5-2014

Relationship Between 1,3-Dichloropropene and Nitrogen Fertility in Cotton in the Presence of Root-knot and Reniform Nematodes

Amanda Michelle Greer
University of Arkansas, Fayetteville

Relationship Between 1,3-Dichloropropene and Nitrogen Fertility in Cotton in the Presence of Root-knot and Reniform Nematodes

Relationship Between 1,3-Dichloropropene and Nitrogen Fertility in Cotton in the Presence of Root-knot and Reniform Nematodes

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Plant Pathology

by

Amanda Michelle Greer
University of Arkansas at Monticello
Bachelor of Science Agriculture, 1996

May 2014
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Dr. Terry Kirkpatrick
Thesis Director

Dr. Nathan Slaton
Committee Member

Dr. John Rupe
Committee Member

Dr. Craig Rothrock
Committee Member

ABSTRACT

The use of soil fumigation for nematode management in cotton (*Gossypium hirsutum*) has become increasingly popular in recent years in the absence of effective resistant cultivars. While soil fumigation is relatively expensive, lint yields have consistently been improved to make this practice profitable in fields with severe nematode pressure. Growers in southern Arkansas have observed changes in cotton growth patterns when severely infested fields are fumigated. The most noticeable change has been excessive (rank) growth resulting in an increased need for growth regulators, especially where the nitrogen fertilization exceeds standard recommendations. Field studies were conducted between 2007 and 2010 to determine if these changes in crop growth are related to nematode control or nitrogen fertilizer rates alone or in combination. Large plot studies were conducted in a field with a history of root-knot nematode (2007) or reniform nematode pressure in (2008 – 2009) consisting of twelve row strips that had received Telone II® (1,3-dichloropropene) paired with equivalent sized strips that received no fumigation. Within these strips five nitrogen rates (34, 101, 123, 146, and 224 kg N/ha) were applied in 30 m long plots. In 2009 and 2010, microplot studies were also conducted in the reniform location. Six row strips that had received Telone II® at 28 l/ha were paired with equivalent sized strips that received no fumigation. Within each strip, three nitrogen rates (0, 101, 146 kg N/ha) were applied in 3 m long plots. Results show yearly variability due to nematicide application and suggest that maintaining fertility is beneficial whether or not nematodes are controlled. Excess growth above normal cotton parameters was not observed due to the inputs.

ACKNOWLEDGEMENTS

Thanks be to God who opens doors of opportunity to those willing to enter.

Thanks to the faculty and staff of the University of Arkansas and Cooperative Extension Service, including my student workers, who have all helped me in ways too numerous to list.

Also, thanks go out to Mr. Bruce Bond who allowed my field trials to be done on his farm, worked patiently with me to get them done, and waited patiently to see the results.

Thanks to my family who hung in there and provided support throughout this long process.

Without all their help this would not have been possible.

DEDICATION

This thesis is dedicated to Mr. Charles Denver who got me started in cotton consulting when I was an undergraduate. He believed in me and has served as a mentor and friend to me all these years. I thank him so much for everything he has taught me. Because of him, I am where I am today.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Cotton (*Gossypium hirsutum*) is an important economic crop in Arkansas, with USDA-NASS reporting about 235,000 planted hectares and an estimated harvest of 1,297,000 bales, yielding an economic return of $420,710,000 for 2012. Crop loss estimates for plant-parasitic nematodes in Arkansas for 2011 totaled about 4% of the crop (Blasingame and Patel, 2012). Producers in southeastern Arkansas commonly encounter both *Meloidogyne incognita* (Kofoid and White, 1919; Chitwood, 1949), the southern root-knot nematode, and *Rotylenchulus reniformis* (Linford and Oliveira, 1940), the reniform nematode, as economic pests in cotton fields (Bateman et al, 2000; Anonymous, 2013). The root-knot nematode is a sedentary endoparasite that infects cotton roots and causes root knots or galling. The juvenile J2 penetrates the root cortex with its stylet establishing a feeding site or giant cell. Symptoms of root-knot infection in cotton include root galling, plant stunting, increased wilting, and decreased yields. (Thomas and Kirkpatrick, 2001) Cotton plants grown in root-knot nematode infested areas may display foliar symptoms of nutrient deficiencies, including nitrogen deficiency.

The reniform nematode female is a sedentary semi-endoparasite that infests cotton roots attaching itself to a feeding site and beginning the reproductive process. The male reniform are not parasitic and may or may not contribute to the reproductive process. Symptoms of reniform infestation in cotton include plant stunting, fruit abortion, suppressed root growth, and lowered yield. Cotton plants grown in reniform nematode-infested areas may display foliar symptoms of nutrient deficiencies (Koenning *et al*. 2004). Reniform nematodes can quickly increase their population once introduced in cotton fields in the southeast part of Arkansas (Monfort, 2008). Traditionally, growers with high nematode populations have applied nitrogen fertilizer at rates that are higher than would normally be recommended by the Cooperative Extension Service based on soil test reports even though there is no current literature to support such action. The perception is additional N may "counteract" nematode damage and increase yields. Unfortunately, routine application of excess nitrogen fertilizer is of concern both economically and from an environmental standpoint because of the potential for surface and groundwater issues (Delgado and Bausch, 2005). Burris *et al* (2010) found that applying higher nitrogen fertilizer rates without fumigant had lower yields than where fumigant was applied in conjunction with lower fertilizer rates.

Fertilizer may affect nematode population densities. Kularathna *et al* (2014) found that reniform nematode reproduction decreased as P levels increased in greenhouse studies, but not in the field. Ahmad and Siddiqui (2009) found that N-P-K fertilizer suppressed *M. incognita* populations in tomato. Mineral fertilizers had a negative effect on nematode populations in certain crops (Berankova and Saly, 1980), and Gruzdeva *et al*. (2007) reported a correlation between nitrogen (N), phosphorus (P), and potassium (K) individually or in combinations with declining nematode population densities. Urea, in combination with molasses was effective in lowering *Meloidogyne arenaria* in squash (Rodriguez and King, 1980) and Melakeberhan (1999) found that soybean performance was greater where the soybean cyst nematode (*Heterodera glycines*) was present when there was a balanced supply of nutrients. Conversely, Luc *et al* (2007) and Ebelhar *et al* (2011) have reported that soil fertility had no effect on nematode damage to turf and cotton, respectively. McLean *et al* (2003) found that occasionally anhydrous ammonia applications may reduce reniform populations but not more than commercial nematicides.

Both micro and macro nutrients may be important in crop responses under nematode pressure (Stewart, *et al*., 2010). Behm *et al*., (1995) found that fertilizing corn with zinc (Zn) stimulated the hatch of eggs of *Heterodera glycines.* Phosphorus fertilization was associated with reduced penetration of roots of sugar beets by juveniles of *Heterodera schachtii* (Bell, 1996). Similarly, Wolcott *et al*. (2008) found that high levels of P and Zn were as effective as soil fumigation for increasing cotton lint yield in the presence of both reniform and root-knot nematodes. Increased root-knot nematode damage to guava was related to nutrient deficiency (Gomes *et al*., 2008). Because the effects of fertilizers on nematode pathology are not fully understood, investigations of the influence of soil nutrients on nematode biology and pathology will be an additional step toward the development of effective site-specific nematode management.

The use of soil fumigation for nematode management in cotton has become increasingly popular among Arkansas cotton growers. While soil fumigation is relatively expensive, and difficult to apply (Koenning et al, 2004; Starr et al, 2007) the practice provides an effective means of mitigating yield losses due to nematodes (Kinlock and Rich, 1998; 2001). Using 1,3-dichloropropene provides control of nematodes but unlike older fumigants, is more limited in spectrum and is not as effective on other soilborne pathogens and weeds (Noling and Becker, 1994). Davis *et al*. (2002) found that 1,3-dichloropropene treated plots numerically reduced nematode populations at midseason but numbers rebounded by harvest and treatments did not statistically increase yield. Lint yields in southern Arkansas have improved sufficiently to make 1,3-dichloropropene treatment attractive. In many fields, particularly where population densities of root-knot or reniform are high, growers have observed changes in cotton growth patterns where fumigants are applied. The most noticeable change has been excessive (rank) plant growth resulting in an increased need for growth regulators, especially where nitrogen fertilizer rates have exceeded standard Cooperative Extension Service recommendations. Qiao *et al*. (2012) found that 1,3-dichloropropene increased plant height, stem diameter, and root size (yield) in ginger while reducing root-knot nematode populations.

LITERATURE CITED

Ahmad, F., and Siddiqui, M.A. 2009. Management of root-knot nematode, *Meloidogyne incognita* in tomato. Pakistan Journal of Nematology 27:369-373.

Anonymous, 2012. National Cotton Council, Cotton Nematode Research and Education Program, Arkansas. Retrieved from http://www.cotton.org/tech/pest/nematode/survey/arkansas.cfm

Anonymous, 2013. National Cotton Council, Population Distributions and Densities Maps. Retrieved from http://www.cotton.org/tech/pest/nematode/distributions.cfm?state=03A

Barber, T. and McClelland, B. 2013 Cotton Quick Facts Nitrogen sources and rates for Arkansas cotton. AG 1276 Retrieved from http://www.arkansascrops.com/wpcontent/uploads/2013/03/2013_Arkansas_Cotton_Quick_Facts.pdf

Bateman, R.J., Kirkpatrick, T.L., Robbins, R.T., and Lorenz, G. 2000. The distribution of root-knot and reniform nematodes in Arkansas, 1990-1999. 2000 Proceedings of the Beltwide Cotton Conference. Vol. 1 Pp. 171.

Behm, J. E., Tylka, G.L., Niblack, T.L., Wiebold, W.J., and Donald, P.A. 1995. Effect of zinc fertilization of corn on hatching of *Heterodera glycines* in soil. Journal of Nematology 27:164-171.

Bell, D. 1996. Influence of phosphate on the population dynamics of *Heterodera schachtii*. Nematropica 26:241.

Berankova, J., and Saly, A. 1980. The effect of mineral fertilizer on soil nematodes. Sbomik UVTIZ, Ochrana Rostlin 16:67-73.

Blasingame, D., and Patel, M.V. 2012 Cotton disease loss estimate committee report. Pp. 341–343 Proceedings of the Beltwide Cotton Conference, Orlando, FL, January 3–6, 2012. Memphis, TN: National Cotton Council of America.

Bourland, F.M., and Watson, C.E., 1990. COTMAP, a Technique for Evaluating Structure and Yield of Cotton Plants, Crop Sci. 30:224–226.

Burris, E., Burns, D., McCarter, K.S., Overstreet, C., Wolcott, M., and Clawson, E. 2010. Evaluation of the effects of Telone II (fumigation) on nitrogen management and yield in Louisiana delta cotton. Precision Agric. 11:239-257.

Davis, R., Bader, M., Kemerait, R., Jost, P., and Mcneill, R. 2002. Comparison of nematicide efficacy in strip-tillage and conventional tillage cotton (abstract). Proceedings of the National Cotton Council Beltwide Cotton Conference. Paper No. 66.

Delgado, J.A. and Bausch, W.C. 2005. Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. Journal of Soil and Water Conservation. 60(6):379-387.

Ebelhar, M.W., Clark, D.R., and Pringle, H.C. 2011. Interaction of nitrogen and potassium fertilization on reniform nematode dynamics in a cotton/corn rotation system. 2011 Beltwide Cotton Conferences, 4-7 January, 2011; Atlanta, GA. National Cotton Council, Cordova, TN, Pp. 1336-1344.

Gomes, V.M., Souza, R.M., Silva, M.M., and Dolinski, C. 2008. Nutritional status of guava (*Psidium guajava* L.) plants parasitized by *Meloidogyne mayagnensis*. Nematologia Brasileira 32:154-160.

Gruzdeva, L.I., Matveeva, E.M., and Kovalenko, T.V. 2007. Changes in soil nematode communities under the impact of fertilizers. Pochvovedenie 6:756-768.

Kinlock, R.A., and Rich, J.R. 1998. Response of cotton yield and *Meloidogyne incognita* soil populations to soil applications of aldicarb and 1,3-D in Florida. Journal of Nematology. 30:639–642.

Kinlock, R.A., and Rich, J.R. 2001. Management of root-knot and Reniform nematodes in ultra-narrow row cotton with 1,3-dichloropropene. Supplement to Journal of Nematology. 33(4S):311-313.

Koenning, S.R., Wrather, J.A., Kirkpatrick, T.L., Walker, N.R., Starr, J.L., and Mueller, J.D. 2004. Plant-parasitic nematodes attacking cotton in the United States: Old and emerging production challenges. Plant Disease. 88:100–113.

Kularathna, M.T., Overstreet, C., McGawley, E.C., Xavier, D.M., and Martin, C.M. 2014. Influence of soil nutrients on reproduction and pathogenicity of *Rotylenchulus reniformis* on cotton. Nematropica 44: *In press*.

Luc, J.E., Crow, W.T., Stimac, J.L., Sartain, J.B., and Gilbin-Davis, R.M. 2007. Effects of *Belonolaimus longicaudatis* management and nitrogen fertility on turf quality of golf course fairways. Journal of Nematology 39:62-66.

Melakeberhan, H. 1999. Effects of nutrient source on the physiological mechanisms of *Heterodera glycines* and soybean genotypes interactions. Nematology 1:113-120.

McLean, K.S., Lawrence, G.W., Overstreet, C., and Young, L.D. 2003. Efficacy of anhydrous ammonia on reniform nematode in cotton. In Proceedings of Beltwide Cotton Conference, National Cotton Council, Memphis, TN pp.282-283.

Monfort, W.S., Kirkpatrick, T.L., and Mauromoustakos, A. 2008. Spread of *Rotylenchulus reniformis* in an Arkansas cotton field over a four-year period. Journal of Nematology 40(3): 161–166.

Noling, J.W. and Becker, J.O. 1994. The challenge of research and extension to define and implement alternatives to methyl bromide. Journal of Nematology, 26(4S):573-586.

Rodriguez-Kabana, R., and King, P.S. 1980. Use of mixtures of urea and blackstrap molasses for control of root-knot nematodes in soil. Nematropica 10:38-44.

Starr, J.L., Koenning, S.R., Kirkpatrick, T.L., Robinson, A.F., Roberts, P.A., and Nichols, R.L. 2007. The future of nematode management in cotton. Journal of Nematology, 39:283-294.

Stewart, J.M., Oosterhuis, D., Heitholt, J.J., Mauney, J.R. (Eds.) 2010 Physiology of Cotton. ISBN 978-90-481-3195-2

Thomas, S.F. and Kirkpatrick T.L. 2001. Root-knot nematodes. Pp. 40-42, T.L. Kirkpatrick and C.S. Rothrock, eds. Compendium of Cotton Diseases Second Edition. APS Press. St Paul, MN.

Wolcott, M., Burris, E., McGawley, E.C., Overstreet, C., and Padgett, B. 2008. Site-specific nematode management - nutrient and texture dynamics. Pp 210-218. Proceedings of the Beltwide Cotton Conferences, 8-11 January, 2008; Nashville, TN. National Cotton Council, Memphis, TN.

Qiao, K., Zhu, Y., Wang, H., Xiaoxue, J., and Wang, K. 2012. Effects of 1,3-dichloropropene as a methyl bromide alternative for management of nematode, soil-borne disease, and weed in ginger (Zingiber officinale) crops in China. Crop Protection 32(2012) 71-75.

CHAPTER 2

RELATIONSHIP BETWEEN SOIL FUMIGATION AND NITROGEN FERTILIZER RATES ON COTTON IN A ROOT-KNOT NEMATODE-INFESTED FIELD

ABSTRACT

An experiment was conducted in a cotton (*Gossypium hirsutum*) field near Portland, Arkansas with a history of severe root-knot nematode (*Meloidogyne incognita*) damage, to evaluate the relationships between nitrogen fertilization rate and soil fumigation on crop performance. Field strips (12 rows each) that were either fumigated preplant with 1,3-dichloropropene (Telone II®) or non-fumigated were used to evaluate the influence of nitrogen fertilization rates of 34, 101, 123, 146, and 224 kg N/ha on crop growth, development and yield. Nematicide application impacted plant height at only two of six weekly measurements within-season, whereas N fertilizer rate was more consistently associated with differences in plant growth, influencing plant height at four of the six times. Fertilization rate also influenced the number of nodes above white flower during the reproductive growth stages. Neither nematode control nor nitrogen rate, affected the seed cotton or lint yield.

INTRODUCTION

Cotton is an important economic crop in Arkansas, with USDA-NASS reporting about 235,000 planted hectares and an estimated harvest of 1,297,000 bales, yielding an economic return of $420,710,000 for 2012. Crop loss estimates for plant-parasitic nematodes in Arkansas for 2011 totaled about 4% of the crop (Blasingame and Patel, 2012). Producers in southeastern Arkansas commonly encounter both *Meloidogyne incognita* (Kofoid and White, 1919; Chitwood, 1949), the southern root-knot nematode, and *Rotylenchulus reniformis* (Linford and Oliveira, 1940), the reniform nematode, as economic pests in cotton fields (Anonymous, 2013). The root-knot nematode is a sedentary endoparasite that infects cotton roots and causes root knots or galling. The juvenile J2 penetrates the root cortex with its stylet establishing a feeding site or giant cell. Symptoms of root-knot infection in cotton include root galling, plant stunting, increased wilting during the heat of the day, and decreased yields (Thomas and Kirkpatrick, 2001). Cotton plants grown in root-knot infested areas also display foliar symptoms of nutrient deficiencies, including nitrogen deficiency (Koenning et al, 2004). Traditionally, some growers in Arkansas with high nematode populations have applied nitrogen fertilizer at rates that are higher than would normally be recommended by the Cooperative Extension Service based on soil test reports even though there is no current literature to support such action. The perception is additional nitrogen may “counteract” nematode damage and increase yields. Unfortunately, routine application of excess nitrogen fertilizer is of concern both economically and from an environmental standpoint because of the potential for surface and groundwater issues (Delgado and Bausch, 2005).

The use of soil fumigation for nematode management in cotton has become increasingly popular among Arkansas cotton growers. While soil fumigation is relatively expensive, and fumigants are difficult to apply (Koenning et al, 2004; Starr et al, 2007), the practice provides an effective means of mitigating yield losses due to nematodes (Kinlock and Rich, 1998). Lint yields in the region have improved sufficiently to make this treatment attractive. In many fields, particularly where population densities of root-knot or reniform nematodes are high, growers have observed changes in cotton growth patterns where fumigants are applied. The most noticeable change has been excessive (rank) plant growth resulting in an increased need for growth regulators, especially where nitrogen fertilizer rates have exceeded standard Cooperative Extension Service recommendations.

The objectives of this research were to: 1) determine the relationship between nematicide and nitrogen fertilizer rate on cotton growth and development, 2) determine if nematode control affects the nitrogen rate required for optimum yield, and 3) monitor nematode-infested sites for increased levels of residual nitrogen.

MATERIALS AND METHODS

In 2007, a study was initiated in a commercial field near Portland, AR with a history of high root-knot nematode pressure. All cotton crop management was performed by the grower as a part of his regular farming operation. Twelve row (96 cm rows) strips 152 m long were fumigated with 1,3-dichloropropene (Telone II®, Dow AgroScience, Indianapolos, IN) at 28 l/ha approximately 6 weeks prior to planting. The cotton variety was DP555 BG/RR. The 1,3-dichloropropene was applied using a modified Orthman six row ripper hipper equipped to apply 1,3-dichloropropene under the row to a depth of 25 cm. (Orthman Manufacturing Inc. Lexington, NE). A John Deere hipper (John Deere, Moline, IL) was used immediately behind the Orthman to further seal the beds to retain the fumigant.

