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Growth responses of cotton to aldicarb and temperature

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Abstract

Aldicarb, 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime, is a systemic insecticide used extensively for early season insect control in cotton (*Gossypium hirsutum* L.). The indirect effect of aldicarb on cotton due to insect control is well documented; however, much less is known regarding its direct effect on cotton growth and development. The purpose of this research was to test the hypothesis that aldicarb in the absence of insects imposes a direct effect on cotton growth and that aldicarb effectiveness on growth depends on temperature. Cotton plants (cv. Deltapine-50 and DES-119) were grown in outdoor sunlit plant growth chambers under five day/night temperatures (20/12, 25/17, 30/22, 35/27, and 40/32 °C). In one study, aldicarb at 0.56 kg ha^{-1} was applied to soil at sowing. In a second study, aldicarb was first applied at a rate of 0.84 kg ha^{-1} to soil at sowing and applied again at a rate of 2.24 kg ha^{-1} at the stage of flower bud initiation as a side-dressing. Aldicarb increased early season vegetative growth of cotton plants grown at 25/17, 30/22, and 35/27 °C, but not for plants grown at 20/12 and 40/32 °C. Aldicarb also promoted the early formation of cotton flower buds at the five temperature regimes and increased the number of flowers at 30/22 °C. The treated plants had more growing roots, greater root length densities in the 61–80 cm soil depth, and higher root/shoot ratios than control plants at all temperatures. Our results showed that aldicarb promoted cotton earliness by enhancing growth rates and promoting the roots to grow deeper into soil. The responses of cotton to aldicarb depended on temperature, with a greater effect occurring at near optimum temperatures for cotton growth.

Key words: Aldicarb; Cotton; Growth and development; Soil depth; Temperature

1. Introduction

Aldicarb, 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime, is a carbamate compound used as a systemic insecticide in cotton (Colyer et al., 1991; Terry, 1992). It was estimated that 3.5 million acres of cotton was treated with aldicarb in the United States in 1991 (Cooke et al., 1992). Aldicarb, when applied at planting, controls early season pests such as thrips (Slosser, 1993), tarnished plant bugs (Parrott et al., 1985), and nematodes (Smith et al., 1991). This compound has also been widely used for insect control since 1965 in a variety of other crops, including soybean (*Glycine*

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max L.) (Smith et al., 1991) and sweet potato (*Ipomoea batatas* L.) (Chalfant, 1992).

Despite the well-documented effects of aldicarb on pest control, there are conflicting reports about the growth regulatory effects of aldicarb on growth and yield of cotton. Increases and decreases in plant growth and yield have been reported. Hopkins and Taft (1965) first noted phytotoxicity of aldicarb when side-addressed to cotton for pest control. Later, Cowan and Davis (1967) observed a reduction in plant stands when aldicarb was applied in furrows. Womack and Schuster (1986) reported that aldicarb, when applied in the absence of pests, reduced the growth of cotton seedlings. However, many researchers found that aldicarb had positive growth responses on cotton. Aldicarb has been observed to significantly enhance earliness (Durant, 1989), increase yield (Cooke et al., 1992), and improve fiber quality (Christian, 1992) in cotton.

The mode of aldicarb action that results in improved plant growth is unknown, but there are several areas of speculation. One is the known insecticidal and nematicidal property of aldicarb, with some possible microbicidal activity resulting in reduced pest damage. Other speculation suggests a possible hormonal function for aldicarb (Reddy et al., 1990), but no direct evidence is available to support this hypothesis. Scott et al. (1985) speculated that improved cotton yields might be partially due to a plant growth response to the aldicarb. Ragab (1981) showed that aldicarb at low concentrations in the nutrient medium enhanced nutrient uptake and transfer from roots to stems and leaves of cotton plants. Inconsistency of the effects of aldicarb on cotton and other crops may be attributed to several reasons: variation in the environmental conditions and failure to separate the direct and the indirect effects of pest control. The objective of this study was to evaluate the direct effects of aldicarb in the absence of insects on developmental processes of cotton, especially on early season vegetative growth, root morphology, flowering, and dry matter partitioning under a range of temperatures. We hypothesized that aldicarb in the absence of insects has a direct impact on cotton growth and that plant responses to aldicarb soil application depend on growth temperature.

