | 13.8±5.1abc |
| 3.92 in-furrow | 1.0±0.4c | 4.0±1.2abc | 5.0±1.1c |
| 7.85 in-furrow | 3.8±2.5bc | 1.5±0.6bcd | 5.3±2.5c |
| check | 23.5±6.5a | 11.3±3.3a | 34.8±9.0a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.3. Mean number of thrips sampled per plot from 4-leaf stage plants on 14 June 1999, 33 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 6.0±1.8abcd | 16.3±4.3ab | 22.3±6.0abc |
| 0.71 precision placed | 3.0±1.1abcde | 15.5±2.3ab | 18.5±3.3abc |
| 1.44 precision placed | 0.8±0.5cde | 6.2±1.1bc | 7.0±1.4cd |
| 2.15 precision placed | 1.8±0.6bcde | 6.5±3.4bc | 8.3±3.6cd |
| 2.87 precision placed | 0.3±0.3e | 2.7±1.3c | 3.0±1.3d |
| 5.74 precision placed | 1.5±1.0cde | 5.0±2.0bc | 6.5±2.4cd |
| 0.28 in-furrow | 12.5±3.5a | 17.5±4.3ab | 30.0±7.0a |
| 0.56 in-furrow | 8.5±3.2abc | 16.8±2.4ab | 25.3±4.8ab |
| 1.12 in-furrow | 11.8±5.1ab | 24.5±5.4a | 36.3±7.0a |
| 3.92 in-furrow | 1.0±1.0de | 8.8±2.1abc | 9.8±2.5bcd |
| 7.85 in-furrow | 0.5±0.3de | 6.5±2.3bc | 7.0±2.3cd |
| check | 14.0±3.0a | 24.8±5.7a | 38.8±8.6a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.4. Mean number of thrips sampled per plot from cotyledon stage plants on 15 May 2000, 9 days after application of aldicarb by in-furrow or by precision placement of granules, Costal Plain Experiment Station.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 9.5±4.8a | 16.5±2.6ab | 26.0±7.1ab |
| 0.71 precision placed | 0.8±0.8a | 3.5±1.8cd | 4.3±1.8c |
| 1.44 precision placed | 0.5±0.3a | 4.8±1.5bcd | 5.3±0.5c |
| 2.87 precision placed | 0.3±0.3a | 2.2±0.5d | 2.5±1.9c |
| 5.74 precision placed | 0.3±0.3a | 5.2±1.7bcd | 5.5±0.9c |
| 0.28 in-furrow | 1.8±1.2a | 13.2±2.7abc | 15.0±3.8abc |
| 0.56 in-furrow | 1.8±0.8a | 10.5±2.5abcd | 12.3±2.0abc |
| 1.12 in-furrow | 1.0±0.7a | 9.5±2.3abcd | 10.5±2.8bc |
| 3.92 in-furrow | 0.8±0.3a | 3.5±1.6cd | 4.3±1.7c |
| check | 9.0±7.4a | 26.8±7.7a | 35.8±13.4a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.5. Mean number of thrips sampled per plot from 2-leaf stage plants on 24 May 2000, 20 days after application of aldicarb by in-furrow or by precision placement of granules, Coastal Plain Experiment Station.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 40.5±19.6ab | 8.3±1.7a | 48.8±21.5ab |
| 0.71 precision placed | 17.8±4.8ab | 7.5±1.0a | 25.3±5.6ab |
| 1.44 precision placed | 7.5±2.7b | 5.8±2.2a | 13.3±1.4b |
| 2.87 precision placed | 10.3±4.0b | 4.2±0.9a | 14.5±4.9b |
| 5.74 precision placed | 8.3±3.3b | 6.7±0.9a | 15.0±3.8b |
| 0.28 in-furrow | 51.3±16.2ab | 4.7±1.7a | 56.0±17.9ab |
| 0.56 in-furrow | 36.0±15.1ab | 6.0±2.8a | 42.0±17.1ab |
| 1.12 in-furrow | 31.8±8.3ab | 9.5±2.5a | 41.3±10.4ab |
| 3.92 in-furrow | 12.3±3.7ab | 6.5±1.3a | 18.8±2.8ab |
| check | 70.8±15.8a | 9.8±4.1a | 80.5±19.4a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.6. Mean number of thrips sampled per plot from 4-leaf stage plants on 5 June 2000, 32 days after application of aldicarb by in-furrow or by precision placement of granules, Coastal Plain Experiment Station.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 2.0±1.4b | 3.0±0.7a | 5.0±2.0b |
| 0.71 precision placed | 24.5±6.3a | 2.5±0.3a | 27.0±6.1a |
| 1.44 precision placed | 7.0±1.4ab | 5.5±1.6a | 12.5±2.5ab |
| 2.87 precision placed | 17.3±6.1a | 2.7 ±1.1a | 20.0±7.1ab |
| 5.74 precision placed | 8.0±5.4ab | 3.8±1.6a | 11.8±6.1ab |
| 0.28 in-furrow | 10.5±2.8ab | 2.8±0.6a | 13.3±2.3ab |
| 0.56 in-furrow | 13.5±7.2ab | 4.5±2.3a | 18.0±6.8ab |
| 1.12 in-furrow | 9.2±3.1ab | 4.5±1.9a | 13.7±1.3ab |
| 3.92 in-furrow | 18.3±7.6a | 2.5±1.6a | 20.8±9.1ab |
| check | 9.0±2.4ab | 2.8±0.6a | 11.8±2.8ab |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.7. Mean number of thrips sampled per plot from cotyledon stage plants on 14 May 2001, 12 days after application of aldicarb by in-furrow or by precision placement of granules, Coastal Plain Experiment Station.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 0.3±0.3a | 3.7±0.3b | 4.0±0.4b |
| 0.71 precision placed | 0.0±0.0a | 5.8±1.3b | 5.8±1.3b |
| 1.44 precision placed | 0.0±0.0a | 1.8±0.9b | 1.8±0.8b |
| 2.87 precision placed | 0.0±0.0a | 5.3±0.8b | 5.3±0.8b |
| 5.74 precision placed | 0.3±0.3a | 2.3±1.1b | 2.6±1.0b |
| 0.28 in-furrow | 0.8±0.5a | 5.7±2.0b | 6.5±2.3b |
| 0.56 in-furrow | 0.3±0.5a | 4.7±1.9b | 5.0±1.8b |
| 1.12 in-furrow | 0.0±0.0a | 4.3±1.7b | 4.3±1.7b |
| 3.92 in-furrow | 0.0±0.0a | 2.0±1.1b | 2.0±1.1b |
| check | 0.8±0.5a | 35.5±6.2a | 36.3±5.8a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.8. Mean number of thrips sampled per plot from 2-leaf stage plants on 22 May 2001, 20 days after application of aldicarb by in-furrow or by precision placement of granules, Coastal Plain Experiment Station.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 14.0±3.7bcd | 7.0±2.2b | 21.0±5.1bcd |
| 0.71 precision placed | 37.3±10.4bc | 8.5±1.7ab | 45.8±10.5bc |
| 1.44 precision placed | 5.8±2.1cd | 5.0±1.2b | 10.8±1.8bcd |
| 2.87 precision placed | 7.3±3.4cd | 6.0±0.9b | 13.3±3.6bcd |
| 5.74 precision placed | 2.0±0.9d | 3.8±0.9b | 5.8±1.3d |
| 0.28 in-furrow | 41.8±3.3b | 8.0±1.4b | 49.8±3.9b |
| 0.56 in-furrow | 17.5±3.1bcd | 8.5±1.4ab | 26.0±4.2bcd |
| 1.12 in-furrow | 6.8±2.3bcd | 3.5±1.2b | 10.3±3.5cd |
| 3.92 in-furrow | 2.5±1.2d | 5.8±1.5b | 8.3±2.1d |
| check | 203.8±56.3a | 19.5±4.2a | 223.3±59.8a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.9. Mean number of thrips sampled per plot from 4-leaf stage plants on 1 June 2001, 30 days after application of aldicarb by in-furrow or by precision placement of granules, Coastal Plain Experiment Station.

| Rate/Application Method kg product per ha | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 44.5±16.1ab | 8.3±3.3ab | 52.8±19.2ab |
| 0.71 precision placed | 51.0±23.2ab | 9.3±1.2ab | 60.3±22.7ab |
| 1.44 precision placed | 21.0±3.6ab | 12.8±0.9ab | 36.8±4.1ab |
| 2.87 precision placed | 21.5±7.0ab | 10.3±1.8ab | 31.8±6.1ab |
| 5.74 precision placed | 5.0±1.9b | 4.0±1.9b | 9.0±3.5b |
| 0.28 in-furrow | 71.5±27.0a | 23.5±13.0a | 95.0±39.3a |
| 0.56 in-furrow | 82.5±34.1a | 10.3±2.8ab | 92.8±36.8a |
| 1.12 in-furrow | 35.3±11.1ab | 9.5±3.0ab | 44.8±13.8ab |
| 3.92 in-furrow | 23.8±3.6ab | 10.8±2.3ab | 34.6±3.2ab |
| check | 50.8±14.4a | 16.2±3.1ab | 67. 0±15.2a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.10. Mean number of thrips sampled per plot from cotyledon stage plants on 17 May 2001, 9 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 0.0±0.0a | 6.0±1.1de | 6.0±1.1cd |
| 0.71 precision placed | 0.0±0.0a | 14.3±3.4bcd | 14.3±3.4bc |
| 1.44 precision placed | 0.0±0.0a | 5.0±1.8de | 5.0±1.8cd |
| 2.87 precision placed | 0.0±0.00a | 2.3±1.3e | 2.3±1.3d |
| 5.74 precision placed | 0.5±0.3a | 5.3±1.0de | 5.8±0.9cd |
| 0.28 in-furrow | 0.5±0.3a | 26.5±6.0abc | 27.0±6.0ab |
| 0.56 in-furrow | 0.5±0.5a | 28.3±2.5ab | 28.8±2.8ab |
| 1.12 in-furrow | 0.8±0.5a | 26.5±6.5abc | 27.3±6.4ab |
| 3.92 in-furrow | 0.0±0.0a | 10.3±1.0cde | 10.3±1.0cd |
| check | 0.5±0.5a | 43.0±2.9a | 43.5±2.9a |

Means in a column followed by the same letter are not significantly different ($P$=0.05).

Table 2.11. Mean number of thrips sampled per plot from 2-leaf stage plants on 29 May 2001, 21 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 3.3±0.6c | 1.7±0.5bcd | 5.0±0.9cd |
| 0.71 precision placed | 7.3±2.1bc | 6.0±1.4abc | 13.3±3.3bc |
| 1.44 precision placed | 0.8±0.3c | 1.5±0.7cd | 2.3±0.8cd |
| 2.87 precision placed | 0.5±0.3c | 0.8±0.5d | 1.3±0.6d |
| 5.74 precision placed | 1.0±1.0c | 1.3±0.5cd | 2.3±1.3cd |
| 0.28 in-furrow | 36.5±11.4a | 10.8±0.5a | 47.3±11.3a |
| 0.56 in-furrow | 30.8±6.7a | 5.0±0.8abc | 35.8±6.5ab |
| 1.12 in-furrow | 19.8±6.3ab | 7.0±1.0ab | 26.8±5.6ab |
| 3.92 in-furrow | 5.0±2.0bc | 2.3±1.0bcd | 7.3±2.2cd |
| check | 41.0±5.0a | 9.0±1.78a | 50.0±6.2a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.12. Mean number of thrips sampled per plot from 4-leaf stage plants on 6 June 2001, 29 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 6.8±3.3def | 4.2±1.9a | 11.0±5.2def |
| 0.71 precision placed | 29.3±3.6abcd | 8.2±2.1a | 37.5±5.6abcd |
| 1.44 precision placed | 2.5±1.0ef | 5.5±1.9a | 8.0±1.2def |
| 2.87 precision placed | 1.8±1.2f | 2.0±0.8a | 3.8±0.6f |
| 5.74 precision placed | 3.8±2.5ef | 3.5±0.3a | 7.3±2.6ef |
| 0.28 in-furrow | 44.8±14.9abc | 6.7±1.8a | 51.5±16.4abc |
| 0.56 in-furrow | 50.0±6.0ab | 9.8±2.8a | 59.8±4.6ab |
| 1.12 in-furrow | 21.8±6.9bcde | 8.7±2.7a | 30.5±4.2bcde |
| 3.92 in-furrow | 10.0±2.4cdef | 5.8±1.0a | 15.±9.9cdef |
| check | 76.3±16.7a | 8.3±2.5a | 84.6±17.9a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.13. Mean number of thrips sampled per plot from 8+ leaf stage plants on 18 June 2001, 41 days after application of aldicarb by in-furrow or by precision placement of granules, Plant Sciences Farm.

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | Larvae | Adults | Total (larvae + adults) |
| 0.18 precision placed | 4.5±2.6ab | 3.8±1.9a | 8.3±1.8abc |
| 0.71 precision placed | 9.5±2.8a | 5.8±1.8a | 15.3±2.9ab |
| 1.44 precision placed | 6.5±3.1ab | 5.0±2.1a | 11.5±5.0abc |
| 2.87 precision placed | 0.5±0.5b | 2.3±0.9a | 2.8±1.1c |
| 5.74 precision placed | 0.3±0.3b | 3.5±0.9a | 3.8±0.6bc |
| 0.28 in-furrow | 14.3±4.2a | 5.7±0.5a | 20.0±4.2a |
| 0.56 in-furrow | 17.3±4.3a | 8.0±2.4a | 25.3±5.8a |
| 1.12 in-furrow | 6.5±1.5ab | 10.3±2.2a | 16.8±1.8a |
| 3.92 in-furrow | 3.8±1.8ab | 4.5±1.2a | 8.3±1.7abc |
| check | 9.0±2.68a | 7.3±1.4a | 16.3±3.2ab |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 2.14. Thrips damage assessment for cotton seedlings in the treated rows of each plot for 24 May 2000 and 22 May 2001, Coastal Plain Experiment Station.