Each treated strip was paired with a strip of equivalent size that received no fumigation. Twenty plots, 30 meters long, were established randomly within each strip. Nitrogen fertilization rates (total nitrogen applied) of 34, 101, 123, 146, and 224 kg/ha were assigned randomly. The rate of 34 kg/ha was considered the control standard. A rate of 101 kg/ha nitrogen was the rate that was recommended for cotton production based on a soil test report generated by University of Arkansas Soil Testing Laboratory from a field sample submitted by the farmer. The higher nitrogen rate of 123 kg/ha is a rate that would commonly be recommended in the area for normal cotton production (Barber and McClelland, 2013). By contrast the 146 kg/ha nitrogen rate would normally be applied by farmers in known problem fields, specifically in fields with high nematode population densities (Charles Denver, personal communication). The 224 kg/ha rate was chosen as a high-end maximum overage amount that would likely not be considered for economic reasons by growers. Phosphorus and potassium were applied across the entire area based on the farmer's soil test report. Soil samples were taken prior to fertilizer application from each plot to a depth of 12-15 cm and a composite of 12 cores was used to represent each plot. These composite samples were divided and analyzed at the University of Arkansas Soil Testing Laboratory in Marianna, AR for nutrients and at the Arkansas Nematode Diagnostic Laboratory at Hope, AR for nematode population density. Soil was processed by elutriation (Byrd et al, 1976) and centrifugal flotation (Jenkins, 1964). When the cotton was fully established, stand counts were taken as a beginning of the COTMAN procedure and the cotton was scouted weekly for growth according to COTMAN parameters (Oosterhuis and Bourland, 2008)

Liquid nitrogen fertilizer (32% N) was applied at pinhead square at five rates (0, 67, 90, 112, and 191 kg/ha) with a John Deere fertilizer sidedress knife applicator rig (John Deere, Moline, IL) using an AgLeader PF 3000 Pro (AgLeader 2202 S River Side Drive, Ames IA) controller and a Rawson Par (Rawson Control Systems, Inc 116 2nd St E, Oelwien, IA) 4 variable-speed hydraulic motor that was manually switched to apply the correct rate for each plot. At full bloom, 34 kg/ha of nitrogen was applied as urea by air across the entire field. From pinhead square, COTMAN data were collected weekly throughout the growing season until the end of the effective fruiting period which was physiological cutout, (Oosterhuis et al, 1996) or node above white flower (NAWF) = 5 (Bourland et al, 1992; Oosterhuis et al, 1996). COTMAN data included plant heights, the number of main stem nodes, presence or absence of first sympodial position fruit, status of the fruit (a square or a boll), and number of nodes above the uppermost white flower in the first fruiting position (NAWF). Data were collected from ten plants that were arbitrarily selected within the two center rows of each plot with five plants selected from each of the rows near the center of the plot to minimize edge effects. Daily minimum and maximum air temperatures were obtained from a NOAA weather station located at the GPS Gin Co. Inc. in Portland, AR less than 0.8 km from the plots.

After defoliation, final whole plant growth maps (Bourland and Watson, 1990) were conducted on plants from 1.5 m of row from the center two rows near the middle of each plot. Seed cotton was hand-harvested according to boll position. Bolls were placed into brown paper bags according to first position, second position, and all outer positions and transported to the lab where they were dried for 24 hrs at 43 C to remove extraneous moisture. The samples were then cleaned by hand to remove burrs and large trash, weighed and ginned on a bench top cotton gin (maker unknown) to determine lint weight.

Deep core samples were collected after harvest using a tractor mounted Giddings soil sampler (Giddings Machine Company, Windsor, CO). One 4 cm diameter core was collected from the center of each plot to a depth of 1 m. These cores were cut into 15 cm sections, and the soil was air dried and delivered to the University of Arkansas Laboratory in Fayetteville, AR where nitrates were extracted with 2 mol L^{-1} KCl (Mulvaney, 1996) determined by colorimetry (San+ autoanalyzer, Skalar Analytical B.V., Breda, the Netherlands). In addition to deep samples, standard soil samples for nutrient analysis were taken from each plot using a hand held soil probe. Six cores per plot were taken from the center of the plot in a 5 m diameter circle around the point where the deep sample was collected. These cores were mixed together and assayed for nutrient content by the University of Arkansas Soil Testing Laboratory and at Arkansas Nematode Diagnostic Laboratory for nematode population density. COTMAN data were entered into COTMAN III version 03.30.07 (University of Arkansas, Fayetteville, AR) for analysis. Data analysis was performed, using SAS Statistical Analysis Software, version 9.3 (SAS Analytical Institute, Cary, NC).

RESULTS AND DISCUSSION

Root-knot population density was lower ($P=0.07$) in fumigated plots across nitrogen rates prior to planting in 2007, but no differences were detected at harvest (Fig. 2.1). No differences ($P=0.05$) in nematode population density were seen due to fertilizer rate, nematicide application or the interaction between fertilizer rate and nematicide application at harvest (Fig. 2.1). The root-knot nematode population density was considerably higher in all treatments at harvest than at planting. Kinloch and Rich (2001) reported decreases in root-knot densities post-harvest but their results were rate dependent, with population density decreasing with higher rates of 1,3-dichloropropene. In our study, above normal rainfall in July could have impacted these results (Fig. 2.2).

No fertilizer rate × nematicide interaction occurred for plant height. Neither fertilizer rate nor nematicide affected plant height at pinhead square (Table 2.1). Nematicide application resulted in taller plants, although differences were significant only for the second and fourth weeks. Fertilizer rate did not impact plant height at weeks one and two. Plants were taller in general throughout the remaining sampling periods at fertilizer rates that were greater than 34 kg/ha. Plant height of irrigated cotton in Arkansas normally ranges 114 to 127 cm (Oosterhuis and Kerby, 1998), and although plant heights were increased for some rates of nitrogen and for nematicide at some observations, none of the plots in this trial were greater than or equal to these measurements.

The node of the first sympodial branch (first fruiting node) did not differ due to nematicide, fertilizer, or nematicide × fertilizer. The first fruiting node is influenced by various environmental factors including cultivar, weather, and plant density (Stewart et al, 2010).

Nitrogen fertilizer rate resulted in differences in total nodes per plant for all weekly samples except the pinhead square and the last sampling time (Table 2.2). Differences among rates were, however, were less than one node. It is doubtful that these differences would have much impact on yield. It is generally expected for irrigated cotton in Arkansas to have a total of around 23 nodes (Oosterhuis and Kerby, 1998). None of the plots in this trial reached this number, and the tallest plants in our trial only achieved about 17 nodes, indicating that excessive plant growth due to the nitrogen inputs did not occur.

Plant height-to-node ratios were similar for all treatments except for samples taken at week 4 (Table 2.3). A nematicide × fertilizer interaction was found at week 4 with the nematicide-treated plots having a greater ratio of plant height to the number of main stem nodes. A low height-to-node ratio may indicate crop stress while a high ratio (> 2.0) during mid-season indicates excess growth (Oosterhuis and Kerby, 1998). While the combination of nematicide application and nitrogen fertilizer rate appeared to promote excess plant growth during the mid-season period, ratios seldom differed from plants that had not received a nematicide. Consequently, these inputs did not result in extreme plant growth levels, and would not have triggered extra growth regulator applications.

Nematicide application did not affect NAWF, and there was no interaction between nematicide and fertilizer. Additional nitrogen beyond 34 kg/ha, regardless of the rate applied, increased the NAWF early in the season (Fig. 2.3). This trend continued at weeks 3 and 4 with the 34 kg/ha rate resulting in numerically fewer NAWF than the other nitrogen rates. By the end of the season, it is likely that the NAWF was influenced strongly by accumulated heat units (Stewart et al, 2010), and the effect of a low nitrogen fertilization rate was less obvious. If NAWF at first bloom are at 7 or less, this may indicate plant stress and can signify that the plants may enter premature cutout if not managed to remediate the stress. Preferred NAWF at first bloom should be near 10. (Guthrie et al, 1993, Stewart et al, 2010) The highest initial NAWF in this trial was 8.5 indicating there was some stress present. Low overall NAWF across the trial at first bloom regardless of nitrogen implies the presence of a more general stressor besides nitrogen rate, but a lack of response due to nematicide indicates that nematodes were not likely that main stressor. There were no extremely high NAWF counts that would have indicated highly vigorous plots due to these two inputs.

Total boll counts did not differ due to nematicide, fertilizer, or nematicide × fertilizer interaction. Seed cotton and lint yields, either collectively or by fruiting position, were not influenced by nematicide, fertilizer, or nematicide × fertilizer interaction (Table 2.4). Even though there were significant differences in some of the growth indices taken in this trial, none of the responses resulted in differences in yield. Some of these growth differences were small and may have been overshadowed by the impacts of weather conditions.

Soil nitrate concentration at depths from 0 – 76 cm were similar among treatments (Table 2.5). With the exception of the highest fertilization rate (224 kg/ha) which resulted in nitrate levels at 46-61 cm deep that were greater than the other rates, nitrate levels did not vary among treatments. Using the nematicide had no effect on soil nitrate levels deep in the soil profile in this study, and there was no interaction between fertilizer rate and nematicide application. None of the fertilization rates increased deep residual soil nitrogen levels.

CONCLUSION

The relationship between N fertilizer rate and nematode control that could change the nitrogen fertilizer requirements of a cotton crop was not clearly demonstrated in this experiment where root-knot nematodes were present. Relative to the main effects of 1,3-dichloropropene and nitrogen fertilizer, some growth parameters that appeared to be inconsistent may have been related to environmental factors unrelated to nematodes and fertility. Nematicide application impacted plant height at only two of the six measurement times whereas nitrogen fertilizer rate was more consistently associated with differences in plant growth, including the NAWF in two of the four sampling periods and plant height at four of the six measurements. Neither of these inputs, however, caused cotton growth to exceed the growth that would normally be expected. Similarly, neither of the inputs affected the seed cotton or lint yield. The suggestion that growers might be able to lower nitrogen fertilizer rates in nematode-infested fields if a nematicide is applied appears to be unlikely, at least where root-knot nematodes are present at the levels found in this site. These findings were, however, only for one year and should be repeated before conclusions can be drawn.

LITERATURE CITED

Anonymous. 2012. Crop Production Report. Washington, DC:USDA-NASS Publications.

Anonymous, 2012. National Cotton Council, Cotton Nematode Research and Education Program, Arkansas. Retrieved from http://www.cotton.org/tech/pest/nematode/survey/arkansas.cfm

Anonymous, 2013. National Cotton Council, Population Distributions and Densities Maps. Retrieved from http://www.cotton.org/tech/pest/nematode/distributions.cfm?state=03A

Barber, T. and McClelland, B. 2013 Cotton Quick Facts Nitrogen sources and rates for Arkansas cotton. AG 1276 Retrieved from http://www.arkansascrops.com/wpcontent/uploads/2013/03/2013_Arkansas_Cotton_Quick_Facts.pdf

Bateman, R.J., Kirkpatrick, T.L., Robbins, R.T., and Lorenz, G. 2000. The distribution of root-knot and reniform nematodes in Arkansas, 1990-1999. 2000 Proceedings of the Beltwide Cotton Conference. Vol. 1 Pp. 171.

Bourland, F.M., and Watson, C.E., 1990. COTMAP, a Technique for Evaluating Structure and Yield of Cotton Plants, Crop Sci. 30:224–226.

Bourland, F.M., Oosterhuis, D.M., and Tugwell, N.P. 1992 Concept for Monitoring the Growth and Development of Cotton Plants Using Main-Stem Node Counts, Journal of Production Agriculture. 5:532–538.

Blasingame, D., and Patel, M.V. 2011 Cotton disease loss estimate committee report. Pp. 341–343 Proceedings of the Beltwide Cotton Conference, Orlando, FL, January 3–6, 2012. Memphis, TN: National Cotton Council of America.

Burris, E., Burns, D., McCarter, K.S., Overstreet, C., Wolcott, M., and Clawson, E. 2010 Evaluation of the effects of Telone II (fumigation) on nitrogen management and yield in Louisiana delta cotton. Precision Agric. 11:239-257.

Byrd, D.W., Barker, K.R., Ferris, H., Nusbaum, C.J., Griffin, W.E., Small, R.H., and Stone, C.A. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8: 206-212.

Chitwood, B.G. 1949. Root-knot nematodes, part I. A revision of the genus Meloidogyne Goeldi, 1887. Proceedings of the Helminthological Society of Washington. 16 (1949): 90-104.

Delgado, J.A. and Bausch, W.C. 2005. Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. Journal of Soil and Water Conservation. 60(6):379-387.

Guthrie, D., Bourland, F., Tugwell, P, and Hake, K. Charting a course to cutout. Cotton Physiology Today, National Cotton Council, July 1993, Volume 4, No.6.

Jenkins, W.R. 1964 A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692

Kinlock, R.A, and Rich, J.R. 1998. Response of cotton yield and *Meloidogyne incognita* soil populations to soil applications of aldicarb and 1,3-D in Florida. Journal of Nematology. 30:639–642.

Kinlock, R.A., and Rich, J.R. 2001. Management of root-knot and Reniform nematodes in ultra-narrow row cotton with 1,3-dichloropropene. Supplement to Journal of Nematology. 33(4S):311-313.

Koenning, S.R., Wrather, J.A., Kirkpatrick, T.L., Walker, N.R., Starr, J.L., and Mueller, J.D. 2004. Plant-parasitic nematodes attacking cotton in the United States: Old and emerging production challenges. Plant Disease. 88:100–113

Kofoid, C.A. and White, W.A. 1919. A new nematode infection of man. J. Amer. Med. Assoc. 72:567-569.

Linford, M.B., and Oliveira, J.M. 1940. Rotylenchulus reniformis, Nov. gen. N. sp., a nematode parasite of roots. Proceedings of the Helminthological Society of Washington 7:35-42.

Starr, J.L., Koenning, S.R., Kirkpatrick, T.L., Robinson, A.F., Roberts, P.A., and Nichols, R.L. 2007. The future of nematode management in cotton. Journal of Nematology, 39:283-294.

Stewart, J.M., Oosterhuis, D., Heitholt, J.J., Mauney, J.R. (Eds.) 2010 Physiology of Cotton. ISBN 978-90-481-3195-2

Thomas, S.F. and T.L. Kirkpatrick. 2001. Root-knot nematodes. Pp. 40-42, IN: T.L. Kirkpatrick and C.S. Rothrock, eds. Compendium of Cotton Diseases Second Edition. APS Press. St Paul, MN.

Oosterhuis, D.M., Bourland, F.M., Tugwell, N.P., and Cochran, M.J. Terminology and concepts related to the COTMAN crop monitoring system. 1996. Ark. Agric. Exp. Sta. Special Report 174.

Oosterhuis, D.M. and Bourland, F.M. Cotman Users Manual 2008. Retrieved from http://www.cotman.org/files/COTMAN-Manual.pdf

Oosterhuis, D.M. and Kerby, T.A. Measures of Cotton Growth and Development 1998. Retrieved from http://www.cotman.org/files/COTMAN-Manual_Part3.pdf

TABLES AND FIGURES

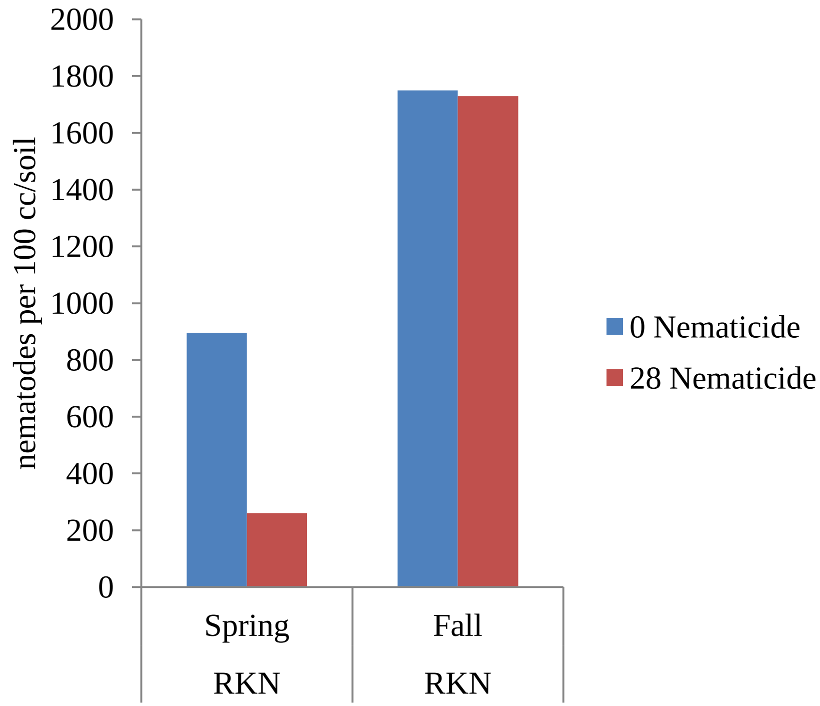


Figure 2.1. Root-knot (RKN) nematode population densities for soil fumigation with a nematicide (28 l/ha of 1,3-dichloropropene) or no fumigation for 2007. Means for spring nematodes differ at *P=0.07*; means for fall nematodes root-knot do not differ.

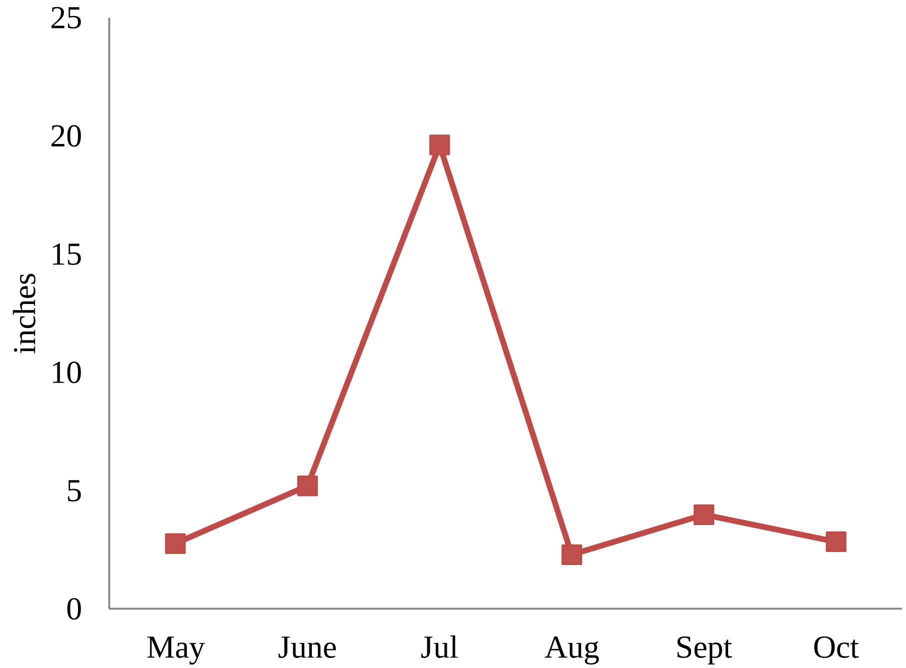


Figure 2.2. Rainfall totals for the 2007 crop season in Portland, AR by month (in inches). Data obtained from the National Weather Service. (http://www.climate.gov/datasearch/)

Table 2.1. Cotton plant height beginning at pinhead square for soil fumigation with a nematicide and nitrogen fertilizer rates in 2007.