2. Materials and methods

2.1. Soil–plant–atmosphere-research (SPAR) units

The soil–plant–atmosphere-research (SPAR) units used in these studies have been described previously (Acock et al., 1985; Reddy et al., 1991). Briefly, each SPAR unit consisted of a soil bin (100 cm high, 200 cm long, and 50 cm wide) containing a rooting medium and an acrylic plastic chamber (200 cm high, 200 cm long, and 150 cm wide) to accommodate aerial parts of the plants. The soil bin was completely surrounded by a wooden box with one removable side to facilitate mapping the roots on the glass face and to exclude light. The viewing glass surface of the soil bin was divided into 7 vertical compartments (24×100 cm each) in which a 1.2×1.2 cm wire reference grid was embedded. Air temperature and carbon dioxide concentration in the chambers and irrigation were controlled by a computer (Digital, Pro 380, Digital Equipment Corp., Maynard, MA, USA*).

A preliminary experiment was conducted mainly to compare the root growth of cotton between the aldicarb-treated and control plants (Experiment I). The experiment was repeated with five temperature treatments added (Experiment II). Root and canopy growth were compared between the aldicarb-treated and control plants. To keep free of insects, chambers were closed during the entire experimental period and opened only to make measurements.

2.2. Plant culture in Experiment I

Soil bins of the SPAR units were filled with a mixture of Leeper clay loam soil and sand (3:1 by volume). The soil was sterilized with methyl bromide prior to placing in the bins to avoid nematode infestation. Cotton (*Gossypium hirsutum* L.,

*Trade name and company name are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by USDA–ARS or Mississippi State University.

cv. Deltapine-50) seed was sown in two SPAR units. A total of 25 plants in 5 rows of 5 plants per row were grown in each SPAR unit until 52 days after emergence (DAE). Plant spacing was 10 cm within row and 40 cm between rows. Aldicarb at rates equivalent to 0.56 kg ha^{-1} was applied to one of the two SPAR units in granular form to each row after covering the seeds with soil.

The temperature in all growth chambers was maintained at 28/23 °C day/night for 14 days during seed germination and emergence to obtain healthy and uniform seedlings. During the remainder of the growing season, air temperature in all growth chambers was maintained at 30/22 °C. Full strength Hoagland's solution (Hewitt, 1952) was applied regularly to meet the optimal nutritional requirement throughout the growing season.

During the growing season, new root length appearing on the glass face of the soil bin was marked with a wax pencil and measured. Simultaneously, the number of actively growing root axes, from every 20 cm soil depth of each panel (7 panels per soil bin), and the deepest root on the glass surface of the soil bin were recorded. The quantity of the root material appearing at any particular depth on the glass viewing surface was assumed to be representative of roots at that depth throughout the compartment (Taylor et al., 1970). From the measurements of rooting intensity (cm root m^{-2} soil), calculations were made to obtain root length density (m root m^{-3} soil) by multiplying rooting intensity with a correction factor. For this calculation, we assumed that all roots in the outer 2 mm layer were visible for measurement.

2.3. Plant culture in Experiment II

The soil and plant management in Experiment II was similar to that in Experiment I. 'DES-119' cotton seed was sown in 10 SPAR units. 'Deltapine-50' and 'DES-119' are the common cotton cultivars with similar growth characteristics grown in many cotton growing areas. Similar responses to aldicarb were expected from these two cultivars. A total of 55 plants in 11 rows of 5 plants per row was grown in each unit. The temperatures in the 10 SPAR chambers were initially maintained at 28/23 °C day/night for 14 days. During the remainder of the growing season, five temperatures, 20/12, 25/17, 30/22, 35/27, and 40/32 °C, were applied to the 10 SPAR chambers (2 chambers per temperature treatment). The day/night temperatures ranging from 25/17 to 35/27 °C are common in many cotton growing areas during the growing season. These temperatures are considered as near optimum for cotton growth and development (Reddy et al., 1991). Both 20/12 and 40/32 °C are extreme temperatures for cotton, but cotton crops experience these temperatures for at least some period during the growing season. Soil temperatures in soil bins were not independently controlled and were influenced to some extent as a result of the imposed temperatures and ambient air temperature (Reddy et al., 1997).