Damage Scale:
1 = no damage   3 = moderate leaf curl and stunting   5 = severe damage and stunting, missing seedlings
2 = slight leaf curl   4 = heavy leaf distortion

| Rate/Application Method | Mean thrips damage rating ± SE | |
|---|---|---|
| kg product per ha | 24 May 2000 | 22 May 2001 |
| 0.18 precision placed | 3.25±0.14a | 2.25±0.14bc |
| 0.71 precision placed | 1.88±0.31bcd | 2.75±0.14abc |
| 1.44 precision placed | 1.75±0.14cd | 2.13±0.31bc |
| 2.87 precision placed | 1.39±0.38d | 2.00±0.20bc |
| 5.74 precision placed | 1.38±0.24d | 1.63±0.13c |
| 0.28 in-furrow | 2.88±0.13ab | 2.88±0.47ab |
| 0.56 in-furrow | 3.00±0.0a | 2.75±0.14abc |
| 1.12 in-furrow | 2.68±0.24abc | 2.63±0.24bc |
| 3.92 in-furrow | 1.75±0.13bcd | 2.00±0.29bc |
| check | 3.63±0.24a | 3.88±0.13a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.15. Mean plant heights for cotton plants 49 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, PSF 1999.

| Rate/Application Method<br>kg product per ha | Mean Plant Height ± SE(cm) |
|---|---|
| 0.18 precision placed | 30.08±2.8ab |
| 0.71 precision placed | 31.3±3.4a |
| 1.44 precision placed | 31.1±5.9a |
| 2.15 precision placed | 33.5±3.6a |
| 2.87 precision placed | 29.8±3.8ab |
| 5.74 precision placed | 29.6±4.3ab |
| 0.28 in-furrow | 27.3±3.4ab |
| 0.56 in-furrow | 29.0±3.2ab |
| 1.12 in-furrow | 31.0±4.15ab |
| 3.92 in-furrow | 29.4±4.1ab |
| 7.85 in-furrow | 28.4±4.1ab |
| check | 22.7±3.1b |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.16. Mean plant heights for cotton plants approximately 50 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Coastal Plain Experiment Station 2000 and 2001, and Plant Sciences Farm 2001.

| Rate/Application Method | Mean Plant Height ± SE(cm) | | |
|---|---|---|---|
| kg product per ha | CPES 2000 | CPES 2001 | PSF 2001 |
| 0.18 precision placed | 44.0±3.0a | 38.4±2.0ab | 24.6±0.5a |
| 0.71 precision placed | 47.2±2.1a | 46.5±1.7a | 24.4±0.6a |
| 1.44 precision placed | 44.6±1.1a | 44.4±2.2a | 24.6±3.0a |
| 2.87 precision placed | 44.8±2.1a | 42.0±0.8ab | 21.8±2.3a |
| 5.74 precision placed | 44.7±2.7a | 39.3±0.9ab | 23.9±2.2a |
| 0.28 in-furrow | 45.9±0.9a | 42.7±2.8ab | 22.5±2.6a |
| 0.56 in-furrow | 46.4±3.5a | 43.0±2.4a | 19.7±3.4a |
| 1.12 in-furrow | 48.5±1.7a | 44.1±1.3a | 20.8±2.4a |
| 3.92 in-furrow | 48.7±2.2a | 43.4±4.3a | 18.9±2.8a |
| check | 40.3±2.5a | 31.8±2.6b | 22.5±4.1a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.17. Phytotoxicity ratings for cotyledon stage plants approximately 12 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Coastal Plain Experiment Station 2000 and 2001.

Phytoxicity Scale:

0 = no aldicarb effect
1 = slight leaf chlorosis
3 = moderate chlorosis; some browning and stuntings
4 = heavy browning of foliage and stunting to plants

| Rate/Application Method kg product per ha | Mean Phytotoxicity Rating ± SE 2000 | 2001 |
|---|---|---|
| 0.18 precision placed | 1.00±0.00c | 0.00±0.00b |
| 0.71 precision placed | 1.75±0.33bc | 0.25±0.25b |
| 1.44 precision placed | 2.50±0.33ab | 1.75±0.25a |
| 2.87 precision placed | 2.25±0.33ab | 2.00±0.41a |
| 5.74 precision placed | 2.75±0.33a | 2.50±0.50a |
| 0.28 in-furrow | 1.00±0.00c | 0.00±0.00b |
| 0.56 in-furrow | 1.00±0.00c | 0.00±0.00b |
| 1.12 in-furrow | 1.00±0.00c | 0.00±0.00b |
| 3.92 in-furrow | 1.00±0.00c | 0.00±0.00b |
| check | 1.00±0.00c | 0.00±0.00b |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.18. Mean seed cotton yield for plants 170 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Plant Sciences Farm 1999.

| Rate/Application Method kg product per ha | Mean Yield ± SE (kg seed cotton/ha) |
|---|---|
| 0.18 precision placed | 2118.4±93.0a |
| 0.71 precision placed | 2157.2±139.5a |
| 1.44 precision placed | 2242.7±235.3a |
| 2.15 precision placed | 2273.1±215.0a |
| 2.87 precision placed | 2326.7±169.8a |
| 5.74 precision placed | 2235.0±197.8a |
| 0.28 in-furrow | 2288.9±205.7a |
| 0.56 in-furrow | 2574.0±258.8a |
| 1.12 in-furrow | 2164.6±229.8a |
| 3.92 in-furrow | 2233.8±282.3a |
| 7.85 in-furrow | 2186.8±205.7a |
| check | 1858.9±229.2a |

Means in a column followed by the same letter are not significantly different ($P$=0.05).

Table 2.19. Mean seed cotton yield for plants approximately 165 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Coastal Plain Experiment Station 2000 and 2001, and Plant Sciences Farm 2001.

| Rate/Application Method kg product per ha | Mean Yield ± SE(kg seed cotton/ha) CPES 2000 | CPES 2001 | PSF 2001 |
|---|---|---|---|
| 0.18 precision placed | 2431.2±101.1a | 2551.3±85.2ab | 4157.8±280.9a |
| 0.71 precision placed | 2515.5±103.3a | 2875.0±128.9a | 3330.3±132.3ab |
| 1.44 precision placed | 2226.8±104.5a | 2830.2±70.6a | 3379.4±88.8ab |
| 2.87 precision placed | 2476.5±49.1a | 2875.2±39.5a | 2612.7±157.4ab |
| 5.74 precision placed | 2305.5±160.1a | 2782.2±40.5a | 1899.7±171.9b |
| 0.28 in-furrow | 2325.2±27.1a | 2509.2±66.7ab | 1753.3±293.2b |
| 0.56 in-furrow | 2362.4±83.7a | 2590.8±127.3ab | 1732.2±238.3b |
| 1.12 in-furrow | 2403.5±126.2a | 2661.2±56.0ab | 2774.5±133.5ab |
| 3.92 in-furrow | 2481.6±85.8a | 2717.5±30.0ab | 1926.7±372.9b |
| check | 1961.7±132.3a | 2185.3±104.7b | 1618.5±202.7b |

Means in a column followed by the same letter are not significantly different ($P$=0.05).

Table 2.20. Mean aldicarb and aldicarb metabolite residue levels in cotyledon stage plants 10 days after planting, Plant Sciences Farm 1999.

| Rate/Application Method kg product per ha | Residue levels in ppm ± SE | | |
|---|---|---|---|
| | Aldicarb | Sulfone | Sulfoxide |
| 0.71 precision placed | 0.13±0.09b | 6.14±1.62ab | 23.85±5.72bc |
| 1.44 precision placed | 0.54±0.34b | 7.96±2.38a | 36.52±7.92b |
| 2.87 precision placed | 2.61±0.61a | 8.98±1.62a | 73.13±11.84a |
| 0.56 in-furrow | 0.08±0.02b | 0.82±0.17c | 1.60±0.19c |
| 3.92 in-furrow | 0.10±0.00b | 2.52±0.26bc | 5.05±1.21c |
| check | 0.03±0.01b | 0.06±0.00c | 0.15±0.05c |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.21. Mean aldicarb and aldicarb metabolite residue levels in 4-leaf stage plants 30 days after planting, Plant Sciences Farm 1999.

| Rate/Application Method kg product per ha | Residue levels in ppm ± SE | | |
|---|---|---|---|
| | Aldicarb | Sulfone | Sulfoxide |
| 0.71 precision placed | 0.44±0.14a | 4.72±09.0a | 2.83±0.55a |
| 1.44 precision placed | 0.06±0.01b | 3.92±0.68a | 3.90±1.38a |
| 2.87 precision placed | 0.05±0.00b | 5.01±1.86ab | 4.64±2.25a |
| 0.56 in-furrow | 0.05±0.00b | 0.91±0.17ab | 0.32±0.12a |
| 3.92 in-furrow | 0.05±0.00b | 1.60±0.39ab | 2.21±1.06a |
| check | 0.05±0.00b | 0.07±0.03b | 0.10±0.01a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.22. Mean aldicarb and aldicarb metabolite residue levels in cotyledon stage plants 10 days after planting, Coastal Plain Experiment Station 2000.

| Rate/Application Method | Residue levels in ppm ± SE | | |
|---|---|---|---|
| kg product per ha | Aldicarb | Sulfone | Sulfoxide |
| 0.18 precision placed | 1.23±0.53ab | 11.12±1.83bc | 2.11±1.31b |
| 0.71 precision placed | 20.57±15.62ab | 60.75±19.50abc | 45.34±21.15 |
| 1.44 precision placed | 29.39±5.21ab | 66.91±7.76ab | 60.49±25.49ab |
| 2.87 precision placed | 20.60±6.61ab | 102.55±10.25a | 54.91±17.9ab |
| 5.74 precision placed | 57.51±35.08a | 116.67±30.80a | 122.16±55.53a |
| 0.28 in-furrow | 1.29±0.50ab | 14.29±6.09bc | 2.40±1.16b |
| 0.56 in-furrow | 1.18±0.71ab | 11.66±1.38bc | 1.11±0.28b |
| 1.12 in-furrow | 1.76±1.07ab | 28.20±3.66bc | 4.78±3.59b |
| 3.92 in-furrow | 1.36±0.29ab | 34.11±4.59bc | 15.41±5.56b |
| check | 0.30±0.26b | 0.88±0.20c | 0.10±0.01a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.23. Mean aldicarb and aldicarb metabolite residue levels in 2-leaf stage plants 20 days after planting, Coastal Plain Experiment Station 2000.

| Rate/Application Method kg product per ha | Residue levels in ppm ± SE | | |
|---|---|---|---|
| | Aldicarb | Sulfone | Sulfoxide |
| 0.18 precision placed | 0.00±0.00b | 4.26±0.30bcd | 2.80±0.96bc |
| 0.71 precision placed | 0.10±0.06b | 6.08±0.76abcd | 29.93±7.93a |
| 1.44 precision placed | 0.25±0.41ab | 7.70±0.47ab | 27.05±4.63a |
| 2.87 precision placed | 0.16±0.01ab | 6.81±0.61abc | 20.78±4.68ab |
| 5.74 precision placed | 0.63±0.29a | 10.50±3.33a | 25.24±5.72a |
| 0.28 in-furrow | 0.00±0.00b | 3.11±0.66bcd | 0.00±0.00c |
| 0.56 in-furrow | 0.00±0.00b | 2.42±0.27bcd | 1.16±0.13bc |
| 1.12 in-furrow | 0.00±0.00b | 1.81±0.72cd | 2.48±1.01bc |
| 3.92 in-furrow | 0.02±0.02b | 5.06±0.45abcd | 23.83±7.96a |
| check | 0.00±0.00b | 0.39±0.22d | 0.00±0.00c |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.24. Mean aldicarb and aldicarb metabolite residue levels in 4-leaf stage plants 30 days after planting, Coastal Plain Experiment Station 2000.

| Rate/Application Method kg product per ha | Residue levels in ppm ± SE | | |
|---|---|---|---|
| | Aldicarb | Sulfone | Sulfoxide |
| 0.18 precision placed | 0.00±0.00a | 0.64±0.17cd | 0.00±0.00c |
| 0.71 precision placed | 0.00±0.00a | 2.34±0.78bcd | 1.34±1.34bc |
| 1.44 precision placed | 0.00±0.00a | 3.44±0.42ab | 0.00±0.00c |
| 2.87 precision placed | 0.00±0.00a | 3.47±0.44ab | 5.00±0.60ab |
| 5.74 precision placed | 0.00±0.00a | 4.09±0.67a | 8.02±2.54a |
| 0.28 in-furrow | 0.58±0.06a | 1.01±0.33bcd | 0.00±0.00c |
| 0.56 in-furrow | 0.00±0.00a | 0.35±0.14cd | 0.00±0.00c |
| 1.12 in-furrow | 0.00±0.00a | 0.72±0.27cd | 0.00±0.00c |
| 3.92 in-furrow | 0.00±0.00a | 1.37±0.37bcd | 0.00±0.00c |
| check | 0.00±0.00a | 0.00±0.00d | 0.00±0.00c |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 2.25. Mean aldicarb and aldicarb metabolite residue levels in 8+ leaf plants 50 days after planting, Coastal Plain Experiment Station 2000.

| Rate/Application Method kg product per ha | Residue levels in ppm ± SE | | |
|---|---|---|---|
| | Aldicarb | Sulfone | Sulfoxide |
| 0.18 precision placed | 0.00±0.00b | 0.00±0.00b | ND |
| 0.71 precision placed | 0.37±0.22ab | 0.16±0.07b | ND |
| 1.44 precision placed | 0.17±0.12ab | 0.29±0.13b | ND |
| 2.87 precision placed | 0.07±0.04ab | 0.53±0.10ab | ND |
| 5.74 precision placed | 0.11±0.04ab | 1.04±0.33a | ND |
| 0.28 in-furrow | 0.44±0.14ab | 0.00±0.00b | ND |
| 0.56 in-furrow | 0.65±0.32a | 0.00±0.00b | ND |
| 1.12 in-furrow | 0.03±0.03b | 0.08±0.08b | ND |
| 3.92 in-furrow | 0.02±0.02b | 0.30±0.19ab | ND |
| check | 0.21±0.02ab | 0.00±0.00b | ND |

Means in a column followed by the same letter are not significantly different (*P*=0.05).
ND = No residue detected.

CHAPTER III

# REDUCING ALDICARB USE IN COTTON FOR THRIPS MANAGEMENT BY UTILIZATION OF PRECISION INSECTICIDE PLACEMENT AND CULTURAL CONTROL PRACTICES[1]

---

Lohmeyer, K. H., J. N. All, and P. M. Roberts. To be submitted to Journal of Economic Entomology.