	Weeks Beginning at Pinhead Square					
	1	2	3	4	5	6
Fertilizer[a] Rate						
	Plant Height (cm)					
34	28.6 a[b]	43.2 a	66.8 b	73.8 b	81.0 c	85.4 b
101	28.9 a	44.3 a	72.1 ab	80.5 a	88.4 bc	94.8 ab
123	31.8 a	46.7 a	76.4 a	84.8 a	92.6 ab	96.4 a
146	28.9 a	44.3 a	74.9 a	81.4 a	90.2 bc	94.3 ab
224	29.5 a	46.2 a	78.1 a	83.3 a	100.0 a	104.6 a
Nematicide[c] (l/ha)						
0	27.6 a	41.8 b	72.0 a	75.8 b	86.5 a	89.0 a
28	31.5 a	48.1 a	75.3 a	85.7 a	94.4 a	101.2 a

[a]Nitrogen rates in kg/ha
[b]Means within columns and main effect followed by the same letter do not differ at $P \leq 0.05$ by LSD
[c]1,3-dichloropropene (Telone II®) applied six weeks pre-plant

Table 2.2 Total nodes per plant beginning at pinhead square among fertilizer rates across nematicide treatments for large plot trial 2007

	Weeks Beginning at Pinhead Square											
	1		2		3		4		5		6	
Fert[a]												
34	7.9	a[b]	10.0	c	12.5	b	14.2	b	14.5	b	15.2	a
101	8.1	a	10.4	bc	12.8	b	14.7	ab	15.6	a	16.5	a
123	8.2	a	10.6	ab	13.4	a	14.9	a	15.8	a	16.5	a
146	7.9	a	10.4	bc	13.2	ab	14.8	ab	15.3	ab	16.2	a
224	8.3	a	10.9	a	13.5	a	15.3	a	15.9	a	17.0	a

[a]Nitrogen rates in kg/ha
[b]Means followed by the same letter in column are not significantly different $P \leq 0.05$ by LSD

Table 2.3. Weekly means of height to node ratios beginning at pinhead square for nematicide × fertilizer for large plot trial 2007

	Weeks Beginning at Pinhead Square					
	1	2	3	4	5	6
	Height to Node Ratios (H:N)					
0 Nematicide[a]	1.36 b	1.58 b	2.16 a	2.00 b	2.24 a	2.20 a
Fert[b]						
34	1.33 a[c]	1.55 a	2.08 a	2.00 c	2.18 a	2.20 a
104	1.35 a	1.60 a	2.10 a	1.98 c	2.10 a	2.08 a
123	1.48 a	1.63 a	2.23 a	2.03 c	2.18 a	2.15 a
146	1.35 a	1.58 a	2.15 a	2.08 c	2.33 a	2.28 a
224	1.28 a	1.53 a	2.23 a	1.93 c	2.43 a	2.28 a
28 Nematicide[a]	1.53 a	1.83 a	2.27 a	2.31 a	2.37 a	2.40 a
Fert[b]						
34	1.53 a	1.88 a	2.13 a	2.13 b	2.25 a	2.23 a
104	1.48 a	1.78 a	2.33 a	2.33 a	2.38 a	2.43 a
123	1.58 a	1.88 a	2.25 a	2.43 a	2.40 a	2.48 a
146	1.55 a	1.80 a	2.30 a	2.25 ab	2.30 a	2.30 a
224	1.53 a	1.80 a	2.33 a	2.40 a	2.50 a	2.55 a

[a]1,3-dichloropropene (Telone II®) in l/ha applied at six weeks pre-plant

[b]Nitrogen rates in kg/ha

[c]Means followed by the same letter in column are not significantly different *P≤0.05* by LSD

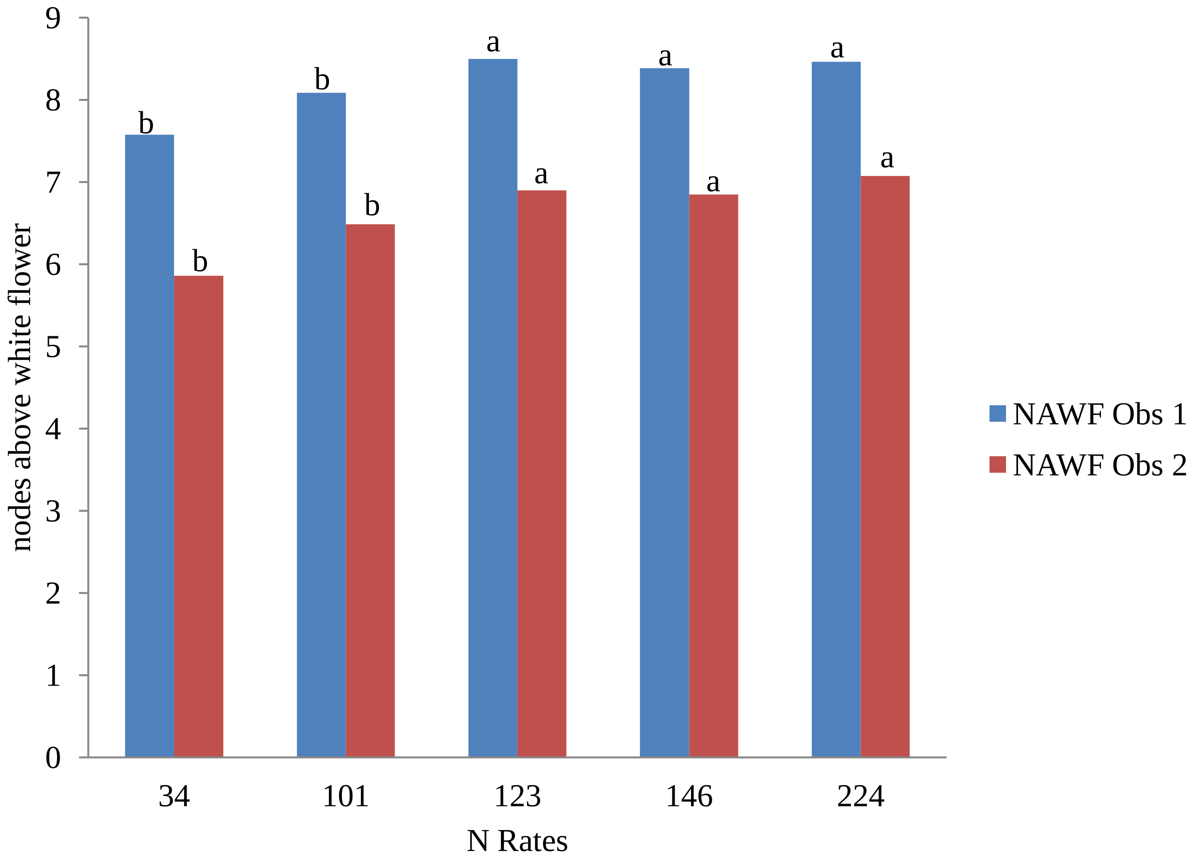


Figure 2.3. Nodes above uppermost white flower (NAWF) at two weekly observation timings beginning at first bloom in 2007 by fertilizer rates (34, 101, 123, 146, and 224 kg N/ha). Columns within an observation time are not significantly different if they have the same letter, LSD *P≤.0.05.*

Table 2.4. Probability values for main and interaction effects of nematicide and fertilizer on seedcotton and lint yield for large plot trial in 2007

	Seedcotton (g)			Lint (g)		
Effect	Position 1	Position 2	Position 3/other	Position 1	Position 2	Position 3/other
Nematicide[a]	0.819	0.3345	0.6522	0.9637	0.4583	0.6166
Fertilizer[b]	0.405	0.1887	0.1465	0.3167	0.2266	0.1227
Nematicide*Fertilizer	0.684	0.1945	0.6091	0.6059	0.2217	0.4864
Nematicide*Block	0.5434	0.3425	0.2687	0.441	0.3999	0.256

[a] 1,3-dichloropropene (Telone II®) applied at six weeks pre-plant

[b] Nitrogen in kg/ha

Table 2.5. Means of deep core (Gidding's) soil nitrogen (mg/kg NO3-N/ha) for fertilizer and nematicide for large plot trial 2007

	mg/kg NO3-N/ha				
	0-15 (cm)[c]	15-30 (cm)	30-46 (cm)	46-61 (cm)	61-76 (cm)
0 Nematicide[a]	30.94a[d]	9.30a	4.78a	3.37a	2.67a
28 Nematicide[a]	35.15a	9.59a	5.33a	3.63a	2.42a
Fert[b]					
34	27.08a	7.35a	3.50a	2.76c	2.26a
104	32.55a	9.72a	5.39a	3.48b	2.65a
123	35.82a	7.96a	4.22a	2.79c	2.06a
146	33.63a	12.18a	5.74a	3.50b	2.28a
224	36.17a	10.02a	6.44a	4.97a	3.49a

[a]l/ha of 1,3-dichloropropene (Telone II®)applied at six weeks pre-plant

[b]Nitrogen rates in kg/ha

[c]Sections of soil cores taken by Gidding's soil sampler and cut into 15 cm sections

[d]Means for fertilizer by nematicide combinations followed by the same letter in column are not significantly different using *P≤0.05* by LSD

APPENDIX A

Appendix A, Table 1. Probability values for main and interaction effects of nematicide and fertilizer on total nodes per plant for large plots, 2007.

Effect	Total nodes per week 1[c]	Total nodes per week 2	Total nodes per week 3	Total nodes per week 4	Total nodes per week 5	Total nodes per week 6
Nematicide[a]	0.8580	0.9626	0.9778	0.2260	0.4135	0.4031
Fertilizer[b]	0.2366	0.0223	0.032	0.0339	0.0262	0.0774
Nematicide*Fertilizer	0.7353	0.8027	0.4414	0.4292	0.8949	0.9293
Nematicide*Block	0.0001	0.011	0.0371	0.6223	0.0083	0.0088

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha six weeks pre-plant
[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha
[c]Total nodes were measured weekly beginning at pinhead square

Appendix A, Table 2. Probability values for main and interaction effects of nematicide and fertilizer on cotton plant height in large blocks, 2007

Effect	Plant Height (cm)					
	Week 1[c]	Week 2	Week 3	Week 4	Week 5	Week 6
Nematicide[a]	0.0700	0.0402	0.5009	0.0047	0.2512	0.1775
Fertilizer[b]	0.1683	0.3757	0.0068	0.0137	0.0099	0.0292
Nematicide*Fertilizer	0.8820	0.9854	0.6083	0.2973	0.8617	0.7251
Nematicide*Block	0.0047	0.0087	0.0005	0.2510	0.0045	0.0011

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha six weeks pre-plant
[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha
[c]Plant heights measured weekly beginning at pinhead square

Appendix A, Table 3. Probability values for main and interaction effects of nematicide and fertilizer on plant height-to-node ratio for large plots, 2007.

	Plant Height-to-Node Ratio					
Effect	Week 1[c]	Week 2	Week 3	Week 4	Week 5	Week 6
Nematicide[a]	0.0700	0.0402	0.5009	0.0047	0.2512	0.1775
Fertilizer[b]	0.1683	0.3757	0.0068	0.0137	0.0099	0.0297
Nematicide*Fertilizer	0.8820	0.9854	0.6083	0.2973	0.8617	0.7251
Nematicide*Block	0.0047	0.0087	0.0005	0.2510	0.0045	0.0011

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant
[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha
[c]Plant height-to-node ratios measured weekly beginning at pinhead square

Appendix A, Table 4. Probability values for main and interaction effects of nematicide and fertilizer on spring and fall root-knot, total bolls at harvest, and first fruiting node (FFN), 2007.

	Root-knot Nematodes/100 cm^3			
Effect	Planting	Harvest	Bolls/plant	FFN[c]
Nematicide[a]	0.0766	0.9648	0.315	0.6164
Fertilizer[b]	0.405	0.9957	0.6502	0.5832
Nematicide * Fertilizer	0.5143	0.4239	0.4457	0.8029
Nematicide*Block	0.0051	0.2308	0.614	0.1728

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

[c]Node of first sympodial branch

Appendix A, Table 5. Probability values for main and interaction effects of nematicide
and fertilizer on nodes above white flower (NAWF) for large plot trial 2007.

Effect	NAWF[c] Obs.1	NAWF Obs.2	NAWF Obs.3	NAWF Obs.4
Nematicide[a]	0.5321	0.549	0.5776	0.4869
Fertilizer[b]	0.0421	0.0028	0.1221	0.1838
Nematicide*Fertilizer	0.7658	0.5413	0.5439	0.7519
Nematicide*Block	0.0015	0.1765	0.0001	0.0001

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant
[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha
[c]Nodes above uppermost first position white flower

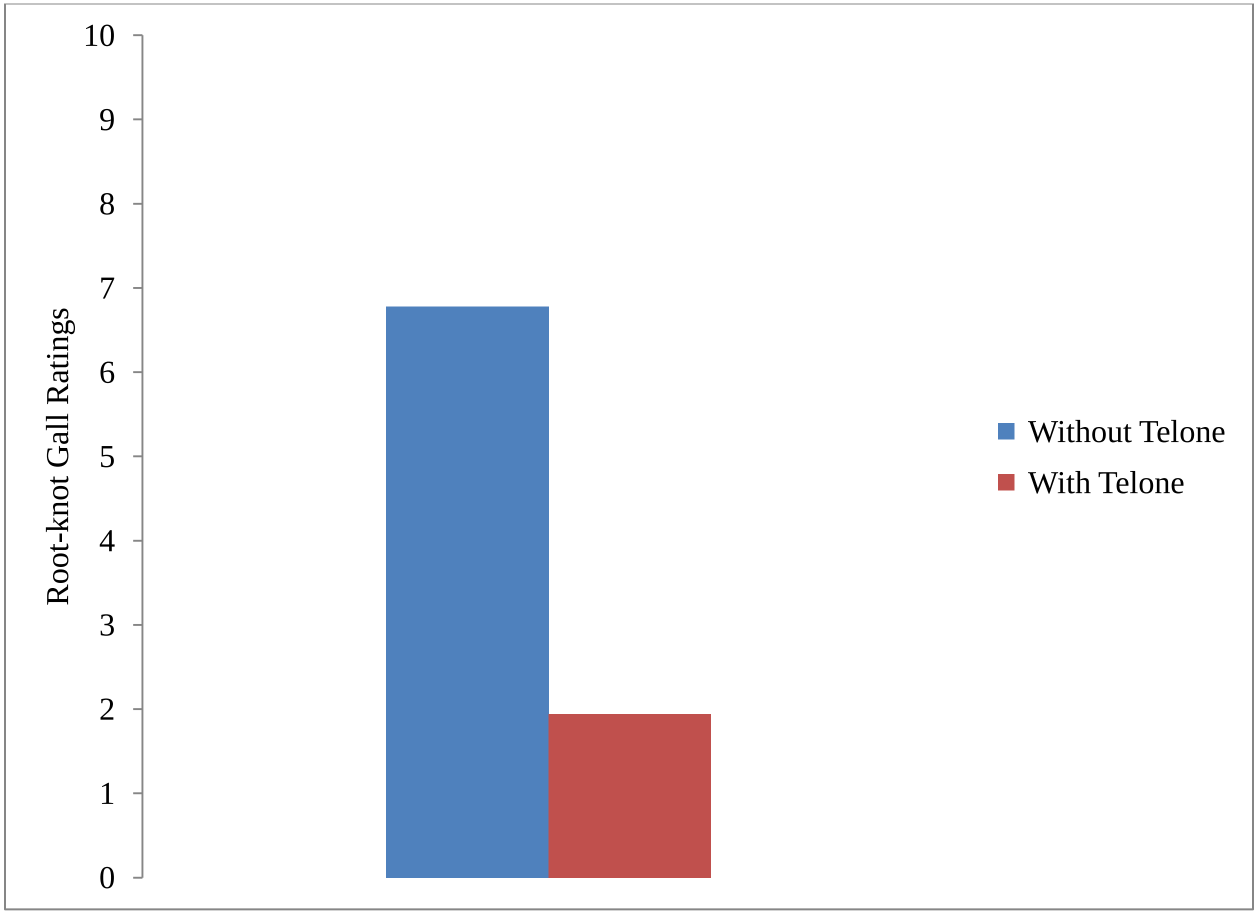
Appendix A, Table 6. Means of seedcotton and lint yields in grams for fertilizer and nematicide for large plot 2007

	Seedcotton			Lint		
	Position 1	Position 2	Position 3/other	Position 1	Position 2	Position 3/other
0 Nematicide[a]	626.00a	252.75a	192.25a	269.25a	108.50a	80.00a
Fert[b]						
34	612.5a[c]	222.5a	147.5a	267.5a	97.5a	62.5a
104	615a	306.25a	237.5a	267.5a	131.25a	103.75a
123	672.5a	246.25a	240a	285a	106.25a	98.75a
146	633.75a	241.25a	157.5a	272.5a	101.25a	62.5a
224	596.25a	247.5a	178.75a	253.75a	106.25a	72.5a
28 Nematicide[a]	634.25a	278.25a	176.25a	270.00a	116.25a	72.65a
Fert[b]						
34	597.5a	198.75a	78.75a	248.75a	85a	30.75a
104	732.5a	247.5a	168.75a	318.75a	105a	71.25a
146	628.75a	287.5a	193.75a	263.75a	116.25a	80a
224	548.75a	330a	218.75a	235a	137.5a	90a

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

[c]Means followed by the same letter in column are not significantly different using *P≤0.05* by LSD



Appendix A, Figure 1. Root-knot gall ratings on a 0-10 scale taken at harvest (October) for the 2007 large plot trial for 1,3-dichloropropene at 0 and 28 L/ha.

CHAPTER 3

RELATIONSHIP BETWEEN SOIL FUMIGATION AND NITROGEN FERTILIZER RATES ON COTTON IN A RENIFORM NEMATODE-INFESTED FIELD

ABSTRACT

A two-year study was conducted in a commercial cotton field in the Portland, Arkansas area to evaluate the impact of reniform nematodes and soil nitrogen fertilization rates on the growth and yield of cotton. Field strips, fumigated approximately six weeks prior to planting with the nematicide 1,3-dichloropropene (Telone II®), were paired with unfumigated strips. Nitrogen rates of 34, 101, 123, 146, and 224 kg/ha was applied within these strips. Nematicide application affected plant height, total nodes, plant height-to-node ratios, nodes above white flower, and yield in outer boll positions on sympodial branches occasionally, but effects were not consistent. Fertilizer application was generally more consistent than nematicide application regarding plant growth and yield. Fertilizer impacted NAWF, total nodes produced, plant height, height-to-node ratio, total boll counts, and seed cotton and lint weights at least one of the two years. Relatively consistent fertilizer effects and a lack of nematicide effect imply that the hypothesis that fertilizer rates can be reduced if a nematicide is applied is incorrect.

INTRODUCTION

Producers in southeastern Arkansas commonly encounter both *Meloidogyne incognita* (Chitwood, 1949; Kofoid and White, 1919) the southern root-knot nematode, and *Rotylenchulus reniformis* (Linford and Olivera, 1940), the reniform nematode, as economic pests in cotton fields (Anonymous, 2013). Crop loss estimates for plant-parasitic nematodes in Arkansas for 2011 totaled about 4% of the crop (Blasingame and Patel, 2012) Reniform nematodes have quickly increased in the last ten years in the southeast part of Arkansas (Monfort, 2008). The reniform nematode female is a sedentary semi-endoparasite that infests cotton roots attaching itself to a feeding site and beginning the reproductive process. The male reniform nematode is not parasitic and may or may not contribute to the reproductive process. Symptoms of reniform infestations in cotton include plant stunting, fruit abortion, suppressed root growth, and lowered yield (Koenning et al. 2004). Cotton plants grown in reniform infested areas also display foliar symptoms of nutrient deficiencies (Koenning et al. 2004). Traditionally, growers have applied nitrogen fertilizer at rates that are higher than would normally be recommended by the Cooperative Extension Service to fields that have a history of high nematode pressure. There is currently no data published in the literature to support such action. The perception is that if a cotton plant is showing what appears to be a nitrogen deficiency, additional nitrogen may counteract this effect and increase yields. Unfortunately, routine application of excess nitrogen fertilizer is of concern both economically and from an environmental standpoint because of the potential for surface and groundwater issues (Delgado and Bausch, 2005).

The use of soil fumigation for nematode management in cotton has become increasingly popular among Arkansas cotton growers. While soil fumigation is relatively expensive, and difficult to apply (Koenning et al. 2004; Starr et al. 2007) the practice provides a relatively effective means of mitigating yield losses due to nematodes (Kinlock and Rich, 1998 and 2001), and lint yields in the region have improved sufficiently to make this treatment attractive. In many fields, particularly where population densities of root-knot or reniform are high, growers have observed changes in cotton growth patterns when fumigants are applied. The most noticeable change has been excessive (rank) plant growth resulting in an increased need for growth regulators, especially where nitrogen fertilizer rates have exceeded standard Cooperative Extension Service recommendations. A two year study was initiated on a farm in Ashley County, Arkansas in a reniform location to address some of these issues.

The objectives of this research were to: 1) determine the effects of nematicide and nitrogen fertilizer rates on cotton growth and development, 2) determine if nematode control affects the nitrogen rate required for optimal yield.

MATERIALS AND METHODS

All cotton crop management was performed by the grower as a part of his regular farming operation. Twelve row, 96 cm per row, strips 152 m long were fumigated with 1,3-dichloropropene (Telone II®, Dow AgroScience, Indianapolos, IN) at 28 l/ha approximately 6 weeks prior to planting the cotton variety was DP445 BG/RR. The 1,3-dichloropropene was randomly applied using a modified Orthman six row ripper hipper equipped to apply the nematicide under the row to a depth of 25 cm. (Orthman Manufacturing Inc. Lexington, NE) A John Deere hipper (John Deere, Moline, IL) was run immediately behind the Orthman to seal the beds to retain the fumigant.

Each treated strip was paired with a strip of equivalent size that received no fumigation. Twenty plots, 30 m long, were established within each strip. Nitrogen fertilization rates (total nitrogen applied) of 34, 101, 123, 146, and 224 kg/ha were assigned randomly. The nitrogen rates were determined for this study as follows: The rate of 34 kg/ha was considered the control standard. A rate of 101 kg/ha was the rate that was recommended for cotton production based on a soil test report generated by University of Arkansas Soil Testing Laboratory based on field samples submitted by the farmer. The higher nitrogen rate of 123 kg/ha is a rate that would commonly be recommended in the area for normal cotton production (Barber and McClelland, 2013). By contrast the 146 kg/ha nitrogen rate would normally be applied by farmers in known problem fields, specifically in fields with high nematode population densities (Charles Denver, personal communication). The 224 kg/ha rate was chosen as a high-end maximum overage amount that would likely not be considered for economic reasons by growers. Phosphorus and potassium were applied across the entire area based on the farmer's soil test report. Soil samples were taken prior to fertilizer application from each plot within the row to a depth of 12-15 cm and a composite of 12 cores was used to represent each plot. These composite samples were divided and analyzed at the University of Arkansas Soil Testing Laboratory in Marianna for nutrients and at the Arkansas Nematode Diagnostic Laboratory at Hope for nematode population density. Soil was processed by elutriation (Byrd et al, 1976) and centrifugal flotation (Jenkins, 1964). When the cotton was fully established, stand counts were taken as a beginning of the COTMAN procedure and the cotton was scouted weekly according to COTMAN parameters (Oosterhuis and Bourland, 2008)

Liquid nitrogen fertilizer (32% N) was applied at five rates (0, 67, 90, 112, and 191 kg/ha) with a John Deere fertilizer sidedress knife applicator rig (John Deer, Moline, IL) using an AgLeader PF 3000 Pro (AgLeader 2202 S River Side Drive, Ames IA) controller and a Rawson Par (Rawson Control Systems, Inc 116 2nd St E, Oelwien, IA) 4 variable-speed hydraulic motor that was manually switched to apply the correct rate for each plot. At full bloom, another 34 kg/ha of nitrogen was applied as urea by air across the entire field, including all plots. From pinhead square, COTMAN data were collected weekly throughout the growing season until the end of the effective fruiting period or physiological cutout, (Oosterhuis et al, 1996) or node above white flower (NAWF) 5, a parameter used to determine the end of harvestable boll production by counting the number of main stem nodes above the uppermost white flower in the first fruiting position (Bourland et al., 1992; Oosterhuis et al, 1996) and included plant heights, the number of main stem nodes, presence or absence of first sympodial position fruit, whether the fruit was a square or a boll, and nodes above white flower. Data were collected from ten plants that were arbitrarily selected within the two center rows of each plot with five plants selected from each of the rows near the center of the plot to minimize edge effects. Daily minimum and maximum air temperatures needed for the COTMAN models were obtained from a NOAA weather station located at the GPS Gin Co. Inc. in Portland, AR less than 0.8 km from the plots.