Aldicarb was applied to one of two SPAR units from each temperature treatment. The other SPAR unit from the same temperature treatment was not treated with aldicarb and served as the control. Two aldicarb applications were made. The first application, at the rate of 0.84 kg ha^{-1}, was made as a soil-dressing at sowing. The second application, at the rate of 2.24 kg ha^{-1}, was made as a side-dressing at 28 DAE for 30/22, 35/27, and 40/32 °C, 33 DAE for 25/17 °C, and 42 DAE for 20/12 °C treatments. The second aldicarb application coincided with initial squaring (flower bud initiation) in each temperature treatment. The rates of aldicarb applied in these experiments were within the standard range of dosage recommended for soil treatment (Parrott et al., 1985; Scott et al., 1985; Colyer et al., 1991).

Plant growth and development parameters including main stem height, numbers of main stem nodes, flowers and growing root axes, and rooting intensity at different soil depths were monitored at various growth stages. At 15 DAE, 30 plants from six alternate rows were harvested and half of them (15 plants) were randomly selected for vegetative growth measurements. At 27 DAE, another 10 plants from two alternate rows were harvested. All 15 remaining plants were harvested at 56 DAE. Plants were dissected into leaves, stems, roots, and fruiting structures including squares, flowers and bolls at each harvest. Total leaf area per plant was measured and plant parts were oven dried at 75 °C and the dry weights of plant parts determined.

2.4. Statistical analysis

Statistical analysis was conducted using SAS procedures (SAS Institute Inc., Cary, NC, USA). The standard errors of the means for main stem height of the aldicarb-treated and control plants were calculated and presented. A least significant difference (LSD) test at 0.05 for biomass partitioning between canopy and roots was also calculated and presented. A pooled root dry weight of 15 plants from each 20 cm soil depth was determined and the average root dry weight of each plant was used. Student's *t*-tests were used to compare the differences in rooting intensity, root length density, and number of roots, from every 20 cm soil depth of 7 panels, between the aldicarb-treated and control plants.

3. Results

3.1. Experiment I

Root growth

The greater number of actively growing root axes was present in the top 40 cm soil profile (Table 1). The number of roots declined dramatically at deeper soil depths for both treatments. There was no significant difference between control and treated plants in the number of actively growing root axes at soil depths of 0–60 cm. However, the aldicarb-treated plants produced significantly more ($P<0.05$) growing root axes in the 61–80 cm depth than did the control plants. Similar results were obtained in rooting intensities and root length densities, and the changes in intensities and densities were due primarily to the changes of number of growing root axes in those soil profiles (Table 1).

Table 1
Influence of aldicarb[a] on number of actively growing root axes, rooting intensities, and root length densities of cotton at different soil depths at 52 days after emergence

Treatment	Soil depth (cm)			
	0–20	21–40	41–60	61–80
	Actively growing root axes (no. m^{-2})			
Control	490[b]	380[b]	320[b]	50[c]
Aldicarb	390[b]	380[b]	260[b]	220[b]
	Rooting intensity (cm m^{-2})			
Control	1100[b]	910[b]	760[b]	175[c]
Aldicarb	1000[b]	850[b]	840[b]	700[b]
	Root length density (m m^{-3})			
Control	5500[b]	4550[b]	3800[b]	875[c]
Aldicarb	5000[b]	4250[b]	4200[b]	3500[b]

[a]Applied at 0.56 kg ha^{-1} as a soil dressing at sowing.
[b,c]Means ($n=7$) within the columns and within each parameter followed by the same letter are not different (Student's *t*-test at 0.05).

3.2. Experiment II

Vegetative growth

Aldicarb stimulated early season vegetative growth of cotton. Aldicarb significantly ($P<0.05$) increased main stem heights for plants grown at 25/17, 30/22, and 35/27 °C at 15 and 27 DAE, but plant heights in these treatments were not different by 56 DAE (Figure 1). This increase in plant height resulted from greater main stem growth rates, longer internodes, and more main stem nodes in the aldicarb-treated plants (data not shown). Aldicarb effects were more significant for plants grown at near optimum temperatures (25/17, 30/22, and 35/27 °C) and less so for the lower (20/12 °C) or higher (40/32 °C) temperatures. The response of total leaf area to aldicarb was similar to that of plant height (data not shown).