**ABSTRACT** Field studies were conducted to evaluate the effectiveness of precision-placed aldicarb treatments (placing the insecticide only with the seed at planting rather than along the entire furrow) in combination with planting and tillage practices for the control of tobacco thrips, *Frankliniella fusca* (Hinds), in seedling cotton. In 2000, a test was performed to evaluate ultra-narrow row and conventional row planting practices in combination with conservation tillage and selected rates of in-furrow and precision-placed aldicarb treatments. Thrips populations were low throughout this test, possibly due to drought conditions and a late planting date. No interaction between tillage practices and planting/aldicarb treatments was observed for any life stage on any sampling date. On the first sampling date, adult and total thrips (adult + larvae) populations were lower in conservation tillage plots when compared to conventional tillage plots. On the second sampling date, larval thrips populations were significantly lower in conservation tillage plots in comparison with conventional tillage plots. The use of ultra-narrow row planting did not appear to increase thrips populations in comparison to conventional row planting. No significant differences in plant heights were observed between conservation and conventional tillage plots or for any planting/aldicarb treatment in comparison with the conventional row check. In 2001, studies were conducted to evaluate the effectiveness of varying rates of precision-placed aldicarb treatments in combination with conservation tillage. Thrips population counts were reduced in conservation tillage plots. No interaction between tillage practices and aldicarb treatments was observed for any sampling date or life stage. Precision-placed aldicarb treatments significantly reduced thrips infestations in comparison with the untreated check and were as effective in reducing thrips populations as the standard in-furrow 3.92

kg product per ha rate. Precision-placed aldicarb at rates of 1.44, 2.87, and 5.84 showed the greatest reduction in thrips populations. Plants from conservation tillage plots were significantly taller than plants from conventional tillage plots. Plants from precision placement treated plots were as tall as plants from plots treated with the standard in-furrow rate. No significant differences in yield were observed between conservation and conventional tillage plots. Yields from precision placement treated plots were as high as those from plots treated with the standard in-furrow rate. Results of these tests indicate that precision placement of aldicarb at planting in combination with conservation tillage could result in a substantial reduction in the amount of aldicarb needed for managing thrips infestations in seedling cotton. Application of a system of this type could result in substantial savings in grower costs as well as a reduction in environmental hazards without a reduction in yield.

KEY WORDS: ultra-narrow row, cotton, aldicarb, Temik®15G, *Frankliniella fusca*, conservation tillage.

## Introduction

One of the most common management practices for controlling thrips infestations in seedling cotton is the use of aldicarb (Temik® 15G) applied in-furrow at-planting. Approximately 680,389 kg of aldicarb are applied annually to cotton in the United States (Williams 2000). Aldicarb is an effective control measure, but it is considered to be one of the most acutely toxic systemic pesticides available for use and poses considerable environmental risks (EXTOXNET 1997, Howard 1991).

One of the most important concerns facing agriculture today is the struggle to control pests in a manner that is both effective and environmentally sound. Current farming technology allows for the placement of seed in-furrow in exact, specific locations. This idea of precision placement can also be applied to insecticide use. Placing the insecticide along with the seed in a specific location would be a more efficient technique of applying planting-time insecticides. If effective, this type of insecticide use could decrease the cost and amount of insecticide needed as well as decreasing human health and environmental risks.

Field tests have shown that precision placement is an effective method for reducing aldicarb rates without affecting efficacy against thrips in cotton (Lohmeyer et al. 2001, All et al. 2000, Roberts et al. 1998). In these studies, various rates of aldicarb were applied at planting by both conventional in-furrow treatments and precision placement of aldicarb along with the seed. Rates of precision-placed aldicarb were found to be as efficient at controlling thrips as the standard 3.92 kg product per ha in-furrow rate, but at rates that were reduced by up to 50%. Residual analysis of treated plants found that aldicarb metabolite levels were higher in plants treated with precision placement

(Lohmeyer et al 2001). Residual levels were highest during the first 20 days after planting and then decreased dramatically by day 50. Higher aldicarb metabolite levels appear to coincide with thrips population peaks, as thrips usually infest only early season plants.

One aspect of thrips management in cotton is the possible utilization of certain cultural practices such as conservation tillage or ultra-narrow row planting as a means of influencing pest populations. Previous research has shown that thrips populations are reduced in cotton that has been planted after a cover crop such as wheat, clover, or canola (All et al. 1992, All 1995, All 1996a, All et al. 1994). Ultra-narrow row planting has been shown to be a viable option for reducing cotton production costs while maintaining yield, but little is known about its effects on pest insect infestations (Jost and Cothren 2000). Preliminary studies have shown that ultra-narrow row planting may increase adult thrips populations (Harris et al.1998).

Precision placement of aldicarb has shown promise as an improved method of thrips control at reduced rates. Cultural control practices such as conservation tillage and ultra-narrow row planting may also decrease thrips numbers in early season cotton. This study was initiated to determine if precision placement of aldicarb in combination with cultural practices such as conservation tillage or ultra-narrow row planting may be an effective method of further reducing aldicarb requirements in cotton.

## Materials and Methods

Experiments were conducted in 2000 and 2001 at the University of Georgia's Plant Sciences Farm (PSF) in Oconee County, near Watkinsville, Georgia. The PSF is located in the southern piedmont region of the state. The test site had Cecil coarse sandy loam soil. Bollgard™ NuCotn 33B cotton seed was used for both tests.

In 2000, a test was conducted to evaluate the efficacy of selected rates of precision-placed and in-furrow aldicarb treatments in combination with two types of cultural methods: 1) conservation versus conventional tillage practices, and 2) ultra-narrow-row spacing versus conventional row spacing methodologies. A split-block design with four-row plots, four replications, and one untreated check per replication was used. Conventional and conservation-tillage blocks were prepared in a field that had been previously planted with wheat. Conventional tillage plots were plowed and disked twice to prepare a smooth seedbed for planting. Cotton seed was planted on 2 June 2000. Conventional row plots were planted in a hill method with a two-row Monesem pneumatic planter. Hills were spaced 0.3 m apart in 1 m wide rows with three seeds per hill. Ultra-narrow row plots were planted with the rows 0.2 m apart using a Tye small grains planter and seed was spaced approximately 0.1 m apart within rows.

In 2001 a test was conducted to compare the efficacy of selected rates of precision placement and in-furrow aldicarb treatments in combination with conventional and strip-tillage practices. A split-block design with four row plots, four replications, and one untreated check was used. Conventional tillage and strip-tillage blocks had been prepared prior to planting in a field that had been previously planted with wheat. Conventional tillage blocks were plowed and disked twice to prepare a smooth seedbed for planting. Cotton seed was planted on 18 May 2001. Conventional tillage plots were planted using a two-row Monesem pneumatic planter. Strip-tillage plots were prepared with a KMC stripper/subsoiler implement followed by the same Monesem pneumatic planter utilized in the conventional tillage plots.

All the plots were planted with the furrow open. Varying rates of aldicarb were then applied to the two middle rows of each plot. Granular aldicarb was applied at planting using two methods: placement of the insecticide along the entire furrow with the seed, or precision placement of the insecticide directly on top of the seed in each hill with a “bazooka” type applicator that was constructed to direct calibrated quantities of insecticide granules onto the top of seed by a trap release system (Wiseman et al. 1980). All insecticide rates are specified as kg product per ha based on 0.965 m wide rows. The open furrows were closed with a garden hoe.

No other insecticides were used on the test plots for 2000 and 2001. Plots were irrigated as needed during the growing season and fertilized with PIX® fertilizer.

**Thrips Sampling.** For the 2000 test, cotton plants were sampled for thrips on 12 June (10 days after planting), 22 June (20 days after planting), 30 June (28 days after planting) and 21 July (49 days after planting). The 2001 test was sampled on 29 May (11 days after planting), 6 June (19 days after planting), 18 June (31 days after planting), and 2 July (45 days after planting).

Sampling consisted of selecting 10 plants at random from each plot and immersing them in a 120 ml specimen cup containing 60 ml of alcohol. On the last sampling date when plants were larger, only the upper portion of the plant was immersed in the containers. Samples were then taken to the laboratory where thrips were identified and counted using a dissecting scope. Voucher specimens were deposited at the University of Georgia’s Natural History Museum.

**Plant Heights.** For both tests, 10 plants were randomly selected from the treated rows of each plot and measured from the soil-line in centimeters. The terminal bud was used as the upper measurement point. Plant heights were taken on 26 July 2000 and 6 July 2001.

**Yield**. Due to a severe midseason drought and plant decline, the 2000 test was not harvested. Plots were mechanically harvested on 1 November 2001. Seed cotton was weighed in the field to determine yield.

**Statistical Analysis.** Thrips counts were square root transformed before analysis. Means for thrips counts, plant heights and seed cotton yield were analyzed using ANOVA. Treatment means were separated using Tukey's Studentized Range Test, with $P<0.05$ (SAS Institute 2000).

## Results

**Thrips Sampling.** For all tests, over 95% of the adult thrips sampled and counted were tobacco thrips, *Frankliniella fusca* (Hinds). A few western flower thrips, *F. occidentalis* (Pergrande) were also present.

**2000.** On 12 June, cotyledon stage cotton plants were primarily infested with adult thrips (Table 3.1). Significantly higher numbers of adult thrips were found in conventional tillage plots as compared to conservation tillage plots ($F = 7.47$; df = 1; 30; $P = 0.0104$). No interaction was observed between tillage practices and planting/aldicarb treatments for adult thrips ($F = 0.67$; df = 5, 20; $P = 0.6496$). No differences in adult thrips populations were observed between the conventional and ultra-narrow row checks; however all other planting/aldicarb treatments significantly reduced adult thrips populations when compared with the ultra-narrow row check ($F = 5.33$; df = 5, 30;

*P* = 0.0013). No significant differences in larval thrips populations were observed between conservation and conventional tillage plots (*F* = 0.06; df = 1, 30; *P* = 0.8009). No interaction was observed between tillage practices and planting/aldicarb treatments for larval thrips (*F* = 0.74; df = 5, 20; *P* = 0.6009). As populations were very low, no significant differences in larval thrips counts were observed for any planting/aldicarb treatment when compared with the conventional row/check (*F* = 0.89; df = 5, 30; *P* = 0.4985).

Significantly higher numbers of total thrips (larvae + adults) were found in conventional tillage when compared to conservation tillage (*F* = 7.87; df = 1, 30; *P* = 0.0087). No interaction between tillage practices and planting/aldicarb treatments was observed for total thrips (*F* = 2.55; df = 5, 20; *P* = 0.1263). No significant differences in total thrips populations were observed between the conventional row and ultra-narrow row checks; however all of the remaining planting/aldicarb treatments significantly reduced total thrips populations when compared to the ultra-narrow row check (*F* = 4.80; df = 5, 30; *P* = 0.0024).

Plants were in the 2-leaf stage on 22 June and were predominantly infested with larval thrips (Table 3.2). Significantly higher numbers of larval thrips were observed in conventional tillage plots when compared with conservation tillage plots (*F* = 4.31; df = 1, 30; *P* = 0.0467). No interaction was observed between tillage practices and planting/aldicarb treatments for larval thrips (*F* = 1.99; df = 5, 20; *P* = 0.1238). No significant differences in larval thrips were observed between the ultra-narrow and conventional row checks; however, ultra-narrow row/precision-placed aldicarb at 3.36 kg product per ha, ultra-narrow row/in-furrow aldicarb at 5.94 kg product per ha, and conventional row/in-furrow 3.92 kg product per ha significantly reduced larval thrips when compared with the ultra-narrow row check ($F = 8.84$; df = 5, 30; $P < 0.0001$).

No significant differences in adult thrips populations were observed between conventional and conservation tillage plots ($F = 3.65$; df = 1, 30; $P = 0.0657$). No interaction was observed between tillage practices and planting/aldicarb treatments for adult thrips ($F = 1.25$; df = 5, 20; $P = 0.3216$). No significant differences in adult thrips populations were observed for any treatment when compared with the conventional row check ($F = 1.73$; df = 5, 30; $P = 0.1586$).

No significant differences in total thrips were observed between conservation and conventional tillage plots ($F = 3.08$; df = 1, 30; $P = 0.892$). No interaction between tillage practices and planting/aldicarb treatments was observed for total thrips ($F = 1.77$; df = 5, 20; $P = 0.1657$). No significant differences in total thrips were observed between the ultra-narrow row and conventional row checks; however, ultra-narrow row/precision-placed aldicarb at 3.36 kg product per ha, ultra-narrow row/in-furrow aldicarb at 5.94 kg product per ha, and conventional row/in-furrow 3.92 kg product per ha significantly reduced total thrips when compared with the ultra-narrow row check ($F = 6.44$; df = 5, 30; $P = 0.0004$).

On 30 June cotton plants had four leaves and had low infestations of adult and larval thrips (Table 3.3). No significant differences in the numbers of adult, larval, or total thrips on plants were observed between conservation and conventional tillage plots (adult: $F = 0.03$; df = 1, 30; $P = 0.8730$; larval: $F = 0.38$; df = 1, 30; $P = 0.5397$; total:

*F* = 0.03; df = 1, 30; *P* = 0.8719). No interaction between tillage practices and planting/aldicarb treatments was observed for adult, larval or total thrips (adult: *F* = 1.50; df = 5, 20; *P* = 0.2344; larval: *F* = 0.43; df = 5, 20; *P* = 0.8211; total: *F* = 0.74; df = 5, 20; *P* = 0.6033). As thrips populations were very low, no differences in planting/aldicarb treatments were observed for adult, larval, or total thrips when compared to the conventional row check (adult: *F* = 1.11; df = 5, 30; *P* = 0.3764; larval: *F* = 1.63; df = 5, 30; *P* = 0.1829; total: *F* = 1.79; df = 5, 30; *P* = 0.1649).

On 21 July cotton plants had 8+ leaves and were infested with low populations of adult and larval thrips (Table 3.4). No significant differences in adult, larval, or total thrips were observed between conservation and conventional tillage plots (adult: *F* = 0.86; df = 1, 30; *P* = 0.3604; larval: *F* = 0.58; df = 1, 30; *P* = 0.4506; total: *F* = 0.22; df = 1, 30; *P* = 0.6426). No interaction between tillage practices and planting/aldicarb treatments was observed for adult, larval, or total thrips (adult: *F* = 0.11; df = 5, 20; *P* = 0.9894; larval: *F* = 0.47; df = 5, 20; *P* = 0.7953; total: *F* = 0.20; df = 5, 20; *P* = 0.9587). No significant differences in adult, larval or total thrips populations were observed for any planting/aldicarb treatment when compared with the conventional row check (adult: *F* = 0.50; df = 5, 30; *P* = 0.7757; larval: *F* = 0.22; df = 5, 30; *P* = 0.9506; total: *F* = 0.38; df = 5, 30; *P* = 0.8604).

**2001.** On 29 May, cotyledon stage plants were predominantly infested with adult thrips (Table 3.5). Very few larval thrips were observed. No significant differences in adult thrips were found between conventional and strip-tillage plots (*F* = 1.10; df = 1, 54; *P* = 0.2983). No interaction between tillage practices and aldicarb treatments was observed for adult thrips (*F* = 1.62; df = 9, 36; *P* = 0.1479). All of the precision-placed aldicarb treatments significantly reduced adult thrips populations in comparison with the untreated check except for the two lowest rates of 0.16, and 0.64 kg product per ha ($F$ = 16.59; df = 9, 54; $P$<0.0001). All the precision placement treatments were as effective at reducing adult thrips populations as the standard in-furrow 3.92 kg product per ha rate.

No significant differences in larval thrips populations were observed between conventional and strip-tillage practices on cotyledon stage plants ($F$ = 2.21; df = 1, 54; $P$ = 0.1429). No interaction between tillage practices and insecticide treatments was observed for larval thrips ($F$ = 0.57; df = 9, 36; $P$ = 0.8107). As larval thrips populations were low, no significant differences in larval thrips were observed for any treatment when compared to the untreated check ($F$ = 0.81; df = 9, 54; $P$ = 0.6118).