After defoliation, final whole plant growth maps (Bourland and Watson, 1990) were conducted on consecutive plants from 1.5 m of row from the center two rows near the middle of each plot. Seed cotton was hand harvested according to boll position. Bolls were placed into brown paper bags according to first position, second position, and all outer positions and transported to the lab where it was dried for 5 days at 43° C. The samples were then cleaned by hand to remove burrs and large trash, weighed and ginned on a bench top cotton gin (Unknown maker) to determine lint weight.

Deep core samples were collected after harvest using a tractor mounted Giddings soil sampler (Giddings Machine Company, Windsor, CO). One core, 4 cm in diameter was collected from the center of each plot to a depth of 1 meter. These cores were cut into 15 cm sections, and the soil was air dried and delivered to the University of Arkansas Laboratory in Fayetteville, AR where nitrates were extracted with 2 mol L^{-1} KCl (Mulvaney, 1996) determined by colorimetry (San+ autoanalyzer, Skalar Analytical B.V., Breda, the Netherlands). In addition to deep samples, standard soil samples for nutrient analysis were taken from each plot using a hand held soil probe. Six cores per plot were taken from the center area of plot in a 5 m diameter circle around the point where the deep sample was collected. These cores were mixed together and assayed for nutrient content by the University of Arkansas Soil Testing Laboratory at Marianna and at Arkansas Nematode Diagnostic Laboratory at Hope for nematode population density. Basic soil texture analysis (Appendix B Table 1) was performed at SEREC, Monticello using the hydrometer method. (Gee et al, 1986) COTMAN data were entered into COTMAN III version 03.30.07 for analysis. Data analysis was performed, using SAS Statistical Analysis Software, version 9.3, SAS Analytical Institute, Cary, NC. The 2008 and 2009 data were analyzed as a split-split plot where the whole plot portion (nematicide) was treated as a randomized complete block with fertilizer the split plot factor and year as the split-split plot factor. The plots were arranged in the same locations for both years.

RESULTS AND DISCUSSION

Spring reniform nematode population densities were higher in 2008 than in 2009 in the large plot trial at (Fig. 3.1). Reniform population was numerically lower in spring for plots where nematicide was applied, but difference was not significant for either year (Appendix B, Fig 1). Nematode numbers did not differ among fertilizer rates for either year. There was no interaction among between nitrogen and nematicide. Reniform numbers increased in all plots in 2008 by harvest. Fall samples for reniform in 2009 were not taken. Differences between years for spring populations, possibly climate, had an overriding effect on the population levels irrespective of treatments applied. Because fall samples for only one year were available, no conclusion may be drawn as to whether fall populations were affected by treatments applied for combined years.

Plant heights at pinhead square were greater in the nematicide treated plots (Fig. 3.2). Heights for the second through the sixth weeks after pinhead square were influenced by a nematicide × year interaction (Fig. 3.3). Nematicide treated plants were taller in 2009 than the untreated, which was the opposite for 2008. The differences in plant height due to nematicide application may have been influenced by other environmental factors that were not measured in this study. Fertilizer rates did not influence plant height during the early part of the growing season (Table 3.1). However, by the third week, all fertilizer rates resulted in taller plants compared with the lowest nitrogen rate.

The first fruiting node (FFN) was significantly different between years (Fig. 3.4). First fruiting node is influenced by many factors including cultivar, weather, and plant density (Stewart et al, 2010). In both years, the node with the first sympodial branch was within the range that would be considered normal (5 to 8). Plants that form their first fruiting branch on nodes less than 5 may have early cutout. Plants that begin fruiting on nodes higher than 8, may not mature the late crop. (Stewart et al, 2010). Climate most likely impacted the position of the first fruiting nodes between years (Appendix B, Fig 2).

Nematicide rate alone affected the height to node (H:N) ratio only in young plants while fertilizer rate impacted this ratio later in the growing season (Table 3.2). All fertilizer rates resulted in greater plant growth in comparison with the control during the latter half of the H:N measurement period. No interaction was detected between nematicide and fertilizer. Nematicide effects on plant growth were strongly influenced by year as indicated by significant nematicide × year interactions in four of the six sampling periods (Fig 3.5). Ratios were not affected differentially by year, and there was no fertilizer × year interaction detected. The application of a nematicide increased crop growth and development in four of the six sampling periods in 2009, but application of the nematicide did not influence H:N ratio in 2008. These data indicate that application of a nematicide may enhance growth in some years, but not in others.

Nematicide application did not affect the NAWF, but a significant nematicide × year interaction occurred for weeks two and three of the observation period (Fig 3.6). Applying a nematicide resulted in decreased NAWF in 2008 but increased in 2009. Nitrogen rate affected NAWF on three of the four sampling dates where the application of nitrogen at any rate other than the lowest rate resulted in a higher number of NAWF (Table 3.3). The significant interaction between year and nematicide rate on two of the four sampling dates implies that, although other factors may impact NAWF, nematode control can enhance crop vigor and node development during this part of the season in some years.

An interaction between nematicide, nitrogen rate, and year was detected for total nodes per plant in the third sampling week (Fig. 3.7A). In 2008 there was little effect of using a nematicide or among nitrogen rates, but in 2009 using a nematicide resulted in an increased number of total nodes per plant across nitrogen rates. Interaction occurred between nematicide and year for week two and between nematicide and fertilizer for week one (Fig. 3.7B). Nitrogen alone affected total nodes in weeks four, five, and six and year alone affected the nodes in weeks five and six (Fig. 3.7B). Plants were taller and produced more nodes in 2009 than in 2008. These data indicate that using 1,3-dichloropropene had variable impact depending upon the year of application and that in some years a fertilizer × nematicide interaction may occur in relation to total nodes.

Total boll counts per plant taken at maturity during plant mapping were significantly different due to year (Fig 3.8A) and to fertilizer effect (Fig 3.8B). Only the lowest level of nitrogen reduced total boll counts and total boll counts were not impacted by application of nematicide. The differences in years were possibly due to climactic differences.

Seed cotton and lint yields for fruiting position 1 did not vary due to nitrogen rate, nematicide rate, year or any interaction among main effects. For position 2, seed cotton yields were different due to nitrogen rate with the lowest rate producing a lower yield than three of the other rates (Table 3.4) and having higher yields in 2009 than 2008 (Fig 3.9), while resulting lint differed only by year. Seed cotton and lint yields for third and other positions were different due to nematicide × year with the nematicide treated plots resulting in lower yields in 2008 but trending higher in 2009 (Fig 3.10). Fertilizer alone affected the outside boll positions resulting in higher yields for the lowest rate (Table 3.4). This seems to indicate that neither nematicide application nor the fertilizer rates used in this study affected position 1. Seed cotton yield for 123 kg N/ha was highest for positions one and two numerically, but was only significant for position two. This significance did not carry into lint yields which may have been related to seed size although there would have been significance in the position 2 lint if $P=0.0889$ had been used. The highest yields for position 3/other bolls are correlated with the lowest nitrogen rate. More investigation is needed as to why the cotton responded in this fashion as it is not adequately explained in this trial. Differences in years may have occurred because of yearly differences in climate and amount of post-cutout factors such as boll rot.

Nitrate levels among depth categories throughout the soil profile in 2008 were similar with and without nematicide, as well as between nitrogen rates (Appendix B, Fig 3). Fertilizer neither accumulated nor declined where nematicide was applied. It does not appear from these data that the impression by growers of a carryover of nitrogen deep in the soil profile is correct. Use of a nematicide in a reniform nematode infested field did not leave an excess of nitrogen that was not taken up by the plants to remain in the soil. Due to a lack of significance for treatments, deep nitrate movement may have been linked more to climate.

CONCLUSION

The idea that there is a relationship between nematodes and fertilizer rate relative to cotton growth and development was not supported by this study. The only parameter showing a nematicide × fertilizer interaction was total nodes per plant at one observation period. Similarly, the hypothesis that applying a nematicide for nematode control results in more robust plant growth was not clearly demonstrated across years, but results imply there was some relationship between the two relative to plant height, total nodes, H:N ratios, NAWF, and in yields for outside position bolls in some years. Applying 1,3-dichloropropene at 28 l/ha alone only impacted the first height measurements at pinhead square, while nitrogen rate alone was generally the most important factor. Nitrogen rate impacted NAWF, total nodes produced, plant height, height to node ratio, total boll counts, and seed cotton and lint weights at least one of the two years. Relatively consistent nitrogen rate effect and a lack of nematicide effect imply that the hypothesis that nitrogen rates can be reduced if 1,3-dichloropropene is applied is incorrect. The main differences that were observed in crop performance parameters were between the lowest nitrogen rate and the higher rates. It is apparent that maintaining nitrogen fertility within a reasonable range is the beneficial regardless of whether or not nematodes are controlled.

LITERATURE CITED

Albers, D.W. 1993. Cotton plant development and plant mapping. G4268. University of Missouri Extension Publication

Anonymous, 2013. National Cotton Council, Cotton Nematode Research and Education Program, Arkansas. Retrieved from http://www.cotton.org/tech/pest/nematode/distributions.cfm?state=03A

Barber, T. and McClelland, B. 2013 Cotton Quick Facts Nitrogen sources and rates for Arkansas cotton. AG 1276 Retrieved from http://www.arkansascrops.com/wpcontent/uploads/2013/03/2013_Arkansas_Cotton_Quick_Facts.pdf

Bateman, R.J., Kirkpatrick, T.L., Robbins, R.T., and Lorenz, G. 2000. The distribution of root-

knot and reniform nematodes in Arkansas, 1990-1999. 2000 Proceedings of the Beltwide Cotton Conference. Vol. 1 Pp. 171.
Blasingame, D., and Patel, M.V. 2012 Cotton disease loss estimate committee report. Pp. 341–343 Proceedings of the Beltwide Cotton Conference, Orlando, FL, January 3–6, 2012. Memphis, TN: National Cotton Council of America.

Bourland, F. M., and Watson, C. E., 1990. COTMAP, a Technique for Evaluating Structure and Yield of Cotton Plants, Crop Sci. 30:224–226.

Bourland, F. M., Oosterhuis, D. M., and Tugwell, N. P. 1992. Concept for Monitoring the Growth and Development of Cotton Plants Using Main-Stem Node Counts, Journal of Production Agriculture 5:532–538.

Byrd, D. W., K. R. Barker, H. Ferris, C. J. Nusbaum, W. E. Griffin, R. H. Small and C. A. Stone. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8: 206-212.

Chitwood, B.G. 1949. Root-knot nematodes, part I. A revision of the genus Meloidogyne Goeldi, 1887. Proceedings of the Helminthological Society of Washington. 16 (1949): 90-104.

Delgado, J.A. and Bausch, W.C. 2005. Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. Journal of Soil and Water Conservation. 60(6):379-387.

Gee, G. W., Gbauder, J. W., and Klute, A. (ed.) 1986. Particle-size analysis. Hydrometer Method. Pp 404-408 Methods of Soil Analysis: Part 1. Amer. Soc. Agron., Madison, WI

Jenkins, W R. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692, 1964. Dept. Entomology and Economic Zoology, Rutgers University, New Brunswick, NJ

Monfort, W.S., Kirkpatrick, T.L., and Mauromoustakos, A. 2008. Spread of Rotylenchulus reniformis in an Arkansas cotton field over a four-year period. Journal of Nematology 40(3): 161–166.

Oosterhuis, D. M. and Bourland, F. M. Cotman Users Manual 2008. Retrieved from http://www.cotman.org/files/COTMAN-Manual.pdf

Oosterhuis, D. M., Bourland, F. M., Tugwell, N. P., and Cochran, M. J. Terminology and concepts related to the COTMAN crop monitoring system. 1996. Ark. Agric. Exp. Sta. Special Report 174.

Stewart, J.M., Oosterhuis, D., Heitholt, J.J., Mauney, J.R. (Eds.) 2010. Physiology of Cotton. ISBN 978-90-481-3195-2

TABLES AND FIGURES

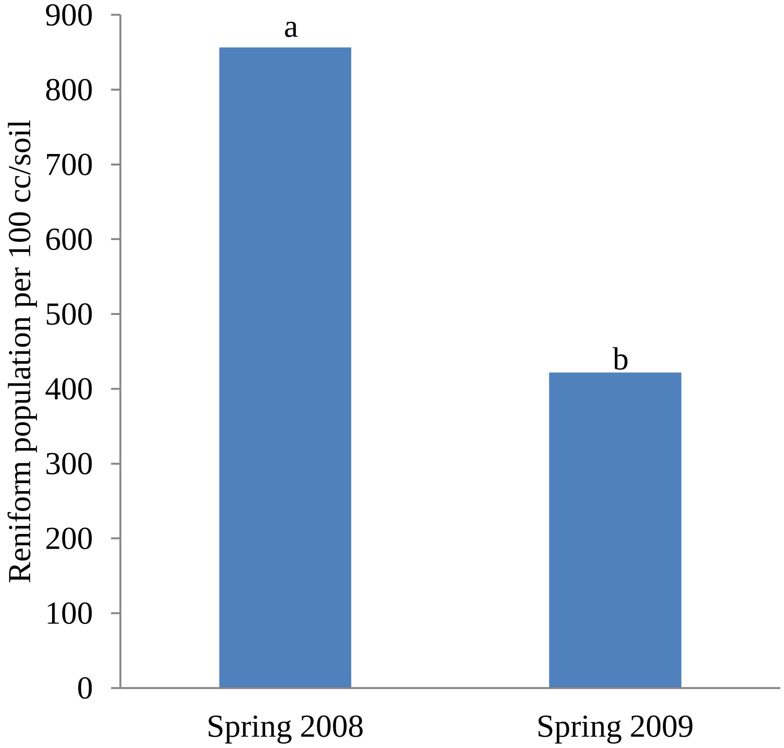


Figure 3.1. Spring reniform nematode population density from 2008 and 2009. Treatments with same letter do not differ significantly, LSD *(P≤0.05).*

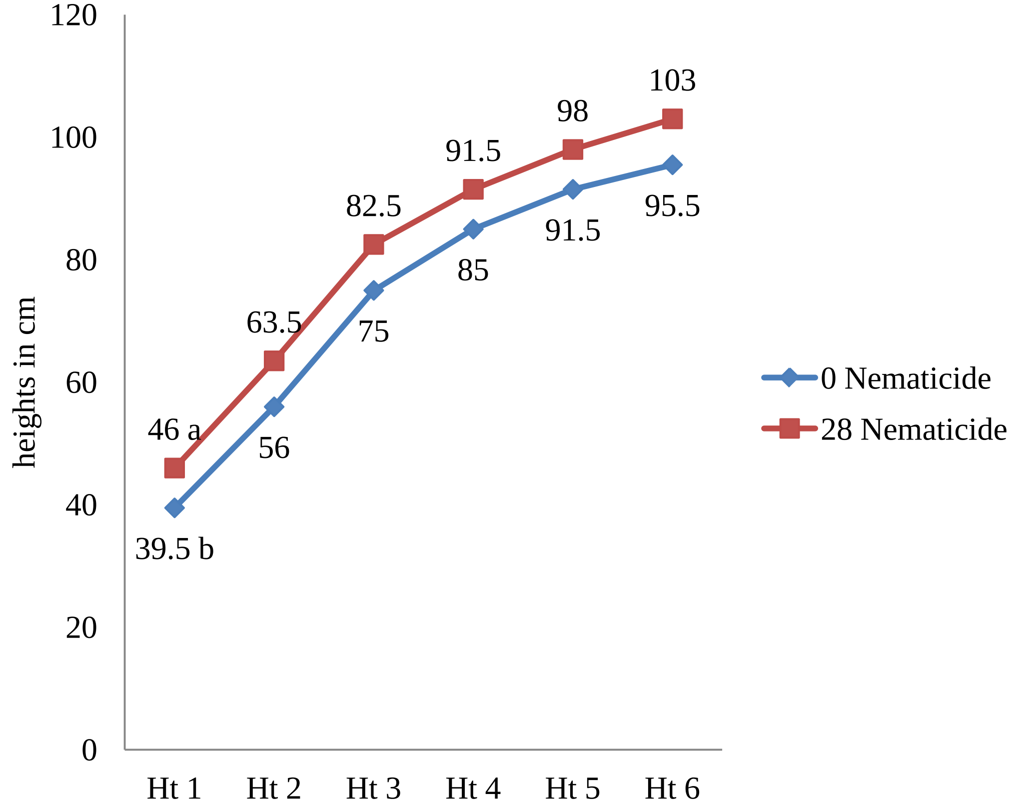


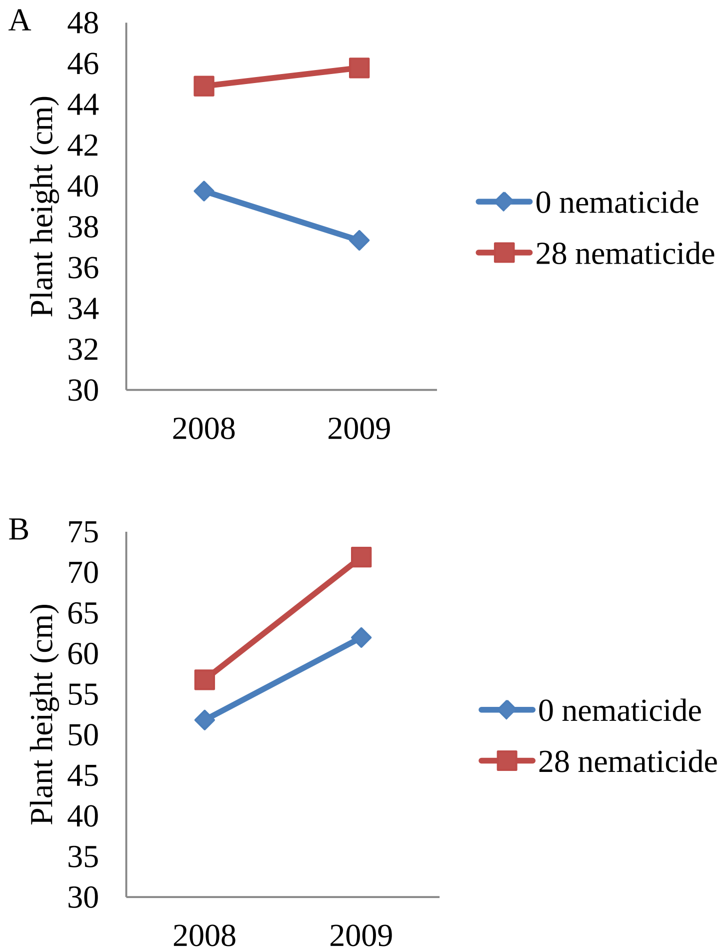
Figure 3.2. Plant heights by nematicide (0, 28 l/ha 1,3-dichloropropene) for combined years 2008 and 2009. Height observed weekly for 6 weeks reported in cm. Means for height during week 1 different between the two nematicide rates at *P≤0.05*, all other observations significant for nematicide by year interaction *P≤0.05* by LSD.