Reproductive growth

Aldicarb also promoted early appearance of cotton squares (flower buds) (Figure 2). For example, 50% of the control plants grown at 25/17 °C (Figure 2-B) had visible squares (≥ 2 mm in size) 33 DAE, but the aldicarb-treated plants were at a similar stage at 29 DAE, 4 days earlier than control plants. The aldicarb-treated cotton also had a shorter duration of square appearance period. For example, at 40/32 °C (Figure 2-E), it took 4 days, from 23 to 27

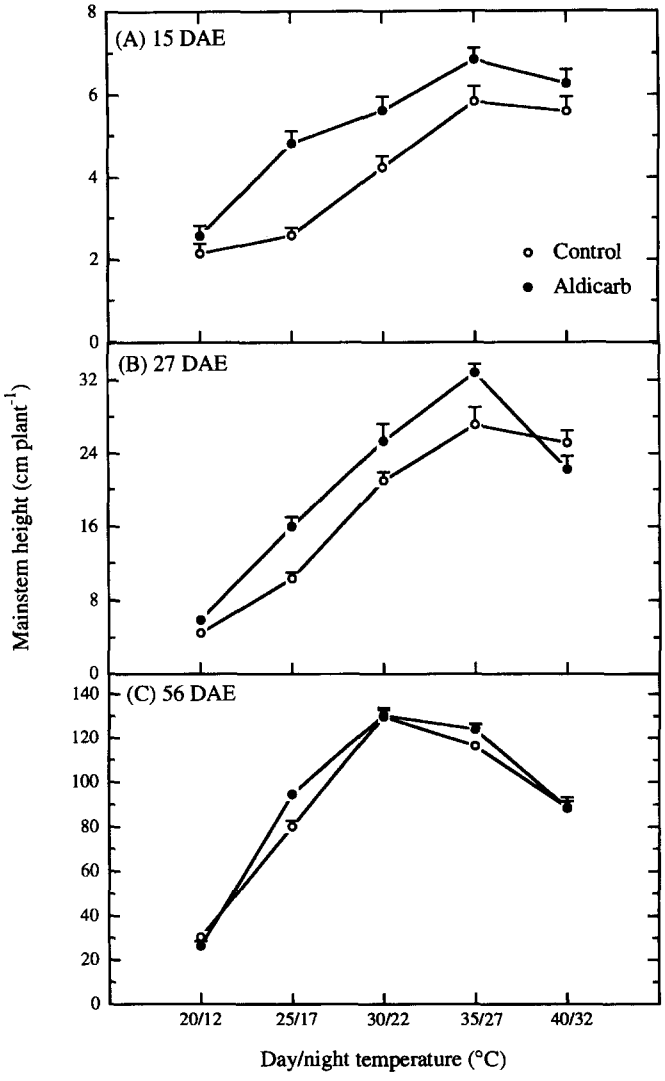

Fig. 1. Cotton main stem height as affected by aldicarb and temperature at 15, 27, and 56 days after emergence (DAE). Vertical bars represent standard errors ($n = 15$, 10, and 9 at 15, 27, and 56 DAE, respectively). Aldicarb was applied as a soil-dressing at sowing (0.84 kg ha^{-1}) and as a side-dressing at initial squaring (2.24 kg ha^{-1}).

DAE, for all treated plants to have squares while it took 7 days for the control plants. The treated plants grown at 35/27 (Figure 2-D) and 30/22 °C (Figure 2-C) did not have visible squares earlier than the control plants, but had a shorter duration of square appearance period. Square appearance for both control and treated plants grown at 20/12 °C (Figure 2-A) was much later than for plants grown at the four higher temperatures, and aldicarb did not affect square appearance at this temperature.

Among the plants grown at five temperatures, only those at 30/22 and 35/27 °C developed flowers before harvest while other plants either did not develop flowers at lower temperatures (20/12 and 25/17 °C) or had early square abscission at the