No significant differences in total thrips populations were found between conventional and strip-tillage plots ($F$ = 1.46; df = 1, 54; $P$ = 0.2327). No interaction between tillage practices and aldicarb treatments was observed for total thrips ($F$ = 1.52; df = 9, 36; $P$ = 0.1784). All precision placed treatments significantly reduced total thrips populations in comparison with the untreated check except precision-placed aldicarb at a rate of 0.64 kg product per ha ($F$ = 17.30; df = 9, 54; $P$ = 0.0001). All precision-placed treatments were as effective at reducing total thrips populations as the standard in-furrow rate of 3.92 kg product per ha.

Plants in the 2-leaf stage on 6 June were predominantly infested with larval thrips. Significantly higher numbers of larval thrips were found in conventional tillage plots as compared with strip-tillage plots (Table 3.6) ($F$ = 10.34; df = 1, 54; $P$ = 0.0022). No interaction was observed between tillage practices and aldicarb treatments for larval thrips ($F$ = 1.02; df = 9, 36; $P$ = 0.4414). All aldicarb treatments except for the lowest in-furrow rate of 0.28 significantly reduced larval thrips populations in comparison to the untreated check ($F$ = 17.95; df = 9, 54; $P$ =<0.0001). All the precision-placed aldicarb treatments were as effective in reducing larval thrips infestations as the standard in-furrow 3.92 kg product per ha rate. Precision-placed aldicarb treatments at rates of 1.44, 2.87, and 5.74 kg product per ha showed the greatest reduction in larval thrips populations when compared to the untreated check.

No significant differences in adult thrips were observed between conventional and strip-tillage plots ($F$ = 0.07; df = 1, 54; $P$ = 0.7956). No interaction between tillage practices and aldicarb treatments was observed for adult thrips ($F$ = 0.91; df = 9, 36; $P$ = 0.5314). All but the two lowest rates of precision-placed aldicarb treatments significantly reduced adult thrips populations in comparison with the untreated check ($F$ = 11.15; df = 9, 54; $P$ <0.0001). All precision-placed aldicarb treatments were as effective in reducing adult thrips infestations as the standard in-furrow rate of 3.92 kg product per ha rate.

Significantly higher numbers of total thrips were found in conventional tillage plots as compared with strip-tillage plots ($F$ = 9.47; df = 1, 54; $P$ = 0.0033). No interaction between tillage practices and aldicarb treatments was observed for total thrips ($F$ = 1.15; df = 9, 36; $P$ = 0.3549). All the precision-placed treatments significantly reduced total thrips infestations in comparison to the untreated check ($F$ = 19.17; df = 9, 54; $P$ < 0.0001). All of the precision-placed treatments were as effective in reducing total thrips as the standard in-furrow rate of 3.92 kg product per ha. Precision-placed aldicarb at rates of 1.44, 2.87, and 5.74 showed the most effective reduction in thrips control when compared with the untreated check.

On 18 June, plants had four leaves and were predominantly infested with larval thrips (Table 3.7). There were significantly higher numbers of larval thrips found in conventional tillage plots as compared with strip-tillage ($F = 20.49$; df = 1, 54; $P < 0.0001$). No interaction between tillage practices and aldicarb treatments were observed for larval thrips ($F = 2.96$; df = 9, 36; $P = 0.0098$). Treatments of precision-placed aldicarb at 1.44, 2.87, and 5.74 kg product per ha significantly reduced larval thrips populations when compared to the untreated check ($F = 11.46$; df = 9, 54; $P < 0.0001$). All precision-placed treatments were as effective at reducing larval thrips as the standard in-furrow rate of 3.92 kg product per ha.

Significantly higher numbers of adult thrips were found in conventional tillage plots as compared with strip-tillage plots ($F = 34.94$; df = 1, 54; $P < 0.0001$). No interaction between tillage practices and aldicarb treatments were observed for adult thrips ($F = 1.55$; df = 9, 36; $P = 0.1685$). No significant differences adult thrips populations were observed for any treatment in comparison to the untreated check ($F = 1.43$; df = 9, 54; $P = 0.2003$).

Significantly higher numbers of total thrips were found in conventional tillage plots as compared with strip-tillage plots ($F = 35.17$; df = 1, 54; $P < 0.0001$). No interaction between tillage practices and aldicarb treatments were observed for total thrips ($F = 1.33$; df = 9, 36; $P = 0.2357$). Precision-placed rates of 1.44, 2.87, and 5.74 kg product per ha significantly reduced total thrips populations in comparison with the untreated check ($F = 11.31$; df = 9, 54; $P =<0.0001$). All precision-placed rates were as effective at reducing total thrips populations as the standard in-furrow rate of 3.92 kg product per ha.

On 2 July plants had 8+ leaves and were infested with larval and adult thrips (Table 3.8). No significant differences in larval thrips were observed between conventional and strip-tillage plots ($F = 0.42$; df = 1, 54; $P = 0.5213$). No interaction between tillage practice and aldicarb treatments was observed for larval thrips ($F = 1.23$; df = 9, 36; $P = 0.3070$). As populations were relatively low, no significant differences in larval thrips populations were observed for any aldicarb treatment in comparison with the untreated check ($F = 1.15$; df = 9, 54; $P = 0.3442$).

No significant differences in adult thrips were observed between conventional and strip-tillage plots ($F = 1.05$; df = 1, 54; $P = 0.3110$). No interaction between tillage practices and aldicarb treatments was observed for adult thrips ($F = 1.87$; df = 9, 36; $P = 0.0882$). As adult thrips populations were low, no significant differences were observed for any aldicarb treatment in comparison with the untreated check ($F = 0.74$; df = 9, 54; $P = 0.6675$).

No significant differences in total thrips were observed between conventional and strip-tillage plots ($F = 1.49$; df = 1, 54; $P = 0.2273$). No interaction between tillage practices and aldicarb treatments was observed for total thrips ($F = 1.65$; df = 9, 36; $P = 0.139$). As with adult and larval thrips populations, no significant differences in total thrips were observed for any treatment when compared to the untreated check ($F = 1.17$; df = 9, 54; $P = 0.3322$).

**Plant Heights.** For the 2000 test, no significant differences in plant heights were observed between conventional and conservation tillage plots (Table 3.9) ($F = 0.04$;

df = 1, 30; $P = 0.8452$). No interaction between tillage practices and aldicarb treatments was observed for plant heights ($F = 2.41$; df = 5, 20; $P = 0.0699$). No significant differences in plant height were observed for any planting/aldicarb treatment when compared to the conventional row check ($F = 1.35$; df = 5, 30; $P = 0.2701$).

In the 2001 test, the plants from strip-tillage plots were significantly taller than plants from conventional plots (Table 3.10) ($F = 27.88$; df = 1, 54; $P < 0.0001$). No interaction between tillage practices and aldicarb treatments was observed for plant heights ($F = 0.67$; df = 9, 36; $P = 0.7283$). Plants from all precision placement treated plots were significantly taller than plants from the untreated check ($F = 16.52$; df = 9, 54; $P < 0.0001$). Plants from precision placement treated plots were as tall as plants from plots treated with the standard in-furrow 3.92 kg product per ha rate.

**Yield.** In 2001, no significant difference in yield was observed between conventional tillage plots and strip-tillage plots (Table 3.11) ($F = 3.55$; df = 1, 54; $P = 0.0560$). No interaction between tillage practices and aldicarb treatments was observed for yield ($F = 0.48$; df = 9, 36; $P = 0.8792$). Precision placement treated plots at rates of 1.44 and 2.87 had significantly higher yields in comparison with the untreated check ($F = 2.69$; df = 9, 54; $P = 0.0117$). All precision placement treated plots had as high a yield as the standard in-furrow rate of 3.92 kg product per ha.

## Discussion

The tests in this study demonstrate that precision placement of aldicarb in combination with conservation tillage may be an effective system for thrips management in cotton at rates that are considerably lower than the standard in-furrow rate currently used in Georgia. The 2000 test showed that precision-placed rates of aldicarb effectively reduced thrips infestations at rates half or less that of the standard in-furrow rate. In general thrips infestations were relatively low for this test, perhaps due to a dry growing season and/or a late planting date. On the first sampling date, when adult thrips infestations were at their highest for this test, significantly higher numbers of total and adult thrips were found in the conventional tillage plots when compared to the conservation tillage plots. On the second sampling date, when larval thrips populations were at their highest, significantly higher populations of larval thrips were found in the conventional tillage plots in comparison with the conservation tillage plots. As populations were low, no other differences in conventional and conservation tillage plots were observed for any other life stage on the last two sampling dates.

The use of ultra-narrow row planting practices in combination with aldicarb treatments did not appear to consistently influence thrips populations. On the first two sampling dates, when total thrips populations were at their highest, the ultra-narrow row check had the highest number of thrips present when compared to the other treatments. However, no significant differences in thrips populations were observed between the ultra-narrow row and conventional row checks. When ultra-narrow row planting practices were combined with the use of aldicarb, no notable differences in total thrips populations were observed in comparison with conventional planting practices/aldicarb treatments. No significant differences in planting/aldicarb treatments were observed for any life stage on the last two sampling dates in comparison with the ultra-narrow row or conventional row check. The use of ultra-narrow row planting practices did not appear to enhance thrips populations on seedling cotton when compared to conventional planting practices. This result was different from the work conducted by Harris and coworkers that found increased numbers of adult thrips in ultra-narrow row plots (Harris et al. 1998).

No significant differences in plant heights were observed between conservation and conventional row plots. No significant differences in plant heights were observed for any planting/aldicarb treatment in comparison with the conventional row check.

In 2001 the observed effects of tillage on thrips populations were similar to those found in previous studies. Populations of all stages of thrips were reduced in conservation tillage when compared to conventional tillage (All et al. 1992, All et al. 1994). However, reduction by conservation did not offer enough control to avoid the need for aldicarb use (All 1996b, All et al. 1992). For the 2001 test, precision-placed aldicarb treatments were again as effective in controlling thrips infestations at reduced rates in comparison to the standard in-furrow amount of insecticide. Strip-tillage, which is a type of conservation tillage, effectively reduced adult, larval, and total thrips populations in comparison with conventional tillage on several sampling dates.

The plants in the strip-tillage plots were significantly taller than plants in the conventional tillage plots in the 2001 test. Plants from all precision placement treated plots were significantly taller than plants from the untreated check and were as tall as plants from plots treated with the standard in-furrow 3.92 kg product per ha rate.

No significant differences in yield were observed between conventional and strip-tillage plots. Precision-placed aldicarb at a rate of 1.44 and 2.87 kg product per ha had the highest yields in comparison with the untreated check. All precision placement treated plots had yields that were as high as the yields from plots treated with the standard in-furrow rate of 3.92 kg product per ha.

Efficacy data suggests that precision placement of aldicarb in combination with conservation tillage significantly reduces thrips infestations in seedling cotton. Ultra-narrow row planting can reduce cotton production costs without decreasing yield. This study shows that the use of ultra-narrow row planting in combination with aldicarb treatments does not appear to increase the potential for thrips infestations in cotton. Therefore it may be possible to reduce production costs and insecticide costs without sacrificing yield.

Results from this study indicate that an integrated system that combines precision placement of aldicarb with conservation tillage may be a potential new avenue for thrips control in cotton. Such a system could provide an environmentally safe and cost effective alternative to traditional aldicarb use in cotton by combining judicious use of insecticides with cultural control in the form of conservation tillage.

**Acknowledgements**

The author expresses appreciation to Kurk Lance, Patrick McPherson, Dean Kemp, and the University of Georgia's Agricultural Experiment Station and field crews for field assistance during this study.

**References:**

**All, J. N. 1995.** Insect pest management in conservation tillage for the southeastern United States. Conservation Tillage Workshop. *In* Proceedings Beltwide Cotton Conferences. National Cotton Council of America. p. 78.

**All, J. N. 1996a.** Insect population shifts from conventional to conservation tillage: What to except and how to control. *In* Doublecropping/conservation Tillage Workshop Proceedings. Univ. of GA Coop. Ext. Serv. pp. 12-14.

**All, J.N. 1996b.** Comparing thrips damage in conservation tillage and conventional tillage. National Conservation Tillage Digest. April/May. p. 28.

**All J. N., B. H. Tanner, and P. M. Roberts. 1992.** Influence of no-tillage practices on tobacco thrips infestations in cotton. *In* Proceedings of the 1992 Southern Conservation Tillage Conferences. Univ. of TN. pp.77-78.

**All, J. N., W. K. Vencill, and W. Langdale. 1994.** Five-year study on influence of cultural practices on thrips in seedling cotton. *In* 1994 Georgia Cotton Research-Extension Report. Univ. of Georgia. pp.140-144.

**All, J. N., P. M. Roberts, K. H. Lohmeyer, J. K. Lance, and P. Guillebeau, 2000.** Developing methodology to reduce the use/risk of Temik by precision application during planting operations. *In*: C.W. Bednarz and A. S. Culpepper (eds.), Cotton Research-Extension Report 1999. UGA/CPES Res.-Extn. Publ. No. 4:431. pp. 256-257.

**EXTOXNET. Extension Toxicology Network. 1997.** Pesticide Information Profile. http://ace.orst.edu/cgi-bin/mfs/01/pips/aldicarb.htm.

**Harris, H. M., W. K. Vencill, and J. N. All. 1999.** Influence of row spacing and tillage upon western flower thrips and tobacco thrips in cotton. *In* Proceedings of the Beltwide Cotton Conference. National Cotton Counci. Pp.974-975.

**Howard, P. H**. **1991.** Handbook of environmental fate and exposure data for organic Chemicals: Pesticides, Lewis Publishers, Chelsea, MI.

**Jost, P. H., and J. T. Cothren. 2000.** Growth and yield comparisons of cotton planted in conventional and ultra-narrow row spacings. Crop Science. 40: 430-435.

**Lohmeyer, K. H., J. N. All, P. Bush, P. M. Roberts, and J. K. Lance. 2001.** Hill-drop application of aldicarb to enhance efficiency of thrips management in cotton. *In* Proceedings of the Beltwide Cotton Conference. National Cotton Council. pp. 1114-1116.

**Roberts, P. M. J. N. All, G. Herzog, and P. Guillebeau. 1998.** Precision application of at-planting insecticides for early season thrips control. Cotton Research-Extension Report 1998. UGA/CPES Res.-Extn. Publ. No. 4:176.

**SAS Institute. 2000.** SAS user's guide: statistics. Version 8.2. SAS Institute, Cary, NC.

**Williams, M. R. 2000.** Cotton Insect Loss Estimates - 1999. *In* Proceedings of the Beltwide Cotton Conference. National Cotton Council. pp. 884-887.