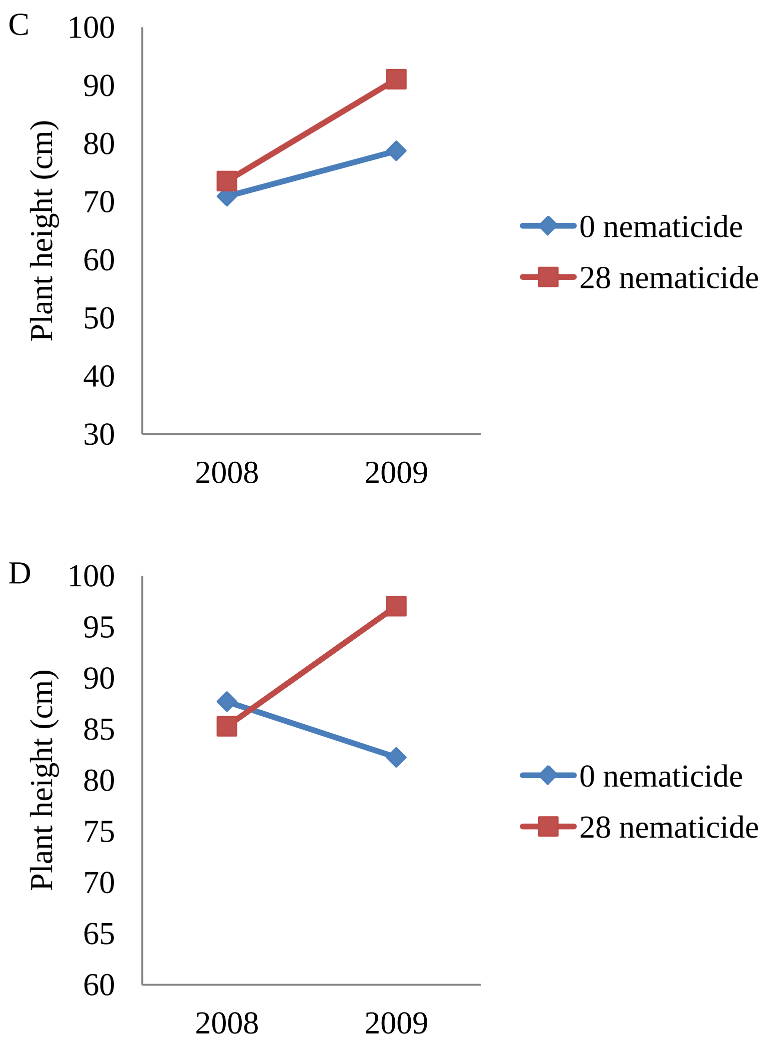
Table 3.1. Weekly plant height (cm) beginning at pinhead square for nitrogen rates for combined years 2008 and 2009

	Weeks Beginning at Pinhead Square					
	1	2	3	4	5	6
Nitrogen[a]						
34	41.8a[b]	57.8a	70.8b	77.4b	81.8b	82.7b
104	42.1a	60.8a	78.7a	88.3a	96.2a	99.9a
123	42.6a	61.4a	81.0a	91.2a	96.9a	103.6a
146	42.5a	61.1a	80.4a	91.2a	99.9a	104.6a
224	40.7a	61.9a	81.0a	92.2a	99.0a	105.3a

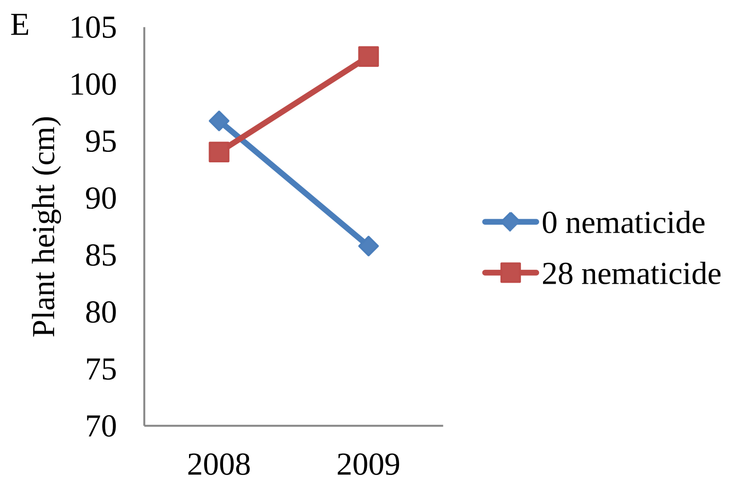
[a]Nitrogen rates in kg/ha

[b]Means followed by the same letter in column are not significantly different *$P \leq 0.05$* by LSD


A
Plant height (cm)
48
46
44
42
40
38
36
34
32
30
2008
2009
0 nematicide
28 nematicide
B
Plant height (cm)
75
70
65
60
55
50
45
40
35
30
2008
2009
0 nematicide
28 nematicide



C
100
90
80
70
60
50
40
30
Plant height (cm)
2008
2009
0 nematicide
28 nematicide
D
100
95
90
85
80
75
70
65
60
Plant height (cm)
2008
2009
0 nematicide
28 nematicide



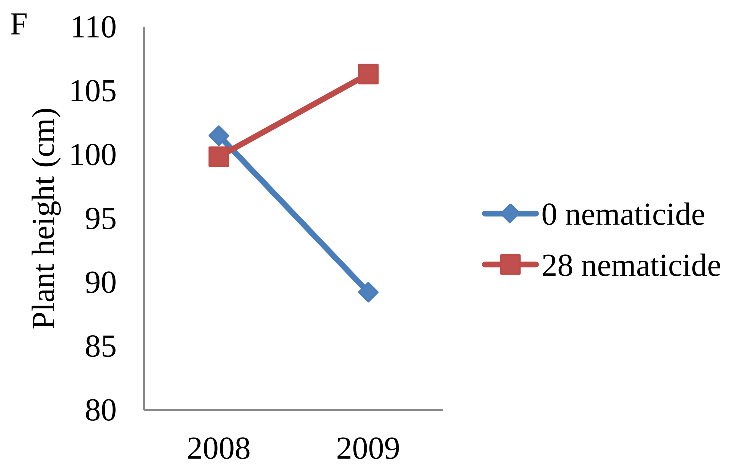


Figure 3.3 A-F. Nematicide by year interaction for plant heights taken weekly for six weeks starting at pinhead square in years 2008 and 2009. Each figure in sequence represents a weekly observation (Fig 10a = week 1, b = week 2, c = week 3, etc.) observations in which weeks 3 through 6 were significant for the interaction at $P \leq 0.05$. Week 2 was significant for the interaction at $P \leq 0.0524$. Nematicide rates 0 and 28 l/ha 1,3-dichloropropene. Week one had no interaction but was significant for nematicide alone at $P \leq 0.05$.

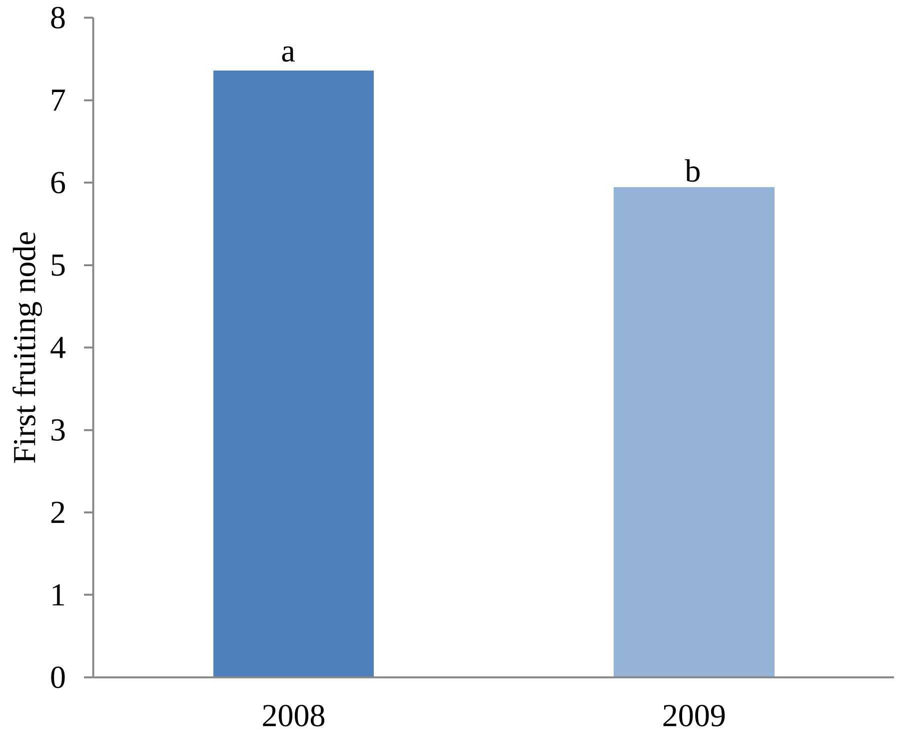
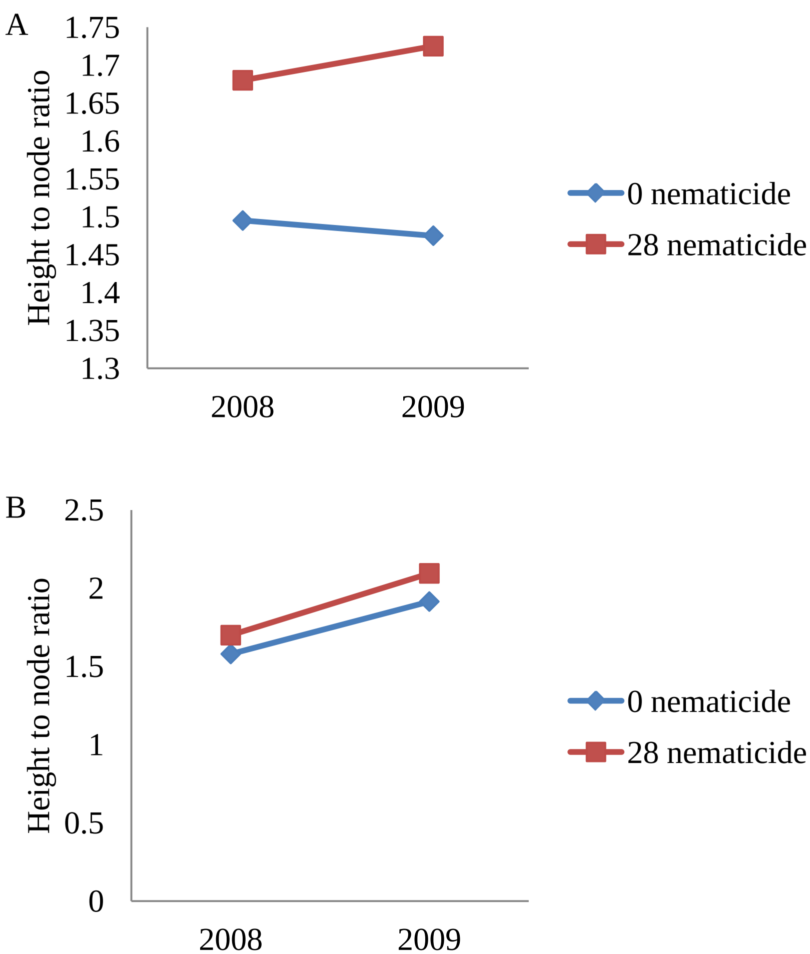


Figure 3.4. First fruiting node by year for 2008 and 2009. Means between years significant at $P \leq 0.05$.

Table 3.2. Means of height to node ratio for fertilizer for large plot trial 2008 and 2009

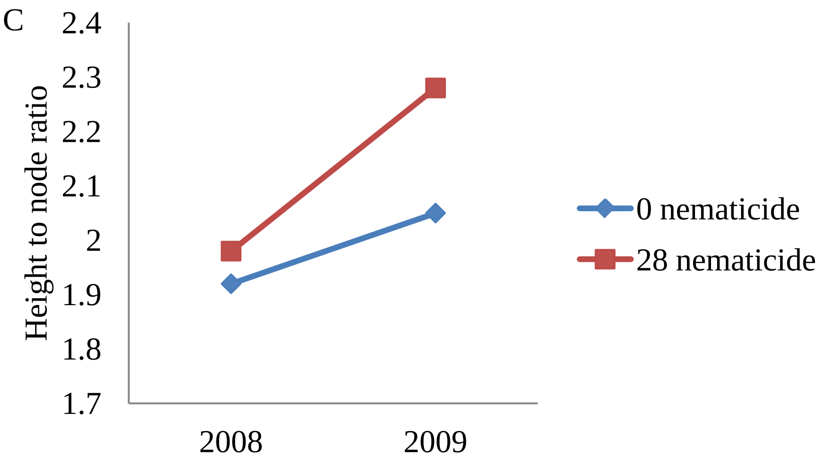
	Weeks Beginning at Pinhead Square					
	1	2	3	4	5	6
Fertilizer[a]	Height to node ratios (H:N)					
34	1.58a[b]	1.78a	1.99a	1.99b	1.93b	1.96b
101	1.58a	1.82a	2.04a	2.07ab	2.11a	2.11a
123	1.64a	1.84a	2.1a	2.14a	2.16a	2.19a
146	1.63a	1.81a	2.1a	2.16a	2.17a	2.17a
224	1.54a	1.86a	2.06a	2.14a	2.17a	2.16a

[a]Nitrogen rates in kg/ha
[b]Means followed by the same letter in column are not significantly different *$P \leq 0.05$* by LSD

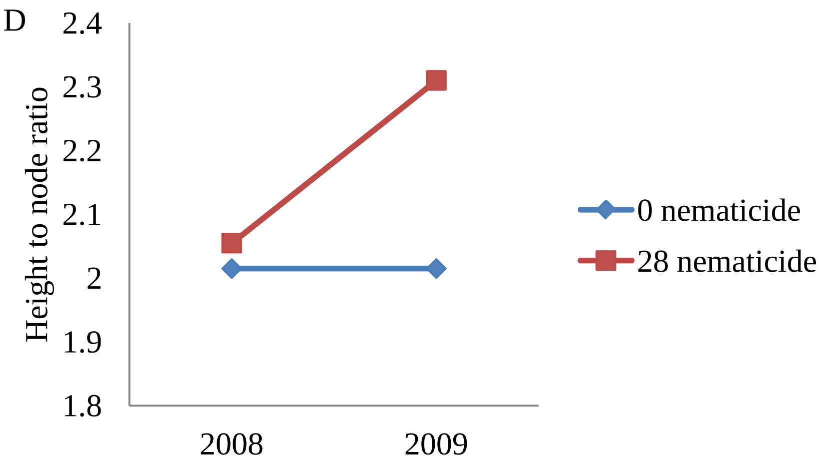


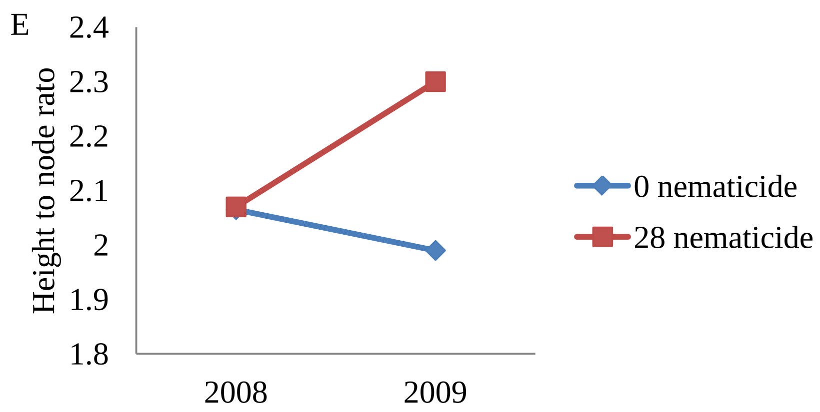
A
Height to node ratio
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
2008
2009
0 nematicide
28 nematicide
B
Height to node ratio
2.5
2
1.5
1
0.5
0
2008
2009
0 nematicide
28 nematicide

C


Height to node ratio
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
2008
2009
0 nematicide
28 nematicide

D


Height to node ratio
2.4
2.3
2.2
2.1
2
1.9
1.8
2008
2009
0 nematicide
28 nematicide



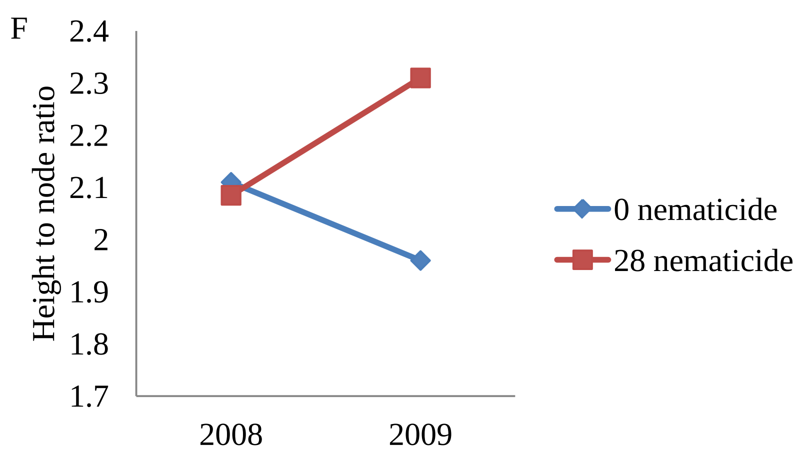


Figure 3.5 A-F. Nematicide by year interaction for height to node ratios taken weekly for six weeks starting at pinhead square in years 2008 and 2009. Each figure in sequence represents a weekly observation (Fig 10a = week 1, b = week 2, c = week 3, etc.) observations in which weeks 3 through 6 were significant for the interaction at $P \leq 0.05$. Nematicide rates 0 and 28 l/ha 1,3-dichloropropene. Weeks 1 and 2 had no interaction but week 1 was significant for nematicide only and week 2 significant for year only at $P \leq 0.05$

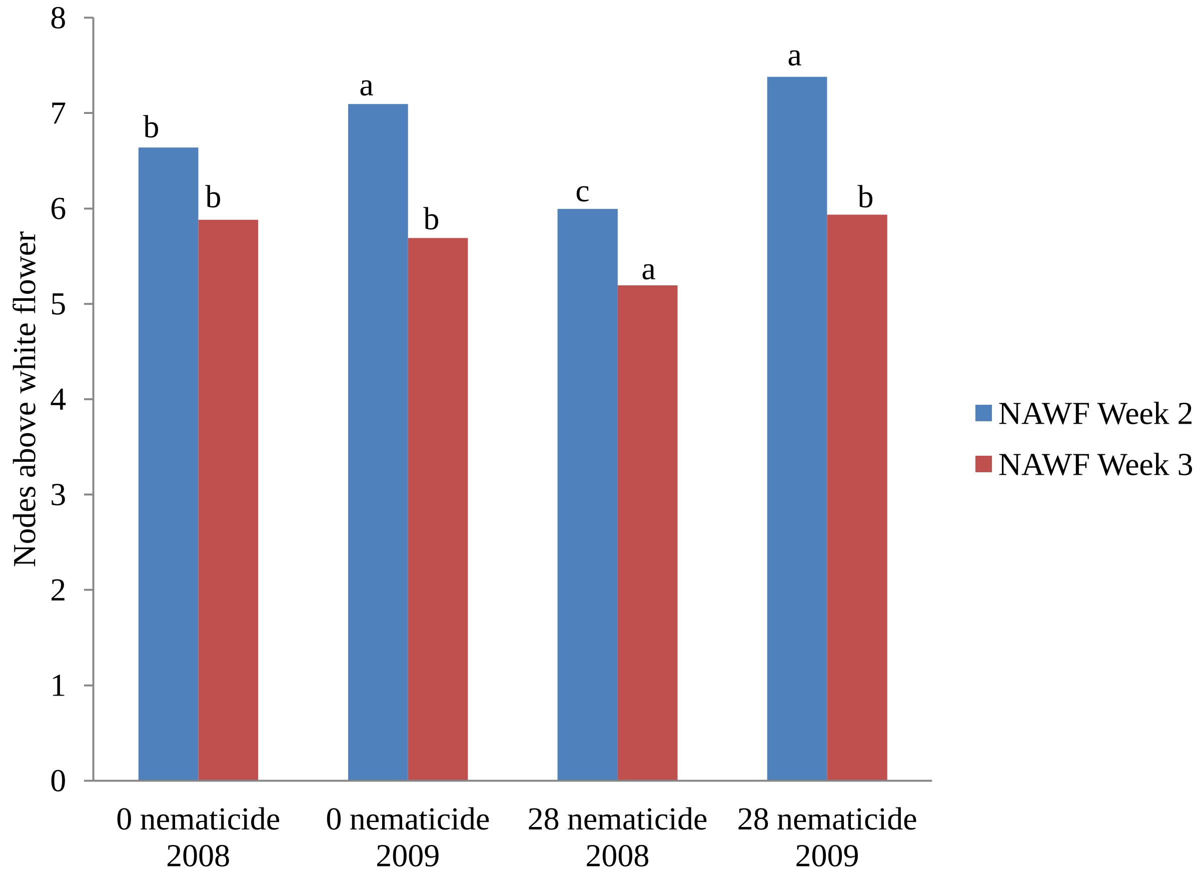


Figure 3.6. Node above white flower (NAWF) counts for weeks 2 and 3 were significantly different due to a nematicide × year interaction at $P \leq 0.05$. Means separation among columns for each weekly observation, not between weeks.