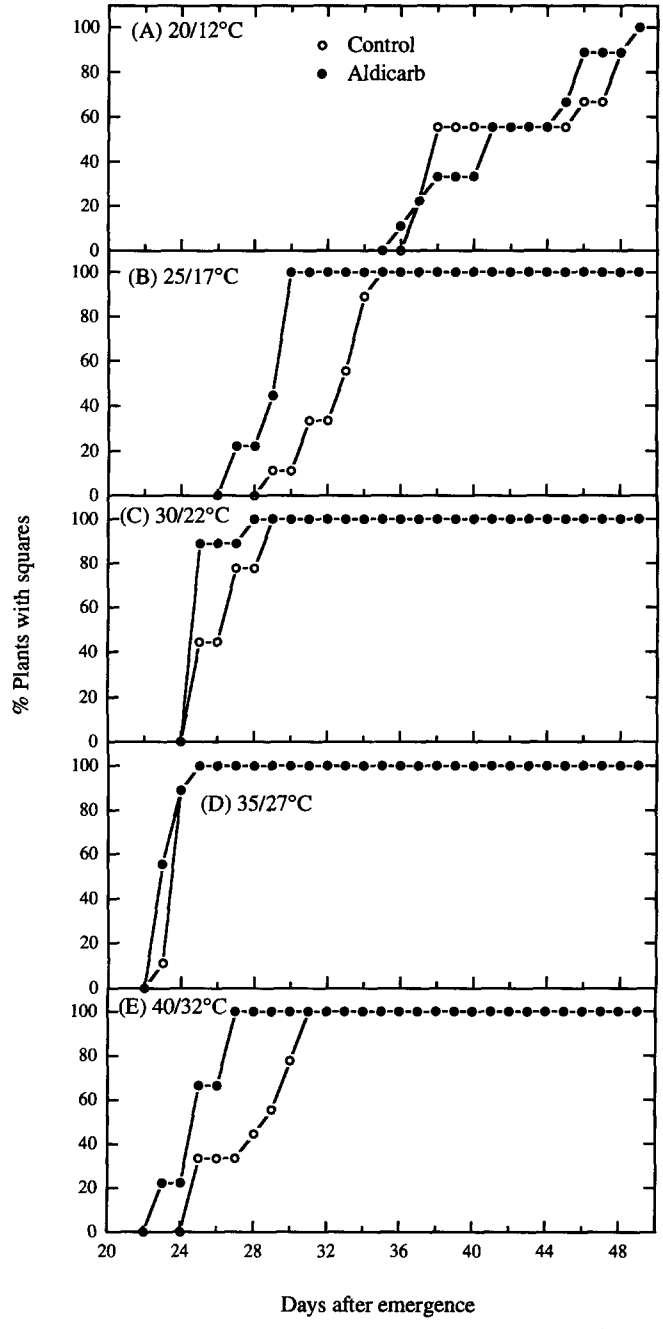

Fig. 2. Influence of aldicarb and temperature on cotton square formation. Aldicarb was applied as a soil-dressing at sowing (0.84 kg ha^{-1}) and as a side-dressing at initial squaring (2.24 kg ha^{-1}).

higher temperature (40/32 °C) during the 56 DAE period. The number of flowers per plant at 30/22 was greater in aldicarb-treated plants than in control plants (Figure 3).

Biomass production

Aldicarb increased the canopy dry weight at early vegetative growth stages (15, 27 DAE) at near optimum temperatures, but did not affect canopy dry

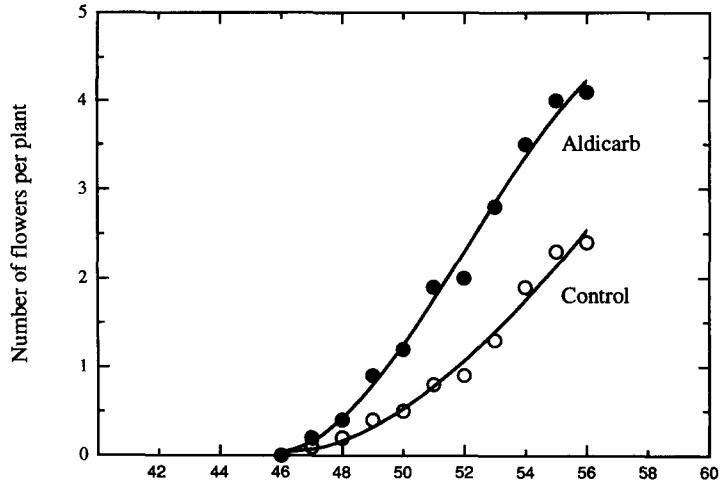

Fig. 3. Influence of aldicarb and temperature on the number of cotton flowers. Aldicarb was applied as a soil-dressing at sowing (0.84 kg ha^{-1}) and as a side-dressing at initial squaring (2.24 kg ha^{-1}).

weight at late growth stages (56 DAE, data not shown). The greatest effect of aldicarb was on root dry weight. The aldicarb-treated plants had a numerically greater root dry weight than control plants at the four higher temperatures (25/17, 30/22, 35/27, 40/35 °C) for all soil depths (Figure 4).