**Wiseman, B. R., F. M. Davis, and J. E. Campbell. 1980.** Mechanical infestation device used in fall armyworm *Spodoptera frugiperda* plant resistance programs. Florida Entomol. 63: 424-432.

Table 3.1. Mean number of thrips sampled per plot from cotyledon stage plants on 12 June 2000, 10 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| Tillage Practice | Mean # of thrips per 10 plants ± SE[a] adults | larvae | total (adults + larvae) |
|---|---|---|---|
| Conventional tillage | 9.9±2.7a | 0.1±0.1a | 10.0±2.7a |
| Conservation tillage | 2.3±0.6b | 0.1±0.1a | 2.4±0.5b |

| Planting Practice Rate/Application Method kg product per ha | Mean # of thrips per 10 plants ± SE[a] adults | larvae | total (adults + larvae) |
|---|---|---|---|
| Conventional 0.71 precision placed | 4.0±2.5b | 0.0±0.0a | 4.0±2.5b |
| Ultra-Narrow 3.36 precision placed | 3.9±2.1b | 0.1±0.1a | 4.0±2.1b |
| Conventional 3.92 in-furrow | 2.4±1.4b | 0.1±0.1a | 2.5±1.4b |
| Ultra-Narrow 5.94 in-furrow | 1.0±0.4b | 0.1±0.1a | 1.1±0.5b |
| Conventional Check | 9.4±4.3ab | 0.0±0.0a | 9.4±4.3ab |
| Ultra-Narrow Check | 16.0±5.3a | 0.4±0.3a | 16.4±5.5a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.2. Mean number of thrips sampled per plot from 2-leaf stage plants on 22 June 2000, 20 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 0.5±0.2a | 3.7±1.0a | 4.2±1.1a |
| Conservation tillage | 0.2±0.1a | 1.8±0.5b | 2.0±0.5a |

| Planting Practice<br>Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | adults | larvae | total (adults + larvae) |
| Conventional<br>0.71 precision placed | 0.1±0.1a | 2.8±1.3ab | 2.9±1.4abc |
| Ultra-Narrow<br>3.36 precision placed | 0.6±0.4a | 1.3±0.7b | 1.9±1.0bc |
| Conventional<br>3.92 in-furrow | 0.3±0.2a | 0.6±0.3b | 0.9±0.3bc |
| Ultra-Narrow<br>5.94 in-furrow | 0.1±0.1a | 0.4±0.3b | 0.5±0.4c |
| Conventional<br>Check | 0.5±0.3a | 5.1±1.8a | 5.6±2.1ab |
| Ultra-Narrow<br>Check | 0.5±0.2a | 6.3±1.9a | 6.8±2.1a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.3. Mean number of thrips sampled per plot from 4-leaf stage plants on 30 June 2000, 28 days after application of aldicarb by in-furrow or precision placement of granules, Plants Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 0.5±0.2a | 0.8±0.2a | 1.3±0.4a |
| Conservation tillage | 0.5±0.2a | 0.5±0.2a | 1.0±0.2a |

| Planting Practice Rate/Application Method kg product per ha | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| | adults | larvae | total (adults + larvae) |
| Conventional 0.71 precision placed | 0.8±0.3a | 0.2±0.2a | 1.0±0.4a |
| Ultra-Narrow 3.36 precision placed | 0.3±0.3a | 0.4±0.3a | 0.7±0.3a |
| Conventional 3.92 in-furrow | 1.0±0.5a | 1.6±0.6a | 2.6±0.8a |
| Ultra-Narrow 5.94 in-furrow | 0.3±0.2a | 0.5±0.3a | 0.8±0.3a |
| Conventional Check | 0.5±0.3a | 0.5±0.3a | 1.0±0.3a |
| Ultra-Narrow Check | 0.5±0.3a | 0.5±0.3a | 1.0±0.4a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.4. Mean number of thrips sampled per plot from 8+ leaf stage plants on 21 July 2000, 49 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 0.7±a0.2 | 0.6±0.2a | 1.3±0.4a |
| Conservation tillage | 1.0±0.2a | 0.4±0.2a | 1.4±0.3a |

| Planting Practice<br>Rate/Application Method<br>kg product per ha | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| | adults | larvae | total (adults + larvae) |
| Conventional<br>0.71 precision placed | 1.0±0.6a | 0.4±0.3a | 1.4±0.7a |
| Ultra-Narrow<br>3.36 precision placed | 0.6±0.3a | 0.5±0.3a | 1.1±0.4a |
| Conventional<br>3.92 in-furrow | 0.9±0.4a | 0.3±0.2a | 1.12±0.3a |
| Ultra-Narrow<br>5.94 in-furrow | 0.4±0.2a | 0.6±0.5a | 1.0±0.5a |
| Conventional<br>Check | 0.9±0.4a | 0.4±0.2a | 1.3±0.5a |
| Ultra-Narrow<br>Check | 1.3±0.2a | 1.00.6a | 2.3±a0.8 |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.5. Mean number of thrips sampled per plot from cotyledon stage plants on 29 May 2001, 11 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 22.9±3.5a | 0.1±a0.1 | 23.0±3.5a |
| Conservation tillage | 23.1±2.8a | 0.5±a0.3 | 23.6±2.8a |

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | adults | larvae | total (adults + larvae) |
| 0.18 precision placed | 21.9±3.8bc | 0.3±0.2a | 22.1±3.9cd |
| 0.71 precision placed | 23.0±4.3bc | 0.8±0.4a | 23.8±4.3bcd |
| 1.44 precision placed | 4.6±1.3d | 0.1±0.1a | 4.7±1.4e |
| 2.87 precision placed | 6.1±1.9d | 0.0±0.0a | 6.1±1.9e |
| 5.74 precision placed | 7.0±1.7d | 0.0±0.0a | 7.0±1.7e |
| 0.28 in-furrow | 50.4±7.0a | 0.1±0.1a | 50.5±7.0a |
| 0.56 in-furrow | 33.6±4.4ab | 0.3±0.2a | 33.9±4.4abc |
| 1.12 in-furrow | 23.1±5.2bc | 0.3±0.3a | 23.4±5.1bcd |
| 3.92 in-furrow | 14.6±3.7cd | 0.0±0.0a | 14.6±3.7de |
| check | 45.1±9.0ab | 1.4±1.4a | 46.5±8.7ab |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.6. Mean number of thrips sampled per plot from 2-leaf stage plants on 6 June 2001, 19 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 14.4±2.1a | 117.0±23.0a | 131.5±24.5a |
| Conservation tillage | 12.6±1.6a | 58.3±9.5b | 70.9±10.6b |

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | adults | larvae | total (adults + larvae) |
| 0.18 precision placed | 14.3±3.1ab | 93.3±37.9bc | 107.6±40.0bc |
| 0.71 precision placed | 11.9±3.4abc | 98.3±11.9bc | 110.2±13.4bc |
| 1.44 precision placed | 6.8±2.4bcd | 8.3±1.6d | 15.1±3.7d |
| 2.87 precision placed | 2.3±0.5cd | 6.8±1.6d | 9.1±2.0d |
| 5.74 precision placed | 2.8±1.0d | 3.9±1.7d | 6.5±1.5d |
| 0.28 in-furrow | 24.8±2.7a | 183.3±49.0ab | 208.1±50.2ab |
| 0.56 in-furrow | 24.3±4.6a | 113.1±35.1bc | 137.4±37.4bc |
| 1.12 in-furrow | 14.9±2.9ab | 69.4±16.2bc | 84.3±18.4bc |
| 3.92 in-furrow | 9.0±1.6bcd | 33.4±9.8cd | 42.4±10.2cd |
| check | 24.5±4.8a | 266.9±59.5a | 291.4±62.0a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.7. Mean number of thrips sampled per plot from 4-leaf stage plants on 18 June 2001, 31 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | l arvae | total (adults + larvae) |
| Conventional tillage | 7.5±0.6a | 28.0±3.8a | 35.5±4.1a |
| Conservation tillage | 3.4±0.4b | 13.2±2.1b | 16.6±2.2b |

| Rate/Application Method | Mean # of Thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | adults | larvae | total (adults + larvae) |
| 0.18 precision placed | 6.8±1.6a | 27.1±8.0ab | 33.9±9.2ab |
| 0.71 precision placed | 4.5±1.3a | 11.9±1.9bc | 16.4±2.3bc |
| 1.44 precision placed | 3.6±0.7a | 4.1±1.6c | 7.7±1.7c |
| 2.87 precision placed | 5.1±1.1a | 5.3±3.4c | 10.4±3.1c |
| 5.74 precision placed | 3.4±0.7a | 4.9±1.8c | 8.3±1.9c |
| 0.28 in-furrow | 7.1±1.6a | 46.6±7.4a | 53.7±8.2a |
| 0.56 in-furrow | 7.5±2.1a | 26.4±7.6ab | 33.9±9.4ab |
| 1.12 in-furrow | 5.0±0.9a | 30.3±8.65ab | 35.3±9.1ab |
| 3.92 in-furrow | 5.6±1.3a | 17.9±5.5bc | 23.5±7.2bc |
| check | 5.8±1.0a | 31.4±5.7ab | 37.2±6.1ab |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.8. Mean number of thrips sampled per plot from 8+ leaf stage plants on 2 July 2001, 45 days after application of aldicarb by in-furrow or precision placement of granules, Plant Sciences Farm.

| | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| Tillage Practice | adults | larvae | total (adults + larvae) |
| Conventional tillage | 2.3±0.4a | 3.8±0.7a | 6.1±0.9a |
| Conservation tillage | 1.6±0.3a | 2.7±0.4a | 4.3±0.5a |

| Rate/Application Method | Mean # of thrips per 10 plants ± SE[a] | | |
|---|---|---|---|
| kg product per ha | adults | larvae | total (adults + larvae) |
| 0.18 precision placed | 1.6±0.8a | 4.5±1.3a | 6.1±1.5a |
| 0.71 precision placed | 1.3±0.4a | 1.8±0.6a | 3.1±0.6a |
| 1.44 precision placed | 1.9±0.8a | 1.6±1.0a | 3.5±1.0a |
| 2.87 precision placed | 1.1±0.4a | 2.5±1.1a | 3.6±1.3a |
| 5.74 precision placed | 2.6±0.8a | 1.1±1.0a | 3.7±1.1a |
| 0.28 in-furrow | 1.6±0.4a | 5.3±1.4a | 6.8±1.4a |
| 0.56 in-furrow | 3.1±1.4a | 4.8±2.3a | 7.9±2.9a |
| 1.12 in-furrow | 1.3±0.5a | 3.6±1.4a | 4.9±1.6a |
| 3.92 in-furrow | 2.6±0.7a | 3.4±1.2a | 6.0±1.7a |
| check | 2.4±0.9a | 4.0±0.9a | 6.4±1.7a |

[a]Actual means; means were square root transformed before analysis. Means in a column followed by the same letter are not significantly different (*P*=0.05, Tukey HSD).

Table 3.9. Mean plant heights for cotton plants on 26 July 2000, 54 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Plant Sciences Farm.

| Tillage Practice | Mean plant height ±SE (cm) |
|---|---|
| Conventional tillage | 24.4±0.9a |
| Conservation tillage | 24.3±0.6a |

| Planting Practice Rate/Application Method kg product per ha | Mean plant height ± SE (cm) |
|---|---|
| Conventional 0.71 precision placed | 25.6±1.2a |
| Ultra-Narrow 3.36 precision placed | 23.1±1.2a |
| Conventional 3.92 in-furrow | 24.5±1.2a |
| Ultra-Narrow 5.94 in-furrow | 25.9±2.1a |
| Conventional Check | 23.8±1.2a |
| Ultra-Narrow Check | 23.2±1.2a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 3.10. Mean plant heights for cotton plants on 6 July 2001, 49 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Plant Sciences Farm.

| Tillage Practice | Mean plant height ± SE (cm) |
|---|---|
| Conventional tillage | 31.8±1.1a |
| Conservation tillage | 37.5±1.4b |

| Rate/Application Method kg product per ha | Mean Plant Height ± SE (cm) |
|---|---|
| 0.18 precision placed | 33.0±2.7bcd |
| 0.71 precision placed | 36.3±1.9abc |
| 1.44 precision placed | 40.9±1.8ab |
| 2.87 precision placed | 43.0±1.6a |
| 5.74 precision placed | 41.4±1.9a |
| 0.28 in-furrow | 26.9±18.7de |
| 0.56 in-furrow | 30.3±1.2cde |
| 1.12 in-furrow | 32.5±3.1cd |
| 3.92 in-furrow | 40.5±1.2ab |
| check | 22.2±1.8e |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

Table 3.11. Mean yield of plots on 1 November 2001, 167 days after treatment with selected rates of aldicarb by precision placement or conventional in-furrow application methods, Plant Sciences Farm.

| Tillage Practice | Mean yield ± SE (kg seed cotton per ha) |
|---|---|
| Conventional tillage | 3590.5±30.8a |
| Conservation tillage | 3103.4±25.8a |

| Rate/Application Method kg product per ha | Mean yield ± SE (kg seed cotton per ha) |
|---|---|
| 0.18 precision placed | 3636.6±114.6ab |
| 0.71 precision placed | 3564.5±186.8ab |
| 1.44 precision placed | 3993.1±225.8a |
| 2.87 precision placed | 4046.1±192.9a |
| 5.74 precision placed | 3694.5±111.8ab |
| 0.28 in-furrow | 3251.3±263.2ab |
| 0.56 in-furrow | 3323.6±187.9ab |
| 1.12 in-furrow | 2878.1±354.9ab |
| 3.92 in-furrow | 3010.4±515.7ab |
| check | 2071.2±154.6b |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

# CHAPTER IV

# REDUCING INSECTICIDE REQUIREMENTS FOR SOIL PEST MANAGEMENT IN FIELD CORN BY USING PRECISION CHEMICAL APPLICATION IN CONVENTIONAL AND CONSERVATION TILLAGE SYSTEMS[1]

---

[1]Lohmeyer, K. H., and J. N. All. To be submitted to Journal of Entomological Science.