Table 3.3. Node above white flower (NAWF) means for various fertilizer rates for large plot trial 2008 and 2009

	Nodes Above White Flower[c]				
	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5[d]
Fertilizer[a]					
34	4.11a[b]	5.71b	4.67b	3.01b	0.94b
101	4.93a	6.90a	5.96a	4.63a	1.72a
123	5.01a	7.02a	5.84a	4.79a	2.00a
146	4.94a	7.18a	6.11a	5.03a	2.03a
224	4.85a	7.08a	5.79a	5.04a	2.07a

[a]Nitrogen rates in kg/ha

[b]Means followed by the same letter in column are not significantly different using $P \leq 0.05$ by LSD

[c]Nodes above white flower taken weekly beginning at appearance of first position white blooms within the plots

[d]2008 mean only for node above white flower (NAWF) 5 as field cut out prior to 5th observation in 2009

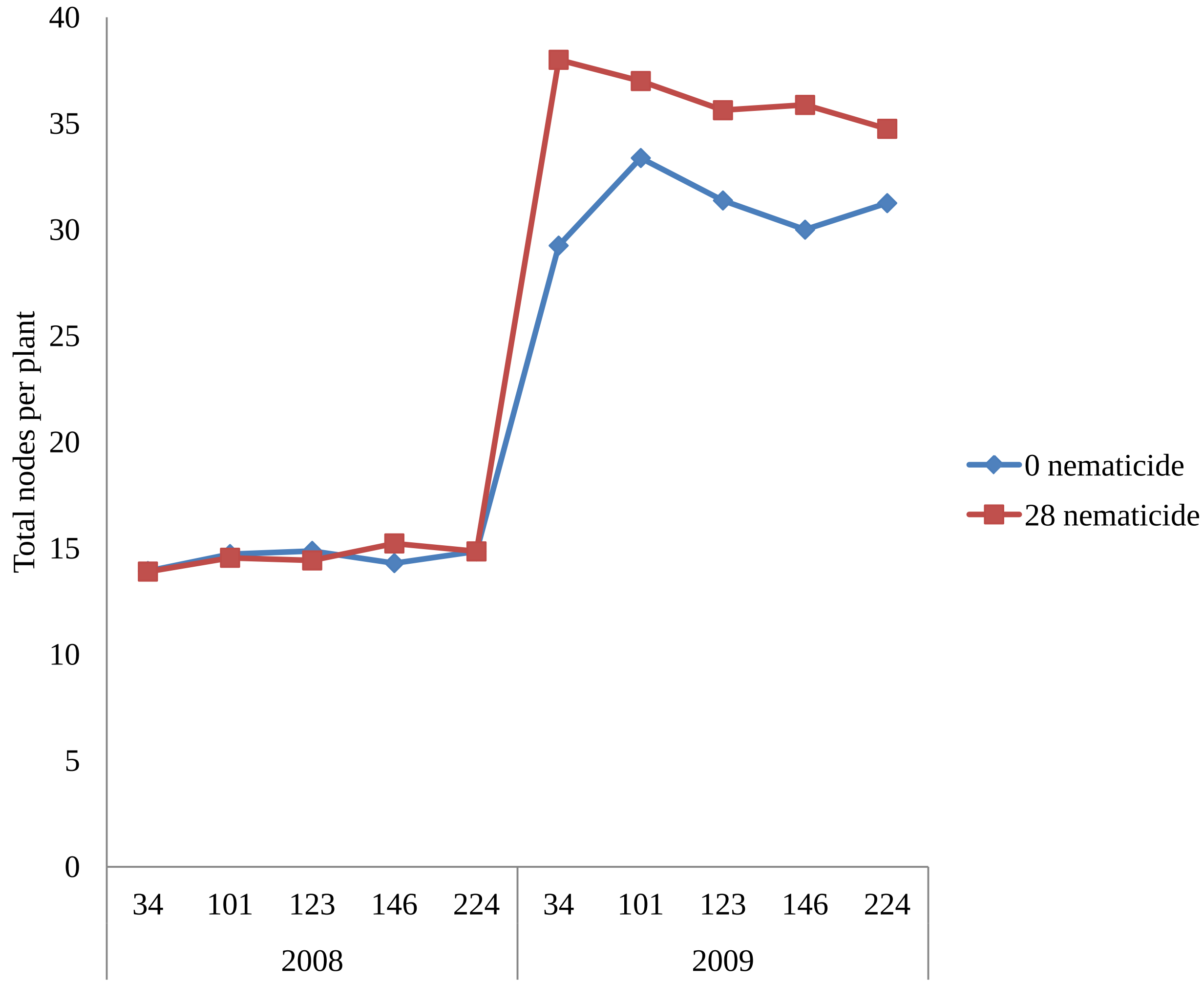


Figure 3.7A. Total nodes per plant for nematicide × fertilizer × year interaction at week 3 at *P≤0.05.* Nematicide rates 0 and 28 l/ha 1,3-dichloropropene. Nitrogen fertilizer applied at 34, 101, 123, 146, and 224 kg N/ha.

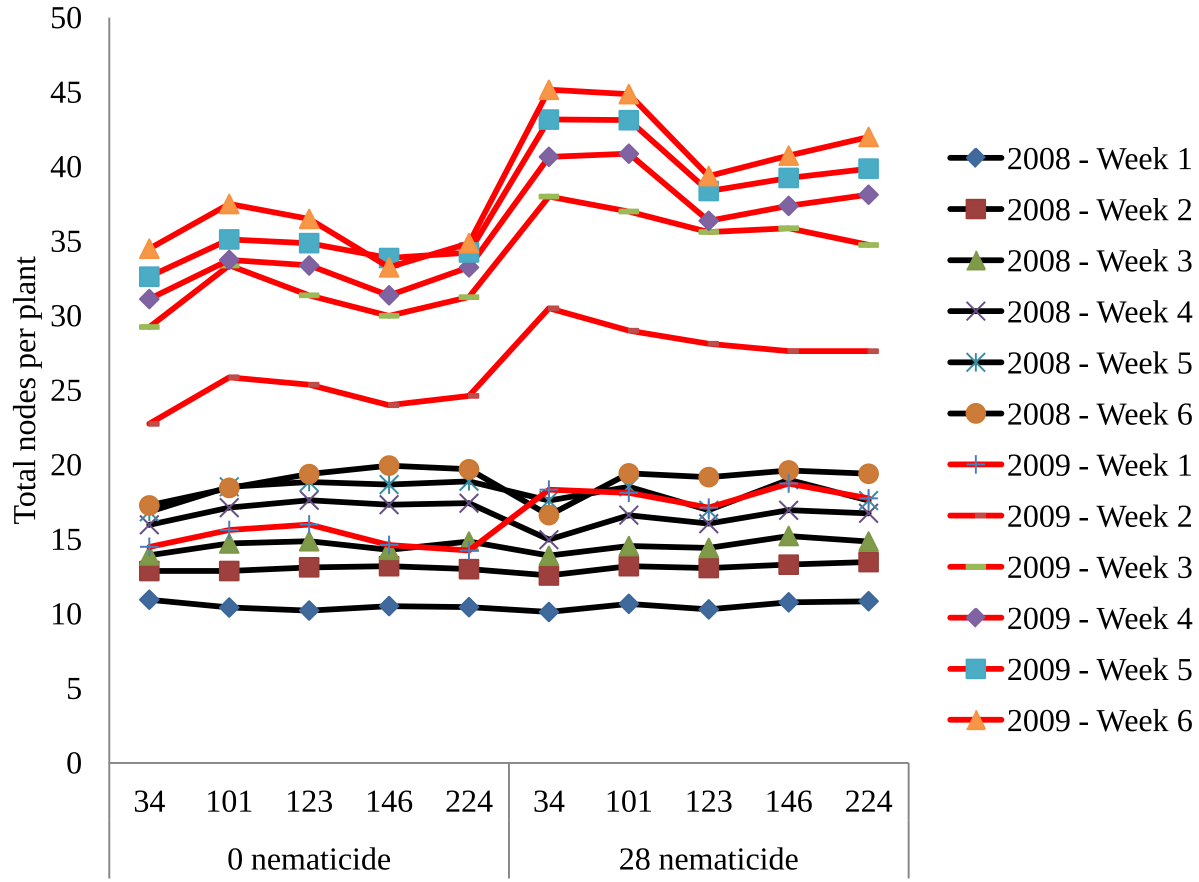


Figure 3.7B. Trends for total nodes per plant taken for 6 consecutive weeks starting at pinhead square for nematicide x fertilizer for years 2008 (black lines) and 2009 (red lines). Week 1 had a nematicide x fertilizer interaction. Week 2 had a nematicide x yr interaction. Week 3 had a nematicide x fertilizer x year interaction. Week 4 was significant for both nematicide x year and fertilizer. Weeks 5 and 6 were significant for fertilizer and also for year but no interaction. Nematicide rates 0 and 28 l/ha 1,3-dichloropropene. Nitrogen fertilizer applied at 34, 101, 123, 146, and 224 kg N/ha (*P≤0.05*).

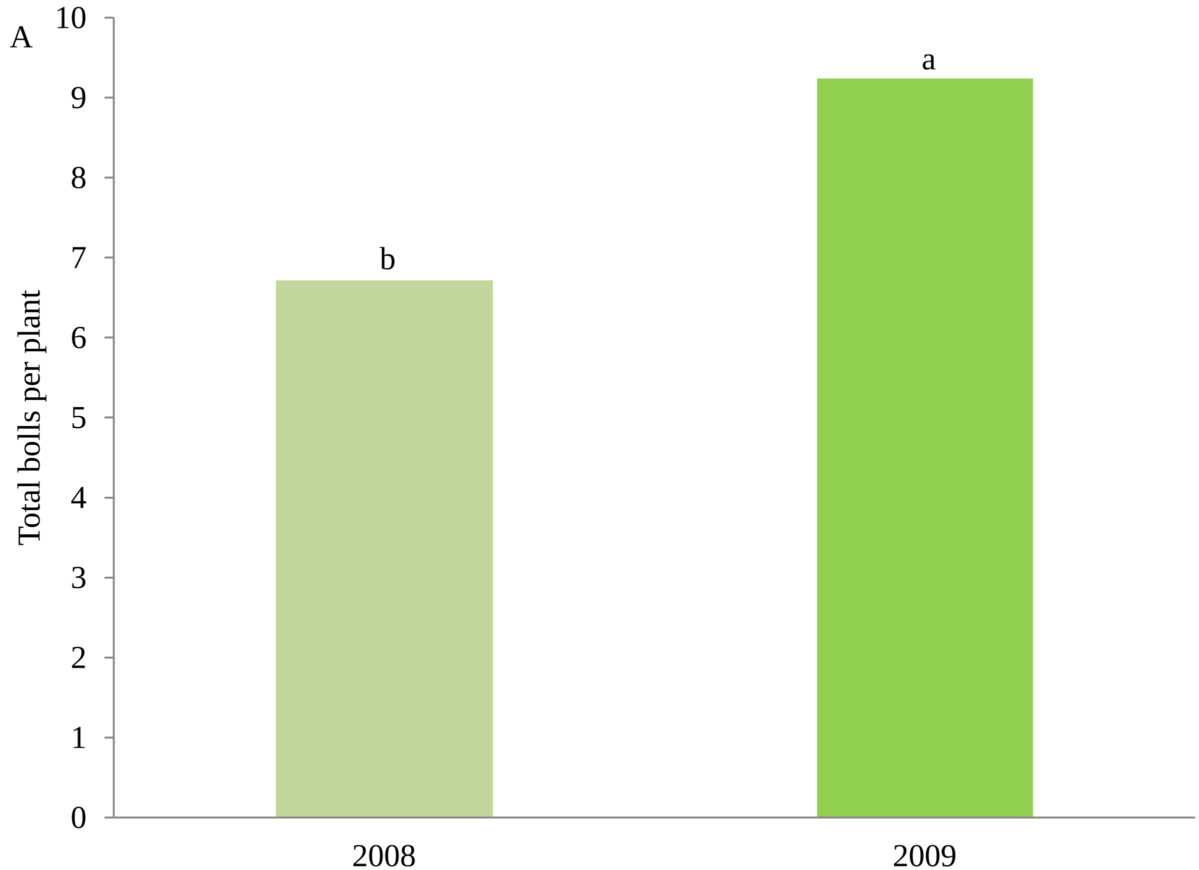


Figure 3.8A. Means of total bolls present per plant (y axis) at harvest for years 2008 and 2009. Means between years are significant at $P \leq 0.05$.

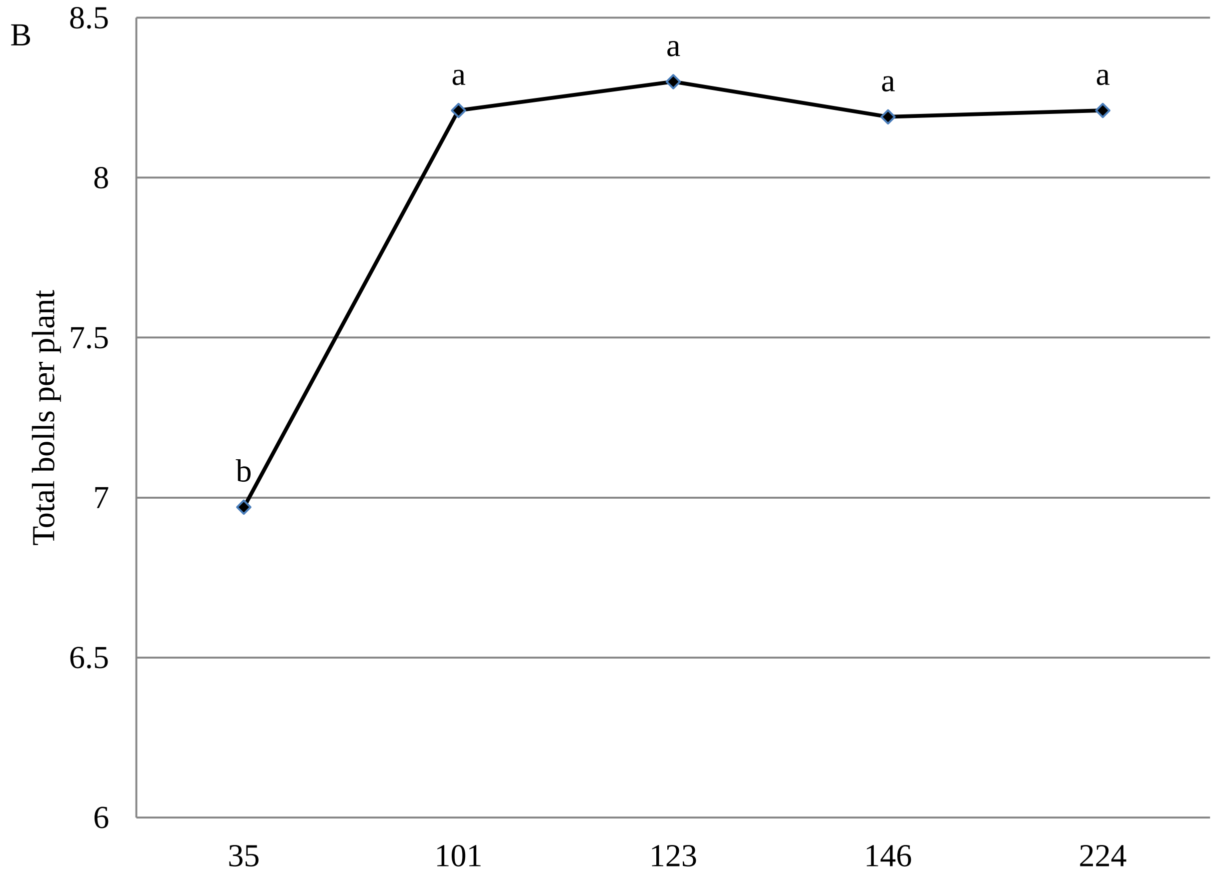


Figure 3.8B. Means of Total bolls per plant (y axis) as affected by fertilizer rates (34, 104, 123, 146, and 224kg N/ha). Means followed by the same letter are not significantly different (*P≤0.05)*.

Table 3.4. Seed cotton and lint yield harvested by boll position for fertilizer rates across nematicide treatment and year in 2008 and 2009.

	Seed cotton (g)			Lint (g)		
Nitrogen[a]	Position 1	Position 2[c]	Position 3/other	Position 1	Position 2	Position 3/other
34	414.62a[b]	142.02b	143.59c	172.77a	59.82a	59.75c
101	463.76a	164.91a	129.77bc	193.94a	67.19a	52.29bc
123	482.11a	180.65a	109.61ab	199.33a	73.56a	43.89ab
146	451.78a	161.53ab	102.55a	184.71a	65.47a	40.81a
224	470.51a	171.84a	97.53a	198.66a	69.88a	39.11a

[a]Nitrogen rates in kg/ha

[b]Means followed by the same letter in column are not significantly different $P \leq 0.05$ by LSD

[c]Position 2 means for seed cotton were significantly different $P \leq .0556$ by LSD

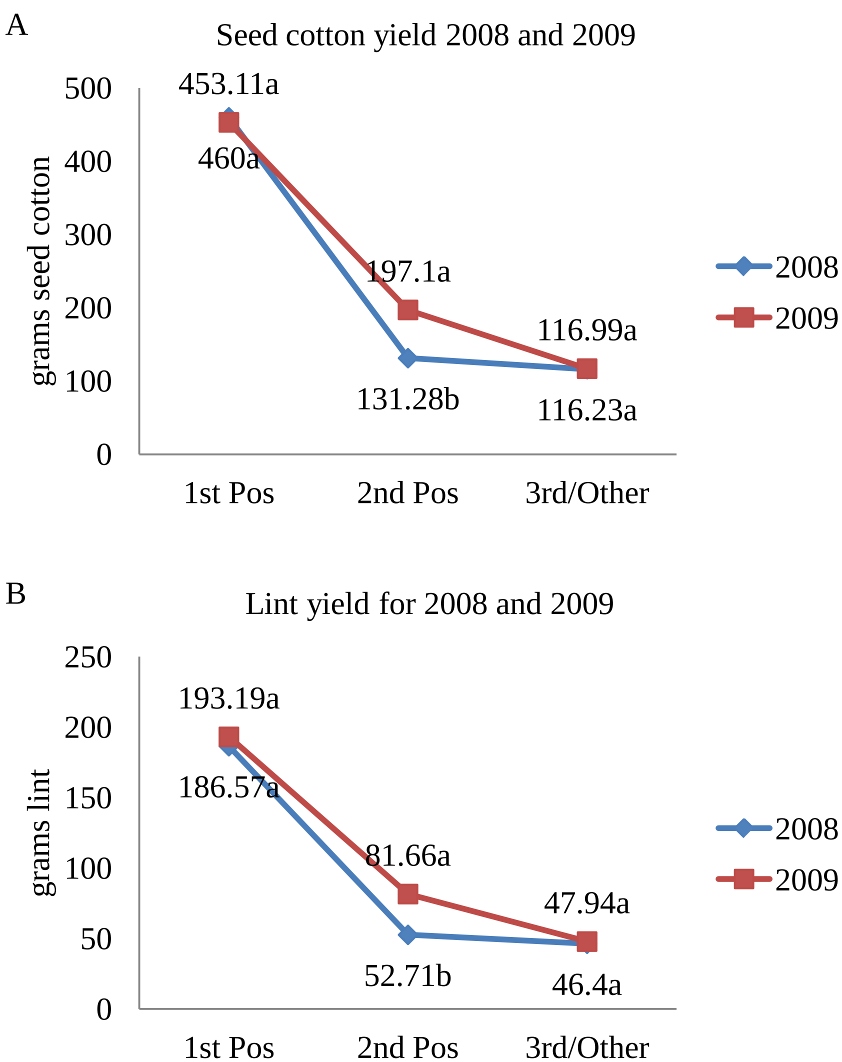


Figure 3.9AB. Seed cotton and lint yields from hand harvested bolls by fruiting position (1st position bolls, 2nd position bolls, and other position bolls) between years 2008 and 2009. Lint was obtained from passing seed cotton through a table top gin. Means were significantly different between years for each position (*P≤0.05)*.