Biomass partitioning

Aldicarb favored the partitioning of dry matter into roots over the canopy at three lower temperatures (20/12, 25/17, 30/22 °C), resulting in higher root/shoot ratios than the control (Table 2). Aldicarb also promoted the partitioning of biomass into the deeper roots over the top roots.

4. Discussion

The results clearly supported our hypothesis that aldicarb in the absence of insects has a direct impact on cotton growth and that plant responses to aldicarb soil application depend on growth temperature. Aldicarb enhanced cotton early season vegetative growth and early square formation. The primary effect of aldicarb was on root growth, especially on the roots in deeper soil depths. Our results are in agreement with the field studies by Scott et al. (1985) and Parrott et al. (1985), but differ from the greenhouse data obtained by Womack and Schuster (1986) that showed a negative response of plants to aldicarb. In the present study, the greater growth response to aldicarb occurred at near optimum temperatures (25/17 to 35/27 °C), while aldicarb at a lower (20/12 °C) or a higher (40/35 °C) temperature had little or no effect on cotton plants. Similar results were obtained from aldicarb-treated soybean plants in which the greatest response to aldicarb occurred at a daily mean temperature of 22 °C (Barker et al., 1988). The sensitivity of plants to aldicarb may also be influenced by other factors. For example, the greatest soybean growth and yield increases caused by aldicarb occurred when the plants were grown in fine-textured soils or soils with high organic matter (Barker et al., 1988).

We did not know the mechanism by which aldicarb promoted cotton canopy and deeper root growth. According to Bowman (1988), aldicarb half-life in Plainfield sand was 3 to 5 days and completely converted to its sulfoxide and sulfone within 2 weeks. The sulfoxide and sulfone decomposition products quickly moved down in the soil. By the second week after application of aldicarb, these metabolites, largely the sulfoxide, moved down 30–40 cm to the 50 cm soil depth Bowman (1988).