**ABSTRACT** Soil insects such as the southern corn billbug *Sphenophorus callosus* (Olivier), lesser cornstalk borer *Elasmopalpus lignosellus* (Zeller), corn wireworms, *Melantotus communis* (Gyllenhal), and sugarcane beetle, *Euetheola rugiceps* (LeConte) cause debilitating damage to corn, *Zea mays* L.. Preventative insecticide applications are often used in the southeastern United States to manage unpredictable infestations of these pests and to avoid stand losses. Methodology that would reduce the quantity of insecticides needed to prevent damage by soil insects would have economic and environmental benefits. New precision farming innovations are being introduced with advances in technology for tillage, planting, and harvesting equipment. New vacuum induced planters allow for precision placement of seed at desirable intervals. This research was initiated to simulate technology for "precision placement" of insecticides in a similar manner. Field experiments investigated the control efficacy of precision-placed soil insecticides compared with standard in-furrow treatments on southern corn billbug, lesser cornstalk borer, corn wireworms, and sugarcane beetle at sites throughout the state of Georgia from 1999-2001. Precision-placed insecticides were placed with the seed at planting with no insecticide along the furrow between seeds. In 1999, T-banded Aztec at a rate of 0.185 kg AI per ha showed a significant reduction in mean percent plant damage caused by southern corn billbug and lesser cornstalk borer. Precision-placed Counter at a rate of 0.563 kg AI per ha, and precision-placed Furadan at a rate of 0.056 kg AI per ha showed significant increases in yield. Banded Counter at a rate of 0.562 kg AI per ha showed the most significant reduction in damage caused by corn wireworms. Banded Counter at a rate of 1.21 kg AI per ha and T-banded Aztec at a rate of 0.185 kg AI per ha showed significant increases in yield. In 2000, in-furrow Regent at a rate of 0.113 kg AI per ha, in-furrow Furadan at a rate of 1.121, banded Counter at a rate of 1.21 kg AI per ha, and precision-placed Furadan at a rate of 0.562 kg AI per ha showed significant reductions in mean percent damage caused by southern corn billbug and lesser cornstalk borer when compared with the untreated check. The degree of injury caused by soil insects may be influenced by cultural practices such as conservation tillage. A test was conducted in 2001 to evaluate precision-placed insecticide treatments in combination with conservation tillage practices for the control of southern corn billbugs and lesser cornstalk borer. Mean percent damage caused by southern corn billbug and lesser cornstalk borer was significantly reduced in conventional tillage compared with conservation tillage. No significant differences in treatments were observed when compared with the untreated check. Significantly greater yield was observed for conventional tillage as compared with conservation tillage. No significant differences in yield were observed for any treatments when compared with the untreated check.

KEY WORDS: *Sphenophorus callosus*, *Elasmopalpus lignosellus*, *Melantotus communis*, *Euetheola rugiceps*, conservation tillage, soil insecticides, field corn, precision placement.

## Introduction

Soil insects such as the southern corn billbug, *Sphenophorus callosus* (Olivier), lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), corn wireworm, *Melantotus communis* (Gyllenhal), and southern corn rootworm, *Diabrotica undecimpunctata howardi* (Barber), caused $2,313,000 in damage in Georgia and required over $2,000,000 in control costs for 1997 (Hudson and All 1997). This degree of damage and cost of control is indicative of problems in other southeastern states.

Growers rely heavily on soil insecticides such as terbufos (Counter®) and carbofuran (Furadan®) applied in a continuous stream of granules or liquid at planting for soil pest control even though they are expensive and potentially toxic to both humans and the environment. Often rates as high as 0.56 kg of active ingredient per 1000m of planted row and costs of $3.38 per 1000m of planted row are used to prevent possible infestations, however even these amounts may fail to provide adequate control of soil insects in corn. Insecticides commonly used for soil insect control pose considerable risk for groundwater contamination and may be toxic to mammals, birds, and fish (Tucker 1970, Howard 1989). Costs are a significant concern, but more important are user safety and reducing environmental impact. These needs drive the demand for a safer, more cost effective alternative.

In corn and several other cropping systems, current farming technology allows for seeds to be placed at planting in regular intervals along the row. Insecticides applied at planting, however, are usually applied in a continuous stream along the row. Insecticides utilized in this manner are applied to protect the seed and the seedling plant, but much of the insecticide ends up being deposited in the space between the seeds. Only a very small amount of the insecticide is placed adjacent to the seeds. It may be possible to eliminate the insecticide that is applied between the seeds without a significant effect on control efficacy. The quantity of insecticide applied per acre could potentially be reduced by 50% or more, but the amount of insecticide adjacent to the seed would remain the same.

Placing the insecticide along with the seed in a specific location would be a more efficient method of applying planting time insecticides. This type of "precision placement" insecticide use would directly reduce environmental risks. Precision placement of soil insecticides in field corn may be an effective method of controlling soil insect pests while reducing grower costs and environmental hazards.

The utilization of cultural control practices, specifically conservation tillage, has been shown to have varying influence on populations of insect pests (All 1979). Significantly more southern corn billbug damage and lower yields occur in conservation tillage compared with conventional tillage treatments, but lesser cornstalk borer cause less damage in conservation tillage compared with conventional tillage. (Javid et al. 1986, All and Gallaher 1977). The use of conservation tillage in combination with precision placement may further enhance the potential for insect management. However, it is important to evaluate each pest situation individually (All et al.1984).

Manufacturers of planting equipment have not developed systems for precision application of planting time insecticides and this research was initiated to evaluate the concept by simulating "precision placement" and comparing it to conventional application of chemicals. This study was conducted to evaluate the efficacy of various rates of precision-placed soil insecticides compared with traditional in-furrow treatments for the control of soil insect pests in field corn at various locations throughout Georgia.

In addition, a study was conducted to evaluate the efficacy of precision placement in combination with conservation tillage.

**Materials and Methods**

Field experiments were conducted between 1999 and 2001 at experiment stations across Georgia: the Southeast Georgia Branch Experiment Station for control of southern corn billbug and lesser cornstalk borer; the Georgia Mountain Branch Experiment Station for control of corn wireworm; the University of Georgia Plant Sciences Farm for control of lesser cornstalk borer; and the Northwest Georgia Branch Experiment Station, for control of sugarcane beetle, *Euetheola rugiceps* (LeConte).

For all tests except the 2001 Southeast Georgia Branch Experiment Station test, a randomized complete block design with four replications and one untreated check per replication was used. For the 2001 Southeast Georgia Branch Experiment Station test, a split-block design with four replications and one untreated check per replication was used. Insecticides were applied to the two middle rows of plots that were 7.62 m long and four rows wide. Dekalb 683 seed was used for all tests.

The insecticide formulations used in the tests were Counter® CR (20% terbufos), Furadan® 4 F (44% carbofuran flowable), Aztec® 2.0 G (2% tebupirimphos; 0.1% cyfluthrin), Force® 1.5 G (3% tefluthrin), and Regent® 4 SC (39.4% fipronil soluble concentrate). In 1999, plots that were to receive treatment at planting were treated with granular insecticides using a 17 cm banded application (insecticide is applied in a uniform band on the soil surface after closing the seed furrow) or a 17 cm T-banded application (insecticide is applied in a band before the seed furrow is closed). Precision placement treated plots were planted using a jab planter and treated with granular insecticides using a bazooka-type applicator. This type of applicator directs calibrated quantities of insecticide granules onto the top of seed by a trap release system (Wiseman et al. 1980).

In 2000 and 2001 all treatments were planted with a two-row Monesem pneumatic planter. Precision placement plots were planted with the furrow open. In 2000, plots were conventionally treated after planting with granular insecticides using a 17.78 cm banded application or a 17.78 cm T-banded application. For 2001, plots were not treated with a T-banded application. For both 2000 and 2001, the precision placement treated plots had granular insecticide placed on top of the seed within the open furrow using a pre-measured amount of insecticide and a PVC tube. Liquid insecticide formulations were applied at planting using two methods: in-furrow application with a backpack sprayer and precision placement of insecticide using a pipette. All insecticide rates are specified as kg (AI)/ha based on 1 m wide rows.

**Southeast Georgia Branch Experiment Station, 1999:** The University of Georgia Experiment Station is located in Burke County, near Midville, Georgia, in the Coastal Plain. The soil type is Marlboro sandy loam. Historically, corn planted in the chosen field has experienced frequent infestations by southern corn billbug and lesser cornstalk borer.

Seed was planted on 6 April 1999 using a four-row John Deere planter. Plots were irrigated as needed throughout the growing season. On 21 April corn seedlings were in the 2-leaf stage. Plants were assessed for southern corn billbug and lesser cornstalk borer damage by surveying all plants in the two middle rows of each plot for stunting, symmetrical feeding holes, and/or silk. Damaged and undamaged plants were counted, adding both southern corn billbug and lesser cornstalk borer damaged plants together. On 5 May plants were in the 4-leaf stage and showed signs of both southern cornstalk borer and lesser cornstalk damage. On 19 August, the ears of a single treated row from each plot were counted and picked by hand. The ears of corn were weighed in kg in the field to determine yield.

**Mountain Branch Experiment Station, 1999:** The University of Georgia's Mountain Branch Experiment Station is located in the southern blue ridge region of the state in Union County, near Blairsville, Georgia. The soil type is Evard loam. The field has a history of corn with frequent infestations of corn wireworms (All et al 1996).

Seed was planted on 19 May 1999 using a four row Cole no-till planter. Plots were not irrigated as rainfall in this growing area was sufficient. To confirm the presence of wireworms in the field 20 plants were selected at random in untreated rows and examined for insect injury and the presence of wireworm larvae on 4 June. All symptomatic plants had wireworm injury and seven plants had late instar corn wireworm larvae present in the soil nearby. On 8 June, 26 June, and 19 July, plants were assessed for wireworm damage by surveying all plants in the two middle rows of each plot for feeding holes, tillered plants, and severely stunted plants. The total number of damaged and undamaged plants was recorded. The middle two rows of each plot were mechanically harvested on 26 October using a Hagé small plot one-row combine. Whole kernel corn was weighed in kg in the field to determine yield.

**Southeast Georgia Branch Experiment Station, 2000:** Seed was planted on 3 April 2000. Plots were irrigated as needed during the growing season. On 18 April corn seedlings were in the two-leaf stage. Plants were assessed for southern corn billbug and lesser cornstalk borer damage by surveying all of the plants in the two middle rows of each plot for stunting and a symmetrical row of holes in leaves. Damaged and undamaged plants were counted. On 25 April plants were in the four-leaf stage and showed signs of both southern corn billbug and lesser cornstalk borer damage. Plants were examined for stunting, tillering, and symmetrical feeding holes. Injured plants were examined and assessed as lesser cornstalk borer damage if there was a larva present or silk in the soil adjacent to a feeding puncture in the plant stem. Plants were assessed as southern corn billbug damage if there were symmetrical feeding holes in the leaves of the plant and/or stunting. Damaged and undamaged plants were counted; adding both southern corn billbug and lesser cornstalk borer damaged plants together. Plants were also sampled for damage on 2, 9, and 16 May. On 27 September, the ears of two treated rows from each plot were counted and picked by hand. The ears of corn were weighed in kg in the field to determine yield.

**Northwest Georgia Branch Experiment Station, 2000:** The University of Georgia's Northwest Georgia Branch Experiment Station is located in the southern valley and ridge region of the state, in Floyd County, near Adairsville, Georgia. The soil type is Waynesboro loam. The field has a history of corn with occasional infestations of sugarcane beetles.

Seed was planted on 27 April 2000. For this test treatments were applied to the second row of 7.6 m long, four-row plots. Plots were not irrigated as rainfall in this growing area was sufficient. On 18 May corn seedlings were in the two-leaf stage and showed signs of sugarcane beetle damage. Plants were assessed for sugarcane beetle damage by surveying all plants in the treated row of each plot for stunting, tillering, and large feeding punctures just below the soil line. Damaged and undamaged plants were counted. On both occasions, searches of treated rows were made above ground and below for the presence of adult beetles. Several adults were found near damaged plants on 23 May. Plants were also sampled for sugarcane beetle damage on 23 May when plants were in the four-leaf stage and 8 June when plants were in the eight-leaf stage. On 18 October the ears of the treated row from each plot were counted and picked by hand. The ears of corn were weighed in kg in the field to determine yield.

**University of Georgia Plant Sciences Farm, 2000:** The University of Georgia's Plant Science Farm is located in the southern piedmont region of the state, in Oconee County, near Watkinsville, Georgia. The soil type is Appling coarse sandy loam. The field has a history of corn with frequent infestations of lesser cornstalk borer.

Seed was planted on 21 June 2000 using a two-row Monesem pneumatic planter. Plots were irrigated during the growing season as needed. On 29 June corn seedlings were in the two-leaf stage. Plants were assessed for lesser cornstalk borer damage by surveying all plants in the two middle rows of each plot for larva presence and silk in the soil adjacent to a feeding puncture in the plant stem. Plants were also sampled for damage on 5 July when plants were in the eight-leaf stage.

**Southeastern Branch Experiment Station, 2001:** Seed was planted on 11 April 2000 using a two-row Monesem pneumatic planter. A conventional and a conservation-tillage section of the field had been prepared prior to planting in a field that had been previously planted with wheat. The conventional tillage portion of the test was treated on 11 April. Due to field conditions, the conservation tillage portion of the test was treated post-plant emergence on 23 April. Precision-placed treatments were placed at the base of the seedling plant. In-furrow treatments were placed along the entire furrow. Plots were irrigated during the growing season as needed. In the conventional tillage portion of the test, corn seedlings were in the two-leaf stage on 23 April. Plants were assessed for southern corn billbug and lesser cornstalk borer damage by surveying all plants in the two middle rows of each plot for stunting, symmetrical feeding holes, and/or silk. Damaged and undamaged plants were counted, adding both southern corn billbug and lesser cornstalk borer damaged plants together. Damage was determined to be primarily southern cornstalk borer. Plants were sampled only from the conventional tillage plots on 23 April due to slower germination in the conservation till plots. Plants from both conventional and conservation tillage plots were sampled on 1 May when plants were in the four-leaf stage and 10 May when plants were in the eight-leaf stage. On 23 August the ears of the treated rows from each plot were counted and picked by hand. The ears of corn were weighed in kg in the field to determine yield.

**Mountain Branch Experiment Station, 2001:** A two-row Monesem planter was used to plant seed on 31 May 2000. Conventional and a conservation-tillage sections of the field had been prepared prior to planting in a field that had been previously planted with wheat. Plots were not irrigated as rainfall in this growing area was sufficient. On 12 June, when plants were in the four-leaf stage, and 29 June, when plants were in the eight leaf stage, plots were assessed for wireworm damage by surveying all plants in the two middle rows of each plot for feeding holes, tillered plants, and severely stunted plants. The total number of damaged and undamaged plants was recorded.

**Northwestern Branch Experiment Station, 2001:** Seed was planted on 26 April 2000 using a two-row Monesem pneumatic planter. Plots were not irrigated as rainfall in this growing area was sufficient. On 9 May corn seedlings were in the two-leaf stage. Plants were assessed for sugarcane beetle damage by surveying all of the plants in the two middle rows of each plot for stunting, tillering, and large feeding punctures just below the soil line. Damaged and undamaged plants were counted.

**Statistical Analysis.** Plant damage data were arcsine square root transformed before statistical analysis. Means for plant damage sampling and yield were analyzed using ANOVA and treatment means were separated using Tukey's Studentized Range Test, with $P<0.05$ (SAS Institute 2000).