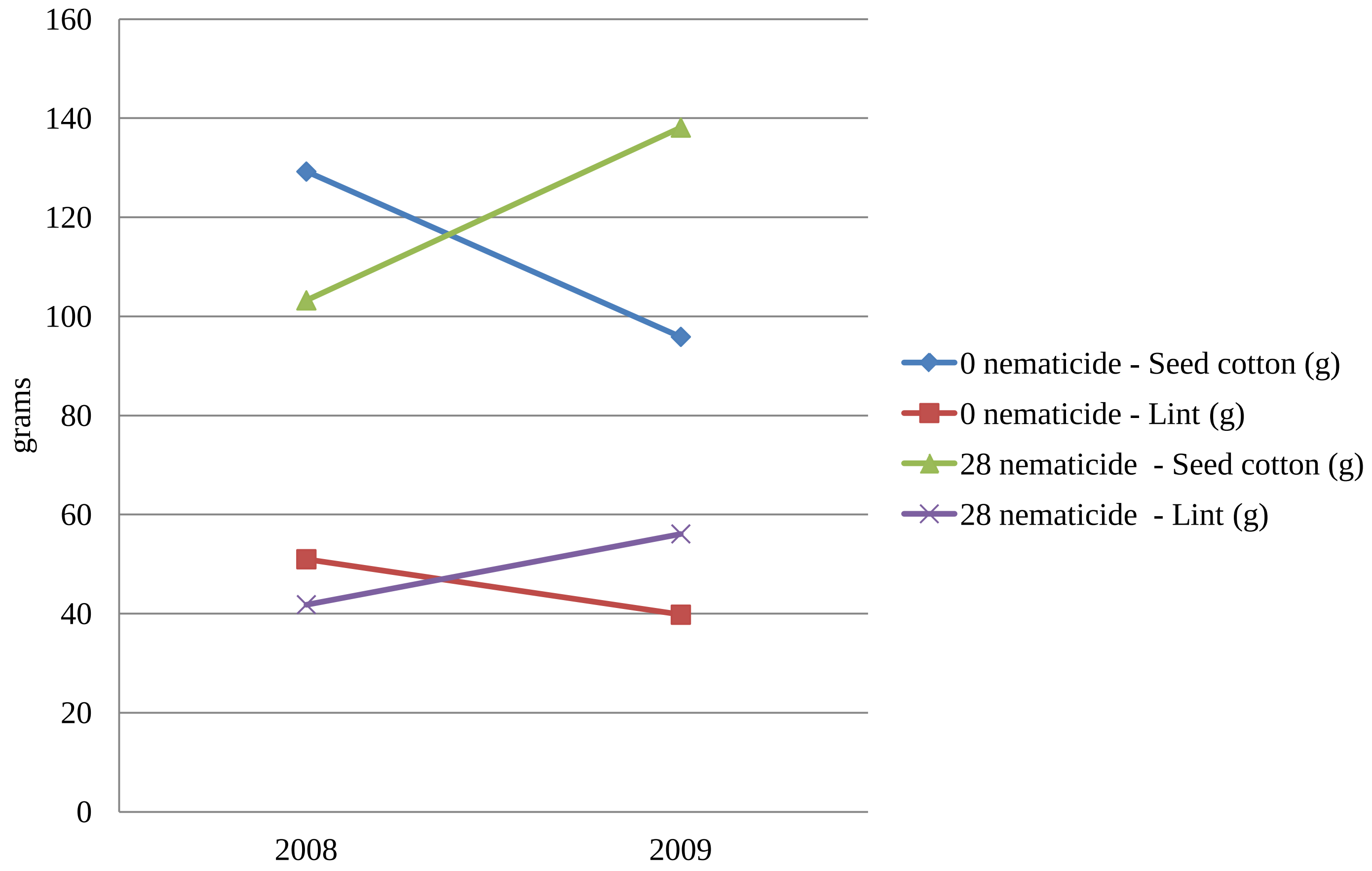
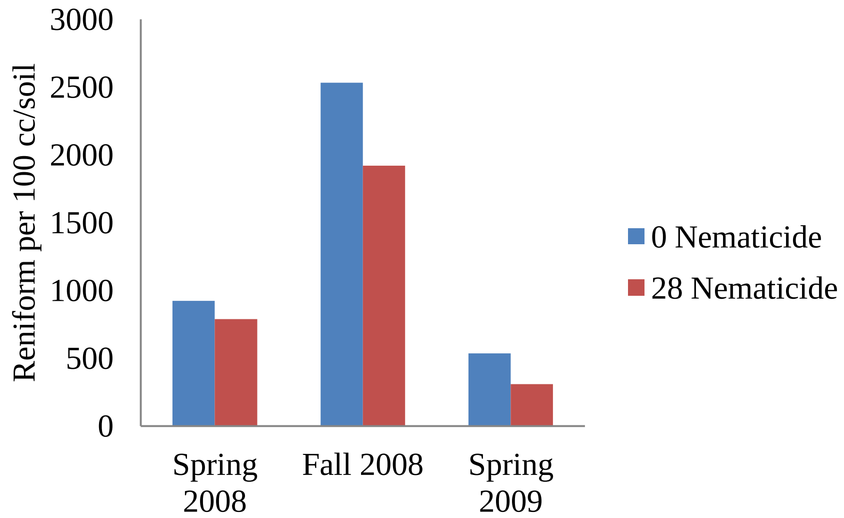
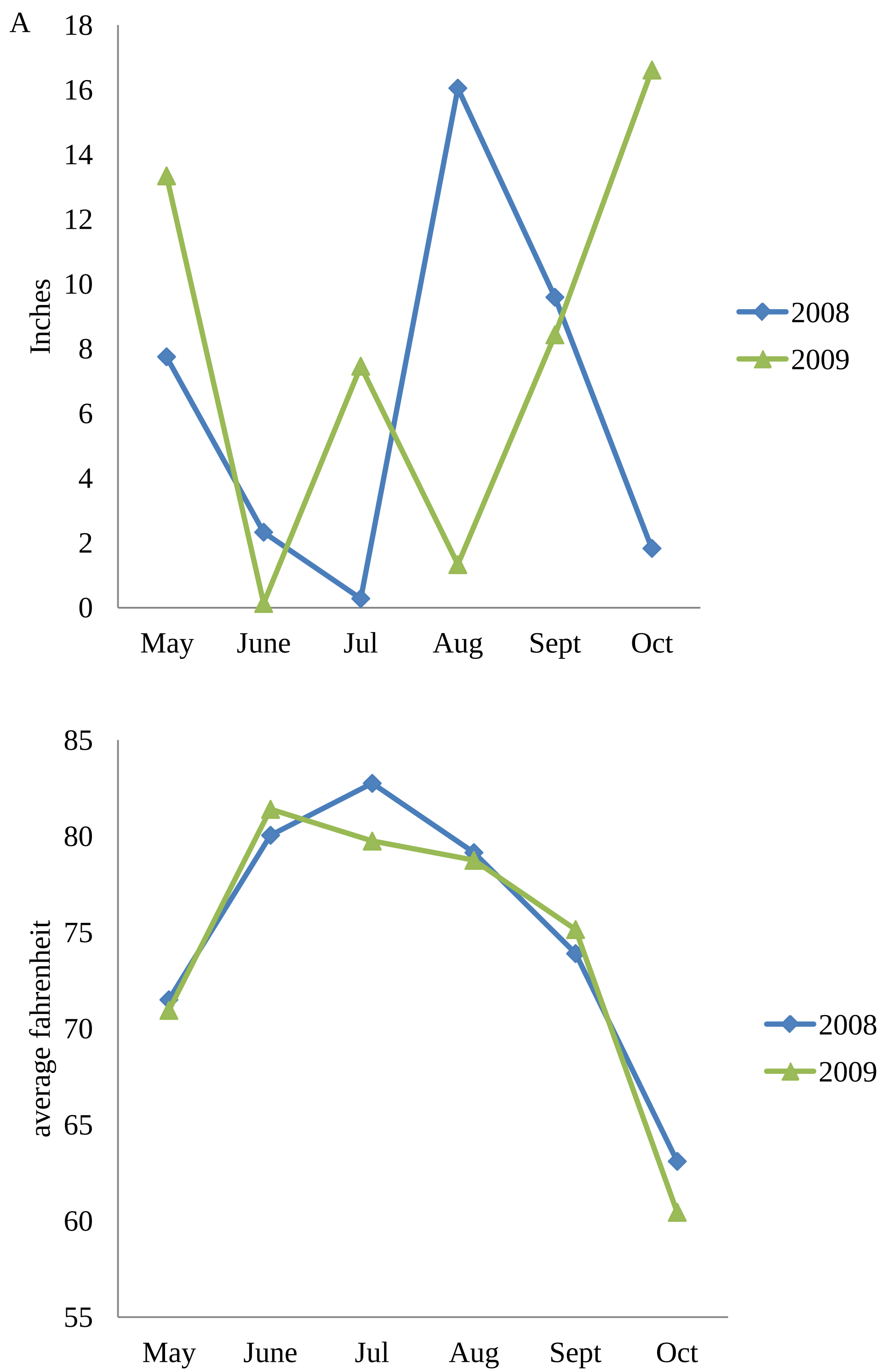


Figure 3.10. Nematicide by year interaction for seed cotton and lint yields in grams for position 3/other position bolls that were hand harvested during final plant mapping and resulting seed cotton passed through a table top gin.

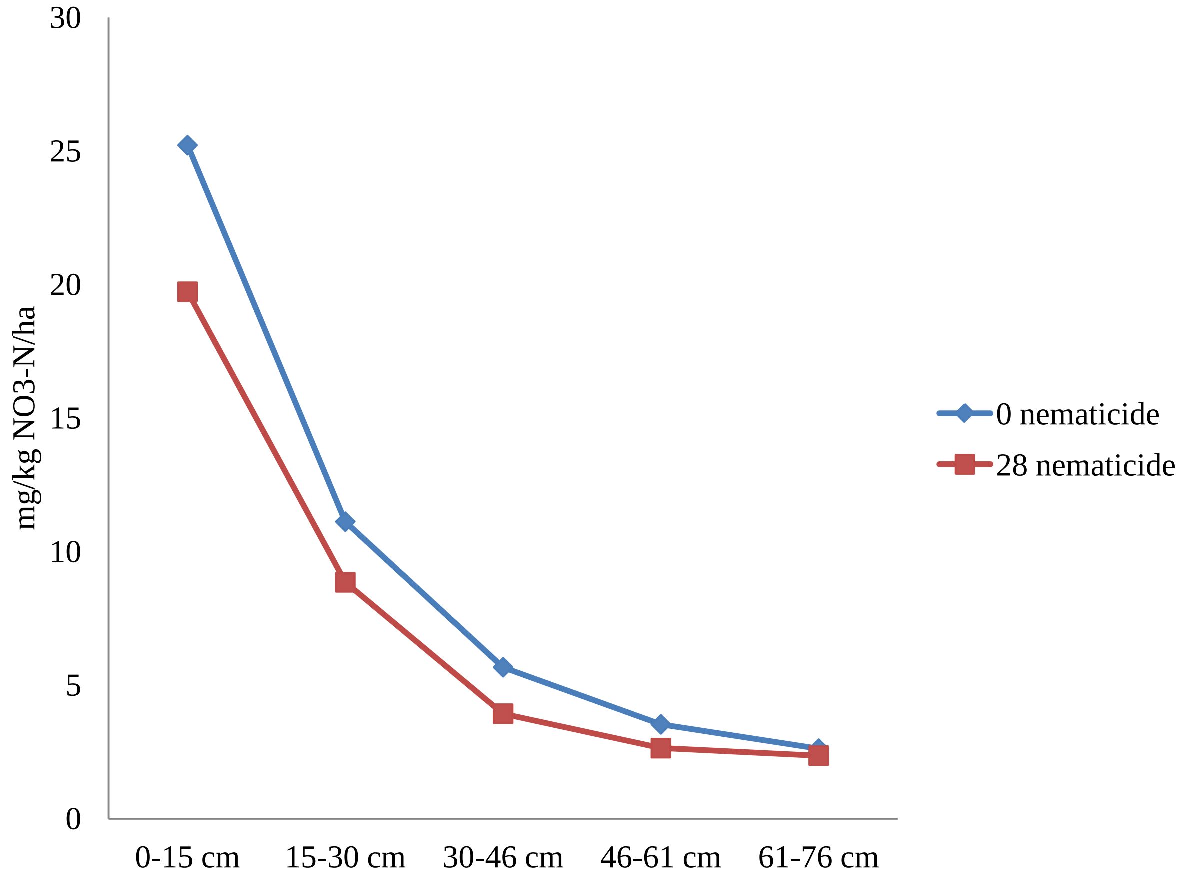
APPENDIX B



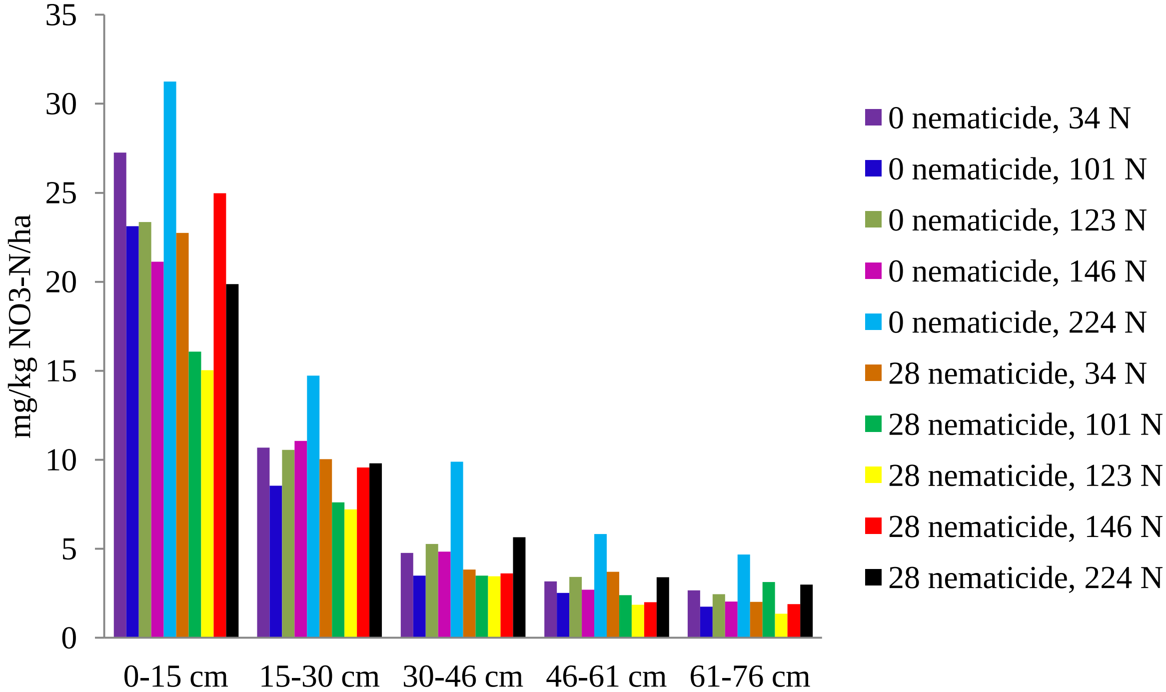
Appendix B, Figure 1. Reniform (*Rotylenchulus reniformis*) population densities from 2008 and 2009 as affected by nematicide application. Means were not significantly different (*P≤0.05)*.



Appendix B, Figure 2A,B. A) Rainfall totals reported in inches for month and year obtained from online reports from National Weather Service.
B) Average daily temperature reported in fahrenheit for month and year obtained from online reports from National Weather Service (http://www.climate.gov/datasearch/)



Appendix B, Figure 3. Gidding's soil core mg/kg NO3-N/ha for two 1,3-dichloropropene rates (0, 28 kg/ha) from deep soil cores taken in October 2008 that were analyzed by 15 cm sections. Results were not significantly different (*P≤0.05)*.



Appendix B, Figure 4. Gidding's soil core mg/kg NO3-N/ha showing combinations for two 1,3-dichloropropene rates (0, 28 kg/ha) and five fertilizer rates (34, 101, 123 146, 224 kgN/ha) from deep soil cores taken in October 2008 that were analyzed by 15 cm sections. Results were not significantly different *P≤0.05*.

Appendix B, Table 1. Soil texture analysis using hydrometer method for large plots 2008, 2009

Plot	Nematicide	Fert	%sand	%silt	%clay	USDA texture class
0101	0	34	44	52	4	fine sandy loam
0102	0	101	22	72	6	silt loam
0103	0	146	26	68	6	silt loam
0104	0	123	68	26	6	silt loam
0105	0	224	28	66	6	silt loam
0201	0	123	26	66	8	silt loam
0202	0	224	28	64	8	silt loam
0203	0	34	20	70	10	silt loam
0204	0	101	24	66	10	silt loam
0205	0	146	26	64	10	silt loam
0301	0	224	28	66	6	silt loam
0302	0	101	24	70	6	silt loam
0303	0	146	22	74	4	silt loam
0304	0	123	26	66	8	silt loam
0305	0	34	22	72	6	silt loam
0401	0	34	24	69	7	silt loam
0402	0	146	22	68	10	silt loam
0403	0	101	18	70	12	silt loam
0404	0	224	26	63	11	silt loam
0405	0	123	30	55	10	silt loam
3101	28	34	36	58	6	silt loam
3102	28	101	26	69	5	silt loam
3103	28	146	28	65	7	silt loam
3104	28	123	36	58	7	silt loam
3105	28	224	32	62	6	silt loam
3201	28	101	17	74	8	silt loam
3202	28	146	20	72	8	silt loam
3203	28	34	24	66	10	silt loam
3204	28	224	18	70	12	silt loam
3205	28	123	20	70	10	silt loam
3301	28	123	26	70	4	silt loam
3302	28	34	24	72	4	silt loam
3303	28	224	24	70	6	silt loam
3304	28	101	20	72	8	silt loam
3305	28	146	22	70	8	silt loam
3401	28	101	20	72	8	silt loam
3402	28	224	18	74	8	silt loam
3403	28	146	18	68	14	silt loam
3404	28	123	20	60	12	silt loam
3405	28	34	22	68	10	silt loam

Appendix B, Table 2. Probability values for main and interaction effects of nematicide and fertilizer on soil deep nitrogen for 2008.

Effect	0-15cm	15-30cm	30-46cm	46-61cm	61-76cm
Nematicide	0.1839	0.2013	0.0826	0.0647	0.2166
Fertilizer	0.8187	0.4781	0.0748	0.1562	0.1839
Nematicide*Fertilizer	0.8336	0.8825	0.6812	0.5555	0.414
Nematicide*Block	0.6329	0.3946	0.5587	0.8585	0.8522

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

Appendix B, Table 3. Probability values for main and interaction effects of nematicide, fertilizer, and year on plant height per plant for
large plots 2008, 2009.

Effect	Plant height week 1 (cm)	Plant height week 2 (cm)	Plant height week 3 (cm)	Plant height week 4 (cm)	Plant height week 5 (cm)	Plant height week 6 (cm)
Nematicide	0.0399	0.1315	0.1506	0.2543	0.1975	0.131
Fertilizer	0.6394	0.3765	0.0114	0.0001	<.0001	<.0001
Nematicide*Fertilizer	0.2514	0.9982	0.9993	0.9486	0.6632	0.8495
Year	0.4845	<.0001	<.0001	0.1212	0.5319	0.1627
Nematicide*Year	0.1355	0.0524	0.0005	0.0001	<.0001	<.0001
Fertilizer*Year	0.4425	0.2674	0.5371	0.9993	0.9026	0.862
Nematicide*Fertilizer*Year	0.4209	0.1483	0.401	0.5851	0.4607	0.5764
Nematicide*Block	<.0001	<.0001	0.0002	0.0001	0.0002	0.0017
Nematicide*Fertilizer*Block	0.8905	0.2572	0.0487	0.6696	0.7392	0.5582

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

Appendix B, Table 4. Probability values for main and interaction effects of nematicide, fertilizer, and year on height to node ratio for large plot trial 2008, 2009

Effect	H/N 1	H/N 2	H/N 3	H/N 4	H/N 5	H/N 6
Nematicide	0.0463	0.2708	0.1905	0.1328	0.1716	0.1100
Fertilizer	0.2500	0.8422	0.3234	0.0179	0.0028	0.0036
Nematicide*Fertilizer	0.1310	0.7773	0.8625	0.5849	0.9932	0.8340
Year	0.7182	<.0001	<.0001	0.0002	0.0116	0.2604
Nematicide*Year	0.3511	0.3738	0.0045	0.0002	<.0001	<.0001
Fertilizer*Year	0.2053	0.1155	0.5454	0.6786	0.9959	0.7276
Nematicide*Fertilizer*Year	0.4145	0.2886	0.5973	0.2880	0.2840	0.2615
Nematicide*Block	<.0001	0.00002	0.0003	<.0001	0.0002	0.0009
Nematicide*Fertilizer*Block	0.7691	0.0496	0.0495	0.3013	0.0639	0.2742

[a] 1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b] Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

Appendix B, Table 5. Probability values for main and interaction effects of nematicide, fertilizer, and year on seed cotton and lint yields for large plot trial 2008, 2009

Effect	Seedcotton Position 1 (g)	Seedcotton Position 2 (g)	Seedcotton Position 3/other (g)	Lint Position 1 (g)	Lint Position 2 (g)	Lint Position 3/other (g)
Nematicide	0.3485	0.9711	0.4173	0.5966	0.9075	0.3845
Fertilizer	0.0896	0.0306	0.0039	0.1018	0.0889	0.0015
Nematicide*Fertilizer	0.7877	0.6180	0.7319	0.6506	0.7037	0.6945
Year	0.7306	<.0001	0.9490	0.4257	<.0001	0.7519
Nematicide*Year	0.8594	0.8853	0.0067	0.4988	0.9322	0.0130
Fertilizer*Year	0.1653	0.5560	0.7085	0.3727	0.7004	0.6503
Nematicide*Fertilizer*Year	0.6332	0.9406	0.4132	0.7651	0.9630	0.4716
Nematicide*Block	0.1630	0.6538	0.2277	0.0951	0.7030	0.2237
Nematicide*Fertilizer*Block	0.9012	0.9653	0.9817	0.8275	0.9692	0.9841

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

Appendix B, Table 6. Probability values for main and interaction effects of nematicide, fertilizer, and year on spring reniform, total bolls at harvest, node above white flower, and first fruiting node for large plot trial 2008, 2009

Effect	Spring reniform	Total Bolls at harvest	NAWF 1	NAWF 2	NAWF 3	NAWF 4	FFN
Nematicide	0.6180	0.7557	0.4310	0.2937	0.2964	0.9386	0.7388
Fertilizer	0.7842	0.0006	0.1814	0.0001	0.0002	<.0001	0.1904
Nematicide*Fertilizer	0.2517	0.8871	0.6358	0.2903	0.1566	0.9937	0.7428
Year	0.0012	<.0001	<.0001	<.0001	0.1530	0.7801	<.0001
Nematicide*Year	0.7025	0.1586	0.3012	0.0089	0.0190	0.0864	0.8447
Fertilizer*Year	0.6348	0.5497	0.9571	0.8816	0.7379	0.4782	0.7615
Nematicide*Fertilizer*Year	0.5443	0.8929	0.6515	0.6653	0.2093	0.6806	0.0878
Nematicide*Block	0.0033	0.0281	0.6980	0.6244	0.3614	0.0572	0.0008
Nematicide*Fertilizer*Block	0.0727	0.8405	0.7200	0.3132	0.5897	0.1772	0.0797

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

Appendix B, Table 7. Probability values for main and interaction effects of nematicide, fertilizer, and year on total nodes per plant for large plot trial 2008, 2009.