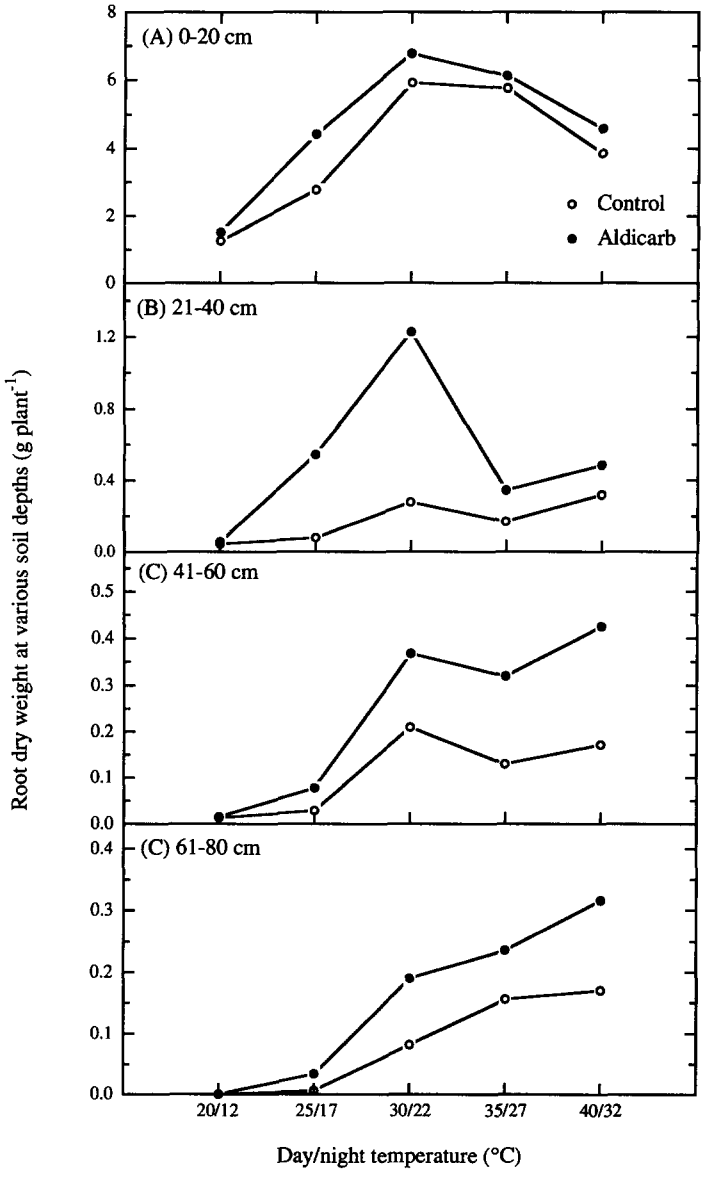

Fig. 4. Influence of aldicarb and temperature on cotton root dry weight at various soil depths at 56 days after emergence. Aldicarb was applied as a soil-dressing at sowing (0.84 kg ha^{-1}) and as a side-dressing at initial squaring (2.24 kg ha^{-1}). Each value of root dry weight is an average of 15 plants from which roots were pooled.

Therefore, it is possible that aldicarb metabolites not aldicarb per se play an important role in promoting cotton growth. The quick downward movement of the sulfoxide is consistent with the increased deeper root growth caused by aldicarb application. More actively growing root axes, and greater rooting intensities and root length densities at deeper soil depths for the aldicarb-treated cotton, would enable plants to explore the whole soil profile more completely and to extract more water and nutrients compared to the control plants. Increased root growth, in turn, may promote the canopy growth and development. Aldicarb may directly affect canopy growth. Andrawes et al. (1973) and

Table 2
Influence of aldicarb[a] and temperature on biomass partitioning and root/shoot ratios in cotton at 56 days after emergence; each value is the mean of 9 observations

Temperature (°C)	Treatment	% total plant dry weight		Root/shoot
		Canopy	Root	
20/12	Control	90.3	9.7	0.11
	Aldicarb	85.2	14.8	0.18
25/17	Control	93.1	6.9	0.07
	Aldicarb	89.1	10.1	0.11
30/22	Control	91.1	8.9	0.10
	Aldicarb	86.5	13.5	0.16
35/27	Control	90.6	9.4	0.10
	Aldicarb	89.5	10.5	0.12
40/32	Control	88.3	11.7	0.13
	Aldicarb	86.6	13.4	0.16
$LSD_{0.05}$		3.2	3.2	0.04

[a]Applied as a soil-dressing at sowing (0.84 kg ha^{-1}) and as a side-dressing at initial squaring (2.24 kg ha^{-1}).

Coppedge et al. (1967) found that a large portion of aldicarb also quickly converted to the sulfoxide degradation product and part of it to a sulfone product in cotton leaves. The insecticidally active sulfoxide may play a role in increased early season vegetative growth caused by aldicarb.

In summary, aldicarb in the absence of insects promoted early season vegetative growth, early flower development, and deeper root growth. The effectiveness of aldicarb on cotton growth varied and was dependent on growing season temperature. The accumulation of aldicarb metabolites in the cotton leaves and rapid downward movement of these metabolites in the soil may play an important role in altering cotton growth and development.

References

Acock, B., Reddy, V.R., Hodges, H.F., Baker, D.N. and McKinion, J.M., 1985. Photosynthetic response of soybean canopies to full-season carbon dioxide enrichment. Agron. J., 77: 942–947.

Andrawes, N.A., Romine, R.R. and Bagley, W.P., 1973. Metabolism and residues of Temik aldicarb pesticide in cotton foliage and seed under field conditions. J. Agr. Food Chem., 21: 379–386.

Barker, K.R., Koenning, S.R., Bostian, A.L. and Ayers, A.R., 1988. Growth and yield responses of soybean to aldicarb. J. Nematol., 20: 421–431.

Bowman, B.T., 1988. Mobility and persistence of metolachlor and aldicarb in field lysimeters. J. Environ. Qual., 17: 689–694.