**Results**

Soil insect infestations at experiment station test sites between 1999 and 2001 proved somewhat unpredictable. Infestations were as expected for some seasons, but non-existent for others. For this reason, damage data were lacking from some tests.

**Southeastern Branch Experiment Station, 1999:** No significant differences in percent damage by lesser cornstalk borer and southern corn billbug were observed among the treatments in comparison with the untreated check on 21 April (Table 4.1) ($F=1.85$; df = 14, 42; $P = 0.0696$). On 5 May, only T-banded Aztec at a rate of 0.185 kg AI/ha showed a significant reduction in plant damage when compared to the untreated check ($F=1.80$; df = 14, 42; $P = 0.079$). Precision-placed Counter at a rate of 0.563 kg AI/ha and precision-placed Force at a rate of 0.056 kg AI/ha showed greatest increase in yield when compared with the untreated check ($F = 2.86$; df = 14, 42; $P = 0.0056$).

**Mountain Branch Experiment Station, 1999:** No significant differences were observed among the treatments when compared to the untreated check with respect to percentage of plants damaged by corn wireworm on 8 June and 26 June (Table 4.2)

(8 June: $F$ =1.44; df = 14, 42; $P$ = 0.1765; 26 June: $F$ = 2.00; df = 14, 42; $P$ = 0.0425). On 19 July, corn banded with Counter at a rate of 0.562 kg AI/ha had the least damage relative to the untreated check ($F$ = 2.33; df = 14, 42; $P$ = 0.0172). T-banded Aztec at a rate of 0.185 kg AI/ha and banded Counter at a rate of 1.21 kg AI/ha exhibited the greatest increase in yield when compared with the untreated check ($F$ = 3.67; df = 14, 27; $P$ = 0.0008).

**Southeastern Branch Experiment Station, 2000:** The percentage of plants damaged by lesser cornstalk borer and southern corn billbug did not differ among treatments on 18 April (Table 4.3) ($F$ = 1.24; df = 14, 42; $P$ = 0.2826). On 25 April in-furrow Regent at a rate of 0.113 kg AI/ha and in-furrow Furadan at a rate of 1.121 kg AI/ha had the greatest reduction in damage when compared to the untreated check ($F$ = 3.32; df = 14, 42; $P$ = 0.0013). On 2 May no significant differences in damage frequency were observed among the treatments when compared to the untreated check ($F$ = 1.31; df = 14, 42; $P$ = 0.2422). On 9 May banded Counter at a rate of 1.121 kg AI/ha showed the greatest reduction in damage when compared with the untreated check ($F$ = 4.07; df = 14, 42; $P$ = 0.0002). On 16 May, corn treated with precision-placed Furadan at a rate of 0.562 kg AI/ha exhibited the greatest reduction in lesser cornstalk borer/southern corn billbug damage when compared with the untreated check ($F$ = 3.46; df = 14, 42; $P$ = 0.0009). Yield did not differ among treatments ($F$ = 0.58; df =14, 42; $P$ = 0.8651).

**Northwest Branch Experiment Station, 2000:** The percentage of plants damaged by sugarcane beetles was comparable among all the treatments on all sampling dates (Table 4.4) (18 May: $F$ = 1.81; df = 14, 42; $P$ = 0.0699; 23 May: $F$ = 0.99; df = 14, 42;

*P* = 0.4838; 8 June: *F* = 2.27; df = 14, 42; *P* = 0.0205). No significant differences were observed for any treatment when compared with the untreated check (*F* = 1.68; df = 14, 24; *P* =0.0963).

**University of Georgia Plant Sciences Farm, 2000**: Insecticide treatments applied to this test were the same as those for the Southeastern Branch Experiment Station, 2000. As insect infestations were lacking, insufficient data were obtained from this test to conduct a meaningful analysis.

**Southeastern Branch Experiment Station, 2001:** Due to slower germination in the conservation tillage portion of the test, only plants from the conventional tillage plots were sampled on 23 April. No significant differences in plant damage by southern corn billbug/lesser cornstalk borer were observed among the insecticide treatments when compared with the untreated check (Table 4.5) (*F* = 0.64; df = 8, 24; *P* = 0.7329).

On 1 May, damage was significantly greater in conservation tillage compared with conventional tillage (Table 4.6) (*F* = 57.35; df = 1, 48; *P* <0.0001). No interaction between tillage practices and insecticide treatments was observed (*F* = 0.75; df = 8, 32; *P* = 0.6437). No significant differences in plant damage were found for any treatments when compared with the untreated check (*F* = 0.71; df = 8, 48; *P* = 0.6818).

On 10 May, no significant differences in damage were observed between conservation and conventional tillage (Table 4.7) (*F* =3.11; df = 1, 48; *P* = 0.0842). No interaction between tillage practices and insecticide treatments was observed (*F* = 2.77, df = 8, 32; *P* = 0.7909). No significant differences in plant damage were observed among the insecticide treatments when compared to the untreated check (*F* = 0.43; df = 8, 48; *P* = 0.8967).

Significantly greater yield was observed for conventional tillage relative to conservation tillage (Table 4.8) ($F = 53.19$; df = 1, 48; $P < 0.0001$). No interaction between tillage practices and insecticide treatments was observed for yield ($F = 0.62$; df = 8, 32; $P = 0.7581$). No significant differences in yield were observed for any insecticide treatment when compared with the untreated check ($F = 0.53$; df = 8; $P = 0.8723$). No significant differences in yield were observed among the insecticide treatments when compared with the untreated check ($F = 0.75$; df = 8, 48; $P = 0.6437$).

**Mountain Branch Experiment Station, 2001:** Insecticide treatments applied to this test were the same as those for the Southeastern Branch Experiment Station, 2001. As insect infestations were lacking and stand counts were low due to crow damage, insufficient data were obtained from this test to conduct a meaningful analysis.

**Northwestern Branch Experiment Station, 2001:** Insecticide treatments applied to this test were the same as those for the Southeastern Branch Experiment Station, 2000. As insect infestations were low, insufficient data were obtained from this test to conduct a meaningful analysis.

## Discussion

The results obtained in this series of experiments mirrors the dilemma that corn farmers in the southeastern United States face relative to managing a sporadic but pernicious group of soil insect pests. Certain insects can produce devastating damage that is difficult to control even with insecticides, while in other instances no infestations occur in fields that have a prior history of pest problems.

Tests conducted to evaluate the efficacy of precision-placed rates of insecticides for controlling wireworms in corn found that precision-placed rates performed as well as traditional in-furrow rates, but were not significantly different from the untreated check. For these tests, wireworm infestations were sporadic, making efficacy comparisons difficult. T-banded Aztec at a rate of 0.185 kg AI/ha exhibited the greatest increase in yield in comparison with the untreated check.

As with wireworms, lack of adequate insect infestations influenced the test conducted to evaluate the efficacy of precision-placed insecticides for controlling sugarcane beetles in corn. Precision-placed rates performed as well as traditional in-furrow rates; however, none of the precision-placed rates of were significantly different from the check. None of the treatments increased yield when compared with the untreated check.

Tests conducted at the Southeastern Branch Experiment station to evaluate precision-placed insecticide rates indicated that precision placement of soil insecticides can provide superior control in mixed infestations of southern corn billbug and lesser cornstalk borer at reduced rates when compared to conventional in-furrow applications. However the results are confounded by the fact that in both years devastating infestations of both insects occurred during dry post-planting conditions that probably did not favor insecticide performance. Under this adverse environment, poor insecticide performance often occurs with lesser cornstalk borer and southern corn billbug infestations (All and Gallaher 1977, All et al. 1979, All et al. 1984).

The observed effects of conservation and conventional tillage on southern corn billbug and lesser cornstalk borer infestations mirror the results of All et al. (1984). Mean percent damage was significantly higher and yields were significantly decreased in conservation tillage as compared with conventional tillage. Hazard for increased southern corn billbug damage is increased in conservation tillage, conversely lesser cornstalk borer infestations are often reduced when compared to conventionally tilled corn. The field at the Southeastern Branch Experiment Station has a resident population of southern corn billbug and a history of severe damage and poor insecticide performance with this pest. The test in 2001 verified that in these types of high-risk pest conditions, the use of preventive insecticide treatments is questionable.

## References

**All, J. N. 1979.** Insect relationships in no-till cropping. Agrichem. Age 23: 22-23.

**All, J. N. and R. N. Gallaher. 1977**. Detrimental impact of no-tillage corn cropping systems involving insecticides, hybrids, and irrigation on lesser cornstalk borer (*Elasmopalpus lignosellus*) infestations. J. Econ. Entomol. 70: 361-365.

**All, J. N. , R. N. Gallaher, and M. D. Jellum. 1979.** Influence of planting date, preplanting weed control, irrigation, and conservation tillage practices on efficacy of planting time insecticide application for control of lesser cornstalk borer *Elasmopalpus lignosellus* in field corn. J. Econ. Entomol. 72: 265-268.

**All, J. N., R. S. Hussey, and P. G. Cummins. 1984.** Southern corn billbug (Coleoptera: Curculionidae) and plant-parasitic nematodes: Influence of no-tillage, coulter-in-row chiseling and insecticides on severity of damage to corn. J. Econ. Entomol. 77: 178-182.

**All, J. N., G. D. Buntin, W. A. Gardner, and R. Harrison. 1996.** Corn wireworm in no-tillage corn. Arthropod Management Tests. Entomol. Soc. Amer. pp.1002-1004.

**Howard, P. H. 1989.** Handbook of environmental fate and exposure data for organic chemicals, Vol. III. US EPA, Washington, DC.

**Hudson, R. D., and J. N. All. 1997**. Summary of losses from insect damage and costs of control in Georgia - field corn insects. www.bugwood.org/s197/fieldcorn97.htm

**Javid, A. M., J. N. All, and J. S. Laisa, 1986.** The influence of cultural treatments on feeding damage of southern corn billbug (Coleoptera: Curculionidae) to corn. J. Entomol. Sci. 21: 276-282.

**Tucker, R. 1970.** Handbook of toxicity of pesticides to wildlife. USDA Fish and Wildlife Service.

**SAS Institute. 2000.** SAS user's guide: statistics. Version 8.2. SAS Institute, Cary, NC.

**Wiseman, B. R., F. M. Davis, and J. E. Campbell. 1980.** Mechanical infestation device used in fall armyworm *Spodoptera frugiperda* plant resistance programs. Florida Entomol. 63: 424-232.

Table 4.1. Lesser cornstalk borer and southern corn billbug damage to seedling corn at the Southeastern Branch Experiment Station, 1999.

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | % plants with damage ± SE[a] April 21 | May 5[b] | Yield ± SE kg/ha |
|---|---|---|---|---|---|
| Aztec 2.0 G | 0.089 | banded | 10.8±1.1a | 26.4±1.4ab | 5069.5±162.1ab |
| Aztec 2.0 G | 0.185 | banded | 12.4±0.9a | 23.8±1.0ab | 5521.9±271.5ab |
| Aztec 2.0 G | 0.185 | T-banded | 8.6±1.5a | 18.6±1.3b | 4508.0±235.6ab |
| Aztec 2.0 G | 0.113 | precision | 13.5±1.2a | 22.6±1.3ab | 5303.5±242.0ab |
| Counter 20 CR | 1.121 | banded | 16.2±0.9a | 28.7±0.9ab | 5428.3217.8±b |
| Counter 20 CR | 0.562 | banded | 16.1±1.2a | 29.8±3.1ab | 3462.9±274.9ab |
| Counter 20 CR | 1.121 | T-banded | 9.7±1.7a | 29.7±2.7ab | 4554.8±183.2ab |
| Counter 20 CR | 0.562 | precision | 13.3±0.3a | 26.0±1.7ab | 5740.3213.7±a |
| Counter 20 CR | 1.121 | precision | 11.3±0.9a | 29.1±2.6ab | 4913.6±167.2ab |
| Force 1.5 G | 0.056 | banded | 6.5±1.9a | 20.8±0.6ab | 5365.0±176.7ab |
| Force 1.5 G | 0.113 | banded | 10.7±1.8a | 27.5±1.2ab | 5147.5±275.9ab |
| Force 1.5 G | 0.113 | T-banded | 4.7±1.5a | 21.8±1.6ab | 4820.0±323.1ab |
| Force 1.5 G | 0.023 | precision | 12.7±1.6a | 26.1±1.0ab | 5709.1145.2±a |
| Check | | | 17.3±1.5a | 34.9±1.3a | 3322.5±224.0b |

Means in a column followed by the same letter are not significantly different (*P*=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.
[b]Total plant damage including both lesser cornstalk borer and southern corn billbug infestations.

Table 4.2. Corn wireworm damage to seedling corn at the Mountain Branch Experiment Station, 1999.

| Treatment/ formulation | Rate kg (AI)/ha | Application Method | % plants with damage ± SE[a] June 8 | June 26 | July 19 | Yield ± SE kg/ha |
|---|---|---|---|---|---|---|
| Aztec 2.0 G | 0.089 | banded | 28.5±0.9a | 17.9±1.1a | 13.4±0.9ab | 7471.6±273.9ab |
| Aztec 2.0 G | 0.185 | banded | 25.0±1.0a | 21.5±3.1a | 17.4±1.0ab | 7331.3±225.5ab |
| Aztec 2.0 G | 0.185 | T-banded | 23.2±1.3a | 17.6±1.5a | 13.3±1.3ab | 9015.9±231.2a |
| Aztec 2.0 G | 0.113 | precision | 22.6±0.5a | 18.6±1.3a | 15.2±0.5ab | 6925.8±245.0ab |
| Counter 20 CR | 1.121 | banded | 24.2±1.8a | 13.8±1.1a | 10.5±1.9ab | 8984.8±248.3a |
| Counter 20 CR | 0.562 | banded | 21.2±2.3a | 11.7±0.4a | 8.0±2.3b | 8610.4±390.5ab |
| Counter 20 CR | 1.121 | T-banded | 18.7±1.1a | 12.2±2.8a | 17.2±1.1ab | 8485.7±539.7ab |
| Counter 20 CR | 0.562 | precision | 21.2±2.5a | 29.1±2.4a | 19.5±2.5ab | 5927.5±303.8ab |
| Counter 20 CR | 1.121 | precision | 20.8±2.1a | 16.1±0.5a | 14.5±2.1ab | 6582.6±133.3ab |
| Force 1.5 G | 0.056 | banded | 18.0±0.5a | 11.9±1.8a | 12.7±0.5ab | 8204.9±382.4ab |
| Force 1.5 G | 0.113 | banded | 18.8±1.1a | 14.7±0.6a | 14.5±1.1ab | 8080.2±286.3ab |
| Force 1.5 G | 0.113 | T-banded | 18.6±1.1a | 10.8±1.1a | 10.0±1.2ab | 8267.2±274.8ab |
| Force 1.5 G | 0.023 | precision | 21.6±1.3a | 23.6±1.8a | 12.1±1.3ab | 5802.6±155.3±b |
| Check | | | 27.7±1.0a | 23.9±3.0a | 20.8±1.3a | 5709.1±353.3b |

Means in a column followed by the same letter are not significantly different ($P$=0.05).

[a]Arcsine square root transformations (data not shown) were performed before analysis.

Table 4.3. Lesser cornstalk borer and southern corn billbug damage to seedling corn, Southeastern Branch Experiment Station, 2000.

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | % plants with damage ± SE[a] April 18[b] | April 25[b] | May 2[b] | May 9[b] | May 16[b] | Yield ± SE kg/ha |
|---|---|---|---|---|---|---|---|---|
| Counter 20 CR | 1.121 | banded | 6.0±0.5a | 13.2±0.6abc | 11.3±1.3a | 18.9±1.1a | 28.7±2.5a | 6781.0±1096.9a |
| Counter 20 CR | 1.121 | T-banded | 11.5±1.3a | 15.3±1.9a | 11.1±1.9a | 10.5±0.9abc | 28.1±2.9a | 4778.1±1287.0a |
| Counter 20 CR | 0.562 | precision | 4.7±0.4a | 10.3±1.0abc | 6.0±1.0a | 16.0±1.1ab | 23.7±1.2abc | 7552.1±1107.7a |
| Counter 20 CR | 1.121 | precision | 0.0±0.0a | 12.0±1.0abc | 11.9±2.5a | 11.1±1.2abc | 22.6±2.3abc | 8938.6±2918.7a |
| Force 3.0 G | 0.113 | banded | 8.6±0.7a | 12.1±1.1abc | 10.9±1.5a | 6.0±1.1bc | 18.6±1.9abc | 7860.3±1576.4a |
| Force 3.0 G | 0.113 | T-banded | 9.6±0.6a | 11.5±0.9abc | 1.8±0.9a | 9.2±1.6abc | 16.4±2.4abc | 7089.2±1139.1a |
| Force 3.0 G | 0.056 | precision | 4.6±0.4a | 11.8±1.1abc | 10.2±1.7a | 14.0±0.7abc | 23.0±1.2abc | 5086.3±1712.4a |
| Force 3.0 G | 0.113 | precision | 8.9±0.7a | 14.5±1.1ab | 12.0±1.1a | 9.7±0.8abc | 22.0±0.6abc | 7089.2±1561.4a |
| Furadan 4 F | 1.121 | in furrow | 8.0±0.9a | 3.9±1.2bc | 12.3±0.9a | 4.2±1.3bc | 9.2±2.1bc | 7860.3±1637.5a |
| Furadan 4 F | 0.562 | precision | 5.8±0.4a | 7.2±0.3abc | 8.3±1.6a | 5.3±0.9bc | 8.9±1.7c | 6781.0±1257.5a |
| Furadan 4 F | 1.121 | precision | 3.8±1.4a | 7.6±1.3abc | 4.5±1.3a | 5.0±1.5bc | 16.8±1.3abc | 6472.8±958.3a |
| Regent 4 SC | 0.113 | in furrow | 7.1±0.9a | 2.8±1.4c | 7.8±1.5a | 5.61.6bc | 16.7±2.0abc | 6627.4±a1242.9 |
| Regent 4 SC | 0.056 | precision | 7.3±0.8a | 5.7±1.7abc | 13.4±1.1a | 2.8±1.4c | 17.8±1.3abc | 6935.7±1387.0a |
| Regent 4 SC | 0.113 | precision | 3.5±0.1a | 8.2±1.6abc | 6.2±1.1a | 4.±1.33bc | 12.7±0.7abc | 8014.0±1307.7a |
| Check | | | 9.0±0.7a | 15.7±1.0a | 8.1±0.5a | 5.1±1.5bc | 26.0±0.6ab | 5702.7±387.7a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.
[b]Total plant damage including both lesser cornstalk and southern corn billbug infestations.

Table 4.4. Sugarcane beetle damage to seedling corn at the Northwest Branch Experiment Station, 2000.

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | % plants with damage ± SE[a] May 18 | May 23 | June 8 | Yield ± SE kg/ha |
|---|---|---|---|---|---|---|
| Counter 20 CR | 1.121 | banded | 15.8±1.5a | 9.7±1.7a | 17.5±0.4a | 11096.2±544.9a |
| Counter 20 CR | 1.121 | T-banded | 17.0±1.6a | 15.8±0.5a | 15.4±2.9a | 10248.8±254.8a |
| Counter 20 CR | 0.562 | precision | 11.5±1.9a | 14.6±1.8a | 6.1±1.8a | 10402.4±607.9a |
| Counter 20 CR | 1.121 | precision | 5.1±2.5a | 11.1±3.7a | 21.9±2.7a | 12020.9±1205.2a |
| Force 3.0 G | 0.113 | banded | 4.9±1.4a | 15.6±1.8a | 16.0±1.0a | 10171.5±251.6a |
| Force 3.0 G | 0.113 | T-banded | 9.9±3.1a | 9.7±3.3a | 18.7±1.5a | 9169.5±229.8a |
| Force 3.0 G | 0.056 | precision | 11.2±2.1a | 10.7±2.0a | 6.9±2.2a | 8322.2±208.6a |
| Force 3.0 G | 0.113 | precision | 12.4±2.4a | 18.7±1.2a | 11.2±2.2a | 9093.3±298.4a |
| Furadan 4 F | 1.121 | in furrow | 7.5±2.2a | 3.7±1.9a | 9.6±2.8a | 9477.7±384.6a |
| Furadan 4 F | 0.562 | precision | 4.5±2.3a | 5.2±2.6a | 5.9±1.8a | 11867.3±447.1a |
| Furadan 4 F | 1.121 | precision | 0.0±0.0a | 2.5±1.3a | 6.9±2.0a | 11481.7±131.3a |
| Regent 4 SC | 0.113 | in furrow | 2.4±1.2a | 6.0±1.6a | 10.3±1.7a | 10479.8±793.2a |
| Regent 4 SC | 0.056 | precision | 4.9±2.4a | 10.2±2.2a | 10.3±2.2a | 10326.2±520.7a |
| Regent 4 SC | 0.113 | precision | 3.6±1.8a | 7.3±2.1a | 2.4±1.2a | 12098.2±428.4a |
| Check | | | 16.1±0.4a | 14.3±4.9a | 20.3±1.6a | 9324.1±115.6a |

Means in a column followed by the same letter are not significantly different ($P$=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.

Table 4.5. Lesser cornstalk borer and southern corn billbug damage to seedling corn in conventional tillage plots at the Southeastern Branch Experiment Station, 23 April 2001.

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | Mean % Plants with Damage ± SE |
|---|---|---|---|
| Counter 20 CR | 1.121 | banded | 1.9±1.0a |
| Counter 20 CR | 0.113 | precision | 6.0±1.6a |
| Counter 20 CR | 0.562 | precision | 10.0±0.8a |
| Counter 20 CR | 1.121 | precision | 6.6±2.1a |
| Furadan 4 F | 1.121 | in- furrow | 1.9±0.9a |
| Furadan 4 F | 0.113 | precision | 4.6±1.4a |
| Furadan 4 F | 0.562 | precision | 5.2±1.5a |
| Furadan 4 F | 1.121 | precision | 6.0±1.7a |
| Check | | | 5.1±1.6a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.
[b]Total plant damage including both lesser cornstalk and southern corn billbug infestations.

Table 4.6. Lesser cornstalk borer and southern corn billbug damage to seedling corn in conventional and conservation tillage plots at the Southeastern Branch Experiment Station, 1 May 2001.

| Tillage Practice | Mean % plants with damage ± SE[ab] |
|---|---|
| Conventional tillage | 13.2±0.2b |
| Conservation tillage | 25.5±0.2a |

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | Mean % Plants with Damage ± SE |
|---|---|---|---|
| Counter 20 CR | 1.121 | banded | 20.4±1.2a |
| Counter 20 CR | 0.113 | precision | 21.5±1.7a |
| Counter 20 CR | 0.562 | precision | 15.4±2.1a |
| Counter 20 CR | 1.121 | precision | 24.5±2.4a |
| Furadan 4 F | 1.121 | in furrow | 14.6±1.5a |
| Furadan 4 F | 0.113 | precision | 17.2±2.0a |
| Furadan 4 F | 0.562 | precision | 21.1±1.6a |
| Furadan 4 F | 1.121 | precision | 15.3±0.9a |
| Check | | | 24.6±a |

Means in a column followed by the same letter are not significantly different ($P$=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.
[b]Total plant damage including both southern corn billbug and lesser cornstalk borer infestations.

Table 4.7. Lesser cornstalk borer and southern corn billbug damage to seedling corn in conventional and conservation tillage plots at the Southeastern Branch Experiment Station, 10 May 2001.

| Tillage Practice | Mean % plants with damage ± SE[ab] |
|---|---|
| Conventional tillage | 31.1±0.3a |
| Conservation tillage | 35.1±0.2a |

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | Mean % Plants with Damage ± SE |
|---|---|---|---|
| Counter 20 CR | 1.121 | banded | 30.3±2.5a |
| Counter 20 CR | 0.113 | precision | 36.2±4.4a |
| Counter 20 CR | 0.562 | precision | 32.1±2.7a |
| Counter 20 CR | 1.121 | precision | 34.8±3.0a |
| Furadan 4 F | 1.121 | in furrow | 34.3±0.8a |
| Furadan 4 F | 0.113 | precision | 30.9±2.3a |
| Furadan 4 F | 0.562 | precision | 34.3±2.8a |
| Furadan 4 F | 1.121 | precision | 30.1±2.1a |
| Check | | | 35.0±0.6a |

Mans in a column followed by the same letter are not significantly different (*P*=0.05).
[a]Arcsine square root transformations (data not shown) were performed before analysis.
[b]Total plant damage including both southern corn billbug and lesser cornstalk borer infestations.

Table 4.8. Yield from conventional and conservation tillage plots at the Southeastern Branch Experiment Station, 2001.

| Tillage Practice | Yield ± SE (kg /ha) |
|---|---|
| Conventional tillage | 2386.5±11.6a |
| Conservation tillage | 1008.2±30.8b |

| Treatment/ Formulation | Rate kg (AI)/ha | Application Method | Yield ± SE kg/ha |
|---|---|---|---|
| Counter 20CR | 1.121 | banded | 1608.6±171.4a |
| Counter 20 CR | 0.113 | precision | 1666.4±190.0a |
| Counter 20 CR | 0.562 | precision | 1849.3±279.5a |
| Counter 20 CR | 1.121 | precision | 1425.5±150.6a |
| Furadan 4 F | 1.121 | in furrow | 1704.7±179.6a |
| Furadan 4 F | 0.113 | precision | 1762.8±125.0a |
| Furadan 4 F | 0.562 | precision | 244223±206.7a |
| Furadan 4 F | 1.121 | precision | 1464.1±216.2a |
| Check | | | 1950.8±170.4a |

Means in a column followed by the same letter are not significantly different (*P*=0.05).

# CHAPTER V

# RESEARCH SUMMARY

# AND CONCLUSION

Between 1999 and 2001, three studies were conducted to evaluate the efficacy of precision-placed insecticides and cultural control practices for management of soil insects in field corn and tobacco thrips in cotton. In general, field studies showed that precision placement of insecticides may be a significant option for reducing planting time insecticide requirements.

Field tests of precision-placed rates and in-furrow rates of aldicarb at planting at two locations in 1999-2001 showed that precision-placed aldicarb treatments significantly reduced thrips populations when compared to the untreated check and a similar if not greater reduction in thrips populations as the standard in-furrow 3.92 kg product per ha rate. Data indicated that field rates of precision-placed aldicarb may be reduced by one half or more and still achieve similar thrips control as conventional in-furrow treatments.

Plants treated by precision placement of aldicarb were as tall or taller than plants treated with in-furrow aldicarb. Residual analysis showed that precision placement treated plants had significantly higher levels of aldicarb and aldicarb metabolites present within the plant when compared to traditional in-furrow treatments during the first 30 days after treatment. By day 50, levels had dropped in plants treated by both precision placement and in-furrow treatments. Plants treated with the highest precision placement aldicarb rates had significantly higher phototoxicity ratings when compared to plants from the untreated check and in-furrow treatments, however this resulted in no loss of yield.

Fields tests conducted in 2000 and 2001 evaluated the efficacy of precision-placed aldicarb treatments in combination with ultra-narrow row planting practices and conservation tillage practices. Tests indicated that precision placement of aldicarb in combination with conservation tillage may be an effective system for thrips management in cotton at rates considerably lower than standard amounts used with in-furrow application. Ultra-narrow row planting practices or the combination of ultra-narrow row did not appear to significantly enhance either larval or adult thrips populations on seedling cotton.

A test conducted in 2001 demonstrated that precision placement of aldicarb in combination with conservation tillage may be an effective system for thrips management in cotton at rates considerably lower than standard amounts used with in-furrow application. Precision placed aldicarb treatments effectively controlled thrips infestations at reduced rates in comparison to the standard in-furrow amount of insecticide. Strip-tillage effectively reduced thrips populations in comparison with conventional tillage on several sampling dates. Plants in strip-tillage plots were significantly taller than plants in the conventional tillage plots. Plants from all precision placement treated plots were significantly taller than plants from the untreated check and were as tall as plants from plots treated with the standard in-furrow 3.92 kg product per ha rate. Plots treated with precision placement showed no decrease in yield when compared to the standard in-furrow 3.92 kg product/ha rate.

Results indicate that an integrated system that combines precision placement of aldicarb with conservation tillage practices may be a potential new avenue for thrips control in cotton. Such a system could provide an environmentally safe and cost effective alternative to traditional aldicarb use in cotton by combining judicious use of insecticides with conservation tillage.

Tests were conducted in 1999-2001 at four sites across Georgia to evaluate the efficacy of precision-placed soil insecticides and conservation tillage for the management of soil insects in field corn. Insect infestations in experiments mirrored the sort of dilemma that field corn farmers in the southeastern United States face in trying to manage a sporadic but destructive group of soil pests. Pest infestations are often hard to predict, but if large, may cause devastating damage and yield loss.

Soil insect damage data indicated that precision placement of soil insecticides provided superior control in mixed infestations of southern corn billbug and lesser cornstalk borer at reduced rates when compared to conventional in-furrow applications. The observed effects of conservation and conventional tillage in field corn mirror the results found by All and co-workers in 1984. Mean percent damage was significantly higher and yields were significantly decreased in conservation tillage as compared with conventional tillage. The potential for increased southern corn billbug damage is increased in conservation tillage but lesser cornstalk borer infestations are often reduced when compared to conventionally tilled corn. The test in 2001 verified that in areas where soil insects are a high risk, the use of preventive insecticide treatments is questionable.