Chalfant, R.B., Hall, M.R., Johnson, A.W., Seal, D.R. and Bondari, K., 1992. Effects of application methods, timing, and rates of insecticides and nematicides on yield and control of wireworms (Coleoptera: Elateridae) and nematodes (Tylenchida: Heteroderidae) that affect sweet potato. J. Econ. Entomol., 85: 878–887.

Christian, M., 1992. Effectiveness of Temik brand insecticide sidedress treatments in controlling cotton aphids on the Texas high plains. Proc. Beltswide Cotton Conf. Published by National Cotton Council of America, Memphis, TN, Vol. 2, pp. 828–830.

Colyer, P.D., Micinski, S. and Nguyen, K.T., 1991. Effect of planting date on the efficacy of an in-furrow pesticide and the development of cotton seedling diseases. Plant Dis., 75: 739–742.

Cooke Jr., F.T., Caillavet, D.F., Scott, W.P. and Parvin Jr., D.W., 1992. The impact of Temik on yields and returns to cotton in the midsouth. Proc. Beltswide Cotton Conf., National Cotton Council of America, Memphis, TN, Vol. 1, pp. 426–427.

Coppedge, J.R., Lindquist, D.A., Bull, D.L. and Dorough, H.W., 1967. Fate of 2-methyl-2-(methylthio)propionaldehyde O-(methylcarbamoyl)oxime (Temik) in cotton plants and soil. J. Agr. Food Chem., 15: 902–910.

Cowan Jr., C.B. and Davis, J.W., 1967. Systemic insecticides for control of the boll weevil and the cotton leafhopper. J. Econ. Entomol., 60: 1038–1041.

Durant, J.A., 1989. Yield response of cotton cultivars to early-season applications of chlordimeform and aldicarb. J. Econ. Entomol., 82: 626–632.

Hewitt, E.J., 1952. Sand and water culture methods used in the study of plant nutrition. Commonwealth Agric. Bur. Tech. Commun., 22. CAB, Farnham Royal, UK, 189 pp.

Hopkins, A.R. and Taft, H.M., 1965. Control of certain cotton pests with a new systemic insecticide, UC-21149. J. Econ. Entomol., 58: 746–749.

Parrott, W.L., Jenkins, J.N., Meredith Jr., W.R., McCarty Jr., J.C. and Bailey, J.C., 1985. Effects of aldicarb on tarnished plant bug (Hemiptera: Miridae) density and cotton yield. J. Econ. Entomol., 78: 155–157.

Ragab, S.M., 1981. Cotton growth and nutrient uptake following Temik (aldicarb) application. J. Agr. Sci., Camb., 97: 731–737.

Reddy, K.R., Reddy, V.R. and Baker, D.N., 1990. Influence of aldicarb on growth, development and photosynthesis of cotton. Proc. Beltswide Cotton Research Conf., National Cotton Council of America, Memphis, TN, p. 44.

Reddy, V.R., Baker, D.N. and Hodges, H.F., 1991. The effects of temperature on cotton canopy growth, photosynthesis, and respiration. Agron. J., 83: 699–704.

Reddy, V.R., Reddy, K.R. and Wang, Z., 1997. Temperature and aldicarb effects on cotton root growth and development. Biotronics, in press.

Scott, W.P., Smith, J.W. and Snodgrass, G.L., 1985. Response of cotton arthropod populations in cotton to various dosages of aldicarb applied in the furrow at planting time. J. Econ. Entomol., 78: 249–257.

Slosser, J.E., 1993. Influence of planting date and insecticide treatment on insect pest abundance and damage in dryland cotton. J. Econ. Entomol., 86: 1213–1222.

Smith, G.S., Niblack, T.L. and Minor, H.C., 1991. Response of soybean cultivars to aldicarb in Heterodera glycines-infested soils in Missouri. Supplement to J. Nematol., 23: 693–698.

Taylor, H.M., Huck, M.G., Klepper, B. and Lund, Z.F., 1970. Measurement of soil grown roots in a rhizotron. Agron. J., 62: 807–809.

Terry, L.I., 1992. Effect of early season insecticide use and square removal on fruiting patterns and fiber quality of cotton. J. Econ. Entomol., 85: 1402–1412.

Womack, C.L. and Schuster, M.F., 1986. Testing the reported positive growth response for cotton, Gossypium hirsutum, treated with aldicarb. J. Econ. Entomol., 79: 1118–1120.