Effect	Total nodes per plant 1	Total nodes per plant 2	Total nodes per plant 3	Total nodes per plant 4	Total nodes per plant 5	Total nodes per plant 6
Nematicide	0.4041	0.0091	0.2314	0.6210	0.7982	0.6057
Fertilizer	0.7022	0.4859	0.0263	0.0008	0.0043	<.0001
Nematicide*Fertilizer	0.0460	0.2090	0.9425	0.2930	0.5168	0.0827
Year	0.0793	0.7304	<.0001	0.0671	0.0020	0.0002
Nematicide*Year	0.1983	0.0337	0.0703	0.0070	0.0823	0.3160
Fertilizer*Year	0.7307	0.8959	0.8527	0.7852	0.8917	0.5114
Nematicide*Fertilizer*Year	0.3342	0.4298	0.0143	0.6411	0.2655	0.6052
Nematicide*Block	0.0249	0.7153	0.2739	0.1079	0.3870	0.4617
Nematicide*Fertilizer*Block	0.5615	0.4835	0.0244	0.6759	0.7452	0.4887

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 34, 101, 123, 146, and 224 kg/ha

CHAPTER 4

SMALL PLOT INVESTIGATIONS OF THE IMPACT OF NEMATODE CONTROL AND NITROGEN FERTILIZER RATES ON COTTON GROWTH AND YIELD IN A RENIFORM NEMATODE INFESTED FIELD

ABSTRACT

Small plots, 3 meters long by 1 row wide were arranged in a split plot design within field-length, 12-row strips of cotton in a field near Portland, AR to evaluate the relationship between soil nitrogen application rates and reniform nematode control. The field-length strips were either fumigated with 1,3-dichloropropene or left untreated. Within each strip, nitrogen rates (applied as urea) included 34, 101, 123, 146, and 224 kg/ha nitrogen. Nematicide application had no effect on plant growth, development, or yield. Applying nitrogen at rates greater than 34 kg/ha increased plant heights, total bolls, total leaf tissue nitrogen, and dry matter but did not affect yield. There was no interaction between 1,3-dichloropropene and nitrogen fertilization rate.

INTRODUCTION

Producers in southeastern Arkansas commonly encounter both *Meloidogyne incognita* (Chitwood, 1949; Kofoid and White, 1919) the southern root-knot nematode, and *Rotylenchulus reniformis* (Linford and Olivera, 1940), the reniform nematode, as economic pests in cotton fields (Anonymous, 2013). Cotton is an important economic crop in Arkansas, with about 580,000 planted acres and an estimated harvest of 1,200,000 bales, equaling to a return of $397,440,000 for 2012 (Anonymous, 2012). Crop loss estimates for plant-parasitic nematodes in Arkansas for 2011 totaled about 4% of the crop (Blasingame and Patel, 2012). Reniform nematodes have quickly increased in the last ten years in the southeast part of Arkansas (Monfort, 2008). The reniform nematode female is a sedentary semi-endoparasite that infects cotton roots attaching itself to a feeding site and beginning the reproductive process. The male reniform is not parasitic and may or may not contribute to the reproductive process. Symptoms of reniform infection in cotton include plant stunting, fruit abortion, suppressed root growth, and lowered yield (Koenning et al. 2004). Cotton plants grown in reniform infested areas also display foliar symptoms of nutrient deficiencies (Koenning et al. 2004). Traditionally, growers have applied nitrogen fertilizer at rates that are higher than would normally be recommended by the Cooperative Extension Service in fields with a history of high nematode pressure even though there is no current published literature to support such action. The perception is that if a cotton plant is showing what appears to be a nitrogen deficiency, additional nitrogen may counteract this effect and increase yields. Unfortunately, routine application of excess nitrogen fertilizer is of concern both economically and from an environmental standpoint because of the potential for surface and groundwater issues (Delgado and Bausch, 2005).

The use of soil fumigation for nematode management in cotton has become increasingly popular among Arkansas cotton growers. While soil fumigation is relatively expensive, and difficult to apply (Koenning et al., 2004; Starr et al, 2007) the practice provides a relatively effective means of mitigating yield losses due to nematodes (Kinlock and Rich, 1998 and 2001), and lint yields in the region have improved sufficiently to make this treatment attractive. In many fields, particularly where nematode population densities are high, growers have observed changes in cotton growth patterns when 1,3-dichloropropene is applied. The most noticeable change has been excessive (rank) plant growth resulting in an increased need for growth regulators, especially where nitrogen fertilizer rates have exceeded standard Cooperative Extension Service recommendations. In addition to large plot research on a farm in Ashley County, this small plot study was conducted.

The objectives of this research were to: 1) determine the effects of nematicide and nitrogen fertilizer rates on cotton growth and development, 2) determine if nematode control affects the nitrogen rate required for optimum yield, and 3) determine if there were differences in nitrogen uptake within the plant.

MATERIALS AND METHODS

Field-length, 6-row strips, 96 cm rows were fumigated with 1,3-dichloropropene (Telone II®, Dow AgroScience, Indianapolos, IN) at 28 liters per hectare approximately 6 weeks prior to planting. The cotton variety was DP445 BG/RR. The 1,3-dichloropropene was applied using a modified Orthman six-row ripper hipper equipped to apply the nematicide under the row to a depth of 25 cm (Orthman Manufacturing Inc. Lexington, NE). A John Deere hipper (John Deere, Moline, IL) was used immediately behind the Orthman to further seal the beds to retain the fumigant. Phosphorus and potassium were applied across the entire area based on the farmer’s soil test report for the field.

Small plots, 3 meters long by 1 row wide were arranged in a split plot design. The main plot was the nematicide treatment, treated with 1,3-dichloropropene at 28 liters/ha or untreated, and the sub-plots were nitrogen rates of 0, 101, and 146 kg/ha. Within each nematicide area, each fertilizer rate was replicated twice. The trial was replicated twice, year treated as a replication in the analysis. The nitrogen rates were determined for this study as follows: The rate of 0 kg/ha was considered the control standard. A rate of 101 kg/ha nitrogen was the recommended rate for cotton production based on soil test report generated by University of Arkansas Soil Testing Laboratory. The 146 kg/ha nitrogen rate would normally be applied by farmers in known problem fields, specifically in fields with high nematode population densities (Charles Denver, personal communication).

Data collected from the small plots included pre-nitrogen fertilization soil samples, spring nematode samples, plant heights, tissue samples, and whole plant maps at harvest with yields by fruit position. Plant populations were adjusted by pulling extra plants in each plot to a density of 11 total plants per plot in 2009 and 8 plants per plot in 2010. The final density each year was based on the lowest number counted in the plot areas during the stand counts for each year. Soil samples were taken prior to fertilizer application from within the row in each plot to a depth of 12-15 cm. A composite of 6 cores was used to represent each plot. These composite samples were divided and analyzed at the University of Arkansas Soil Testing Laboratory in Marianna for nutrients and at the Arkansas Nematode Diagnostic Laboratory at Hope for nematode population density. Soil for nematode assay was processed by elutriation (Byrd et al, 1976) and centrifugal flotation (Jenkins, 1964).

The appropriate amount of nitrogen as urea (46-0-0) for each fertilizer treatment was measured on a gram scale (Ohaus GT4100, Ohaus Scale Corp. Florham Park, NJ 07932 Serial # 1700), placed in Whirl-packs and taken to the field. Using a hoe, a narrow trench was dug alongside the row in the plots to simulate the location of a sidedress fertilizer application and to make sure the urea remained in the plot area. The urea was spread into the trench taking care to spread it evenly along the entire side of the plot. The hoe was then used to push the trench back closed. At midseason the grower's standard practice was to apply 34 kg/ha additional nitrogen to his fields as urea broadcast by aerial application. Immediately prior to the aerial application, the entire test area was covered with breathable, light transmittable, row covers (A.M. Leonard, Inc., Piqua, OH) to prevent additional nitrogen from being applied to the plots. The covers were removed the day following the farmers' application to minimize impact of the row covers on the cotton.

Plant height measurements began at pinhead square and continued for five consecutive weeks. Two plants per plot were selected arbitrarily each week and measured. Heights were averaged.

Three weeks after flowering, the first three consecutive plants in each plot were cut off at the soil line and removed for tissue nutrient analysis. The lower stems below the cotyledonary node and roots were discarded. The plants were dissected into three categories; leaves, stems and petioles, and reproductive structures (fruit). These were placed in paper bags and dried at 43 C for 5 days. The dried plant material was then passed through a plant grinder (Thomas Wiley Lab Mill Model 4, Thomas Scientific, Swedesboro, NJ) and the ground material placed into labeled coin envelopes and sent to the University of Arkansas Soil and Tissue Testing Laboratory in Fayetteville, AR for total nitrogen by combustion using elementar rapid N.

After defoliation, the remaining plants in the plots were mapped using COTMAP (Bourland and Watson, 1990), and seed cotton was harvested by boll position: first position, second position, and other positions. The seed cotton was transported to the lab at Monticello, where it was placed in a plant dryer at 43° C for 24 hr to remove any excess moisture and provide consistent moisture levels throughout the samples. The seed cotton was then weighed.

Data analysis was performed, using SAS Statistical Analysis Software version 9.3 (SAS Analytical Institute, Cary, NC).

RESULTS AND DISCUSSION

Reniform nematode population density was similar in all plots at the beginning of the season although densities were consistently numerically lower after nematicide application (Fig 4.1).

In-season plant heights were not different due to nitrogen rate, nematicide application or their interaction. ($P \leq 0.05$). Final plant heights taken after defoliation were lower for the control where no nitrogen was applied than for either the 101 and 146 kg/ha nitrogen rates (Fig. 4.2).

Total nitrogen in the tissue samples fruit, stems and petioles, and leaves was different due to fertilizer ($P \leq 0.05$) but not nematicide application (Table 4.1). Overall, the higher the nitrogen rate, the higher the tissue nitrogen. Differences in nitrogen concentration due to nematicide application were not seen in this trial. Weights taken on the dried tissue that was used for the tissue analysis differed due to fertilizer for the leaves and the stems and petioles. Leaf and stem weights did not vary due to nematicide treatment. Dried fruit weights were not affected by either fertilizer or nematicide. Our results indicate that plant matter was typically lower where there was no nitrogen used. This is an expected outcome as plants have less dry plant matter when nutrients are deficient (Wullschleger and Oosterhuis, 1990). Nematicide application had no impact on the amount of dry tissue the plant produced.

Means of total bolls at harvest were different due to nitrogen rate with fertilized plots having slightly more ($P \leq 0.05$) (Fig. 4.3). Although significant, numerically the number of bolls per plant differed by less than 1 boll, and did not impact yield. Nematicide did not affect the total boll count nor was there any interaction. Seed cotton harvested by position was not different for any main effect. ($P \leq 0.05$) (Appendix C, Table 5).

CONCLUSION

Nematicide application had no effect on the results of this trial. Applying nitrogen at any rate other than zero impacted plant heights, total bolls, total tissue nitrogen, and dry matter but did not affect yield. There was no interaction between nematicide and nitrogen rate. Nothing suggested that applying the higher rate of nitrogen was of additional benefit and applying nitrogen according to soil test recommendation was the best option for this trial.

LITERATURE CITED

Anonymous, 2012. Crop Production Report. Washington, DC:USDA-NASS Publications.

Anonymous, 2013. National Cotton Council, Cotton Nematode Research and Education Program, Arkansas. Available at http://www.cotton.org/tech/pest/nematode/distributions.cfm?state=03A (verified 2/25/2014)

Blasingame, D., and Patel, M.V. 2012 Cotton disease loss estimate committee report. Pp. 341–343 *In* Proceedings of Beltwide Cotton Conference, Orlando, FL, January 3–6, 2012. National Cotton Council of America, Memphis, TN.

Bourland, F. M., and Watson, C. E., COTMAP, a Technique for Evaluating Structure and Yield of Cotton Plants, Crop Science 1990. 30:224–226.

Byrd, D. W., Barker, K.R., Ferris, H., Nusbaum, C.J., Griffin, W.E., Small, R.H., and Stone, C.A. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. Journal of Nematology 8: 206-212.

Chitwood, B.G. 1949. Root-knot nematodes, part I. A revision of the genus Meloidogyne Goeldi, 1887. Proceedings of the Helminthological Society of Washington 16 (1949): 90-104.

Delgado, J.A. and Bausch, W.C. 2005. Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. Journal of Soil and Water Conservation 60(6):379-387.

Jenkins, W R. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rep. 48:692, 1964. Dept. Entomology and Economic Zoology, Rutgers University, New Brunswick, NJ

Kinlock, R.A, and Rich, J.R. 1998. Response of cotton yield and *Meloidogyne incognita* soil populations to soil applications of aldicarb and 1,3-D in Florida. Journal of Nematology 30:639–642.

Kinlock, R.A., and Rich, J.R. 2001. Management of root-knot and Reniform nematodes in ultra-narrow row cotton with 1,3-dichloropropene. Supplement to Journal of Nematology 33(4S):311-313.

Koenning, S.R., Wrather, J.A., Kirkpatrick, T.L., Walker, N.R., Starr, J.L., and Mueller, J.D. 2004. Plant-parasitic nematodes attacking cotton in the United States: Old and emerging production challenges. Plant Disease 88:100–113

Kofoid, C.A. and White, W.A. 1919. A new nematode infection of man. Journal of the

American Medical Association 72:567-569.

Linford, M.B., and Oliveira, J.M. 1940. Rotylenchulus reniformis, Nov. gen. N. sp., a nematode parasite of roots. Proceedings of the Helminthological Society of Washington 7:35-42.
Monfort, W.S., Kirkpatrick, T.L., and Mauromoustakos, A. 2008. Spread of Rotylenchulus reniformis in an Arkansas cotton field over a four-year period. Journal of Nematology 40(3): 161–166.

Starr, J.L., Koenning, S.R., Kirkpatrick, T.L., Robinson, A.F., Roberts, P.A., and Nichols, R.L. 2007. The future of nematode management in cotton. Journal of Nematology 39:283-294.

Wullschleger, S.D. and Oosterhuis, D.M., 1990. Canopy development and photosynthesis of cotton as influenced by nitrogen nutrition. Journal of Plant Nutrition 13(9),1141-1154.

TABLES AND FIGURES

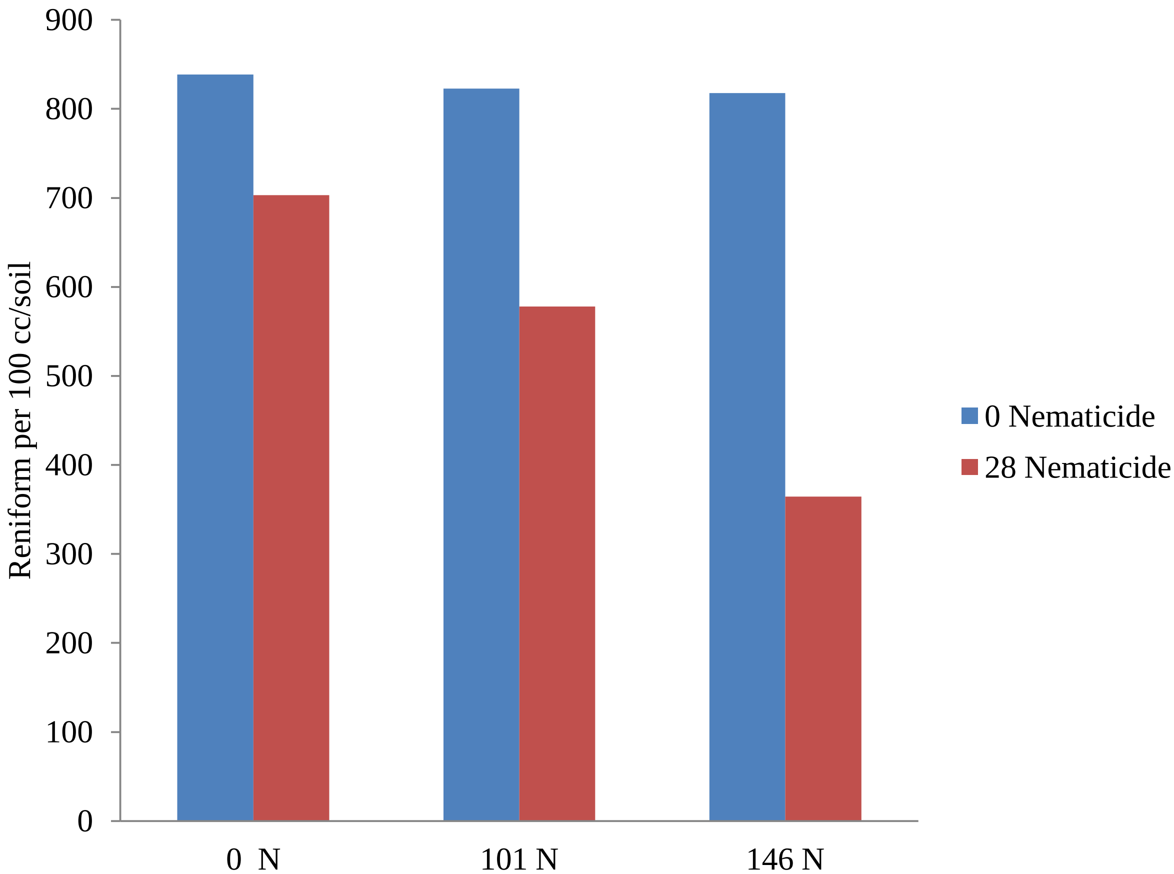


Figure 4.1. Spring Reniform populations for small plot trial for nitrogen rates of 0, 101, and 146 kg N/ha and 1,3-dichloropropene rates of 0 and 28 l/ha. Means were not significantly different using $P \leq 0.05$ for the main effects or nematicide.

Table 4.1. Dry matter weights and percent total nitrogen in plant tissue for small plots over years 2009 and 2010.

	Dry weight (g)			Total Nitrogen %		
Nitrogen[a]	Fruiting structures	Stems and Petioles	Leaves	Fruiting structures	Stems and Petioles	Leaves
0	27.84a[b]	84.98c	58.82b	2.60b	1.86b	2.15c
101	34.71a	108.70b	73.38a	2.87a	2.24a	2.38b
146	31.42a	113.52a	74.13a	2.99a	2.49a	2.58a

[a]Nitrogen rates in kg/ha

[b]Means followed by the same letter in column are not significantly different using $P \leq 0.05$

[c]% total nitrogen by combustion with elementar rapid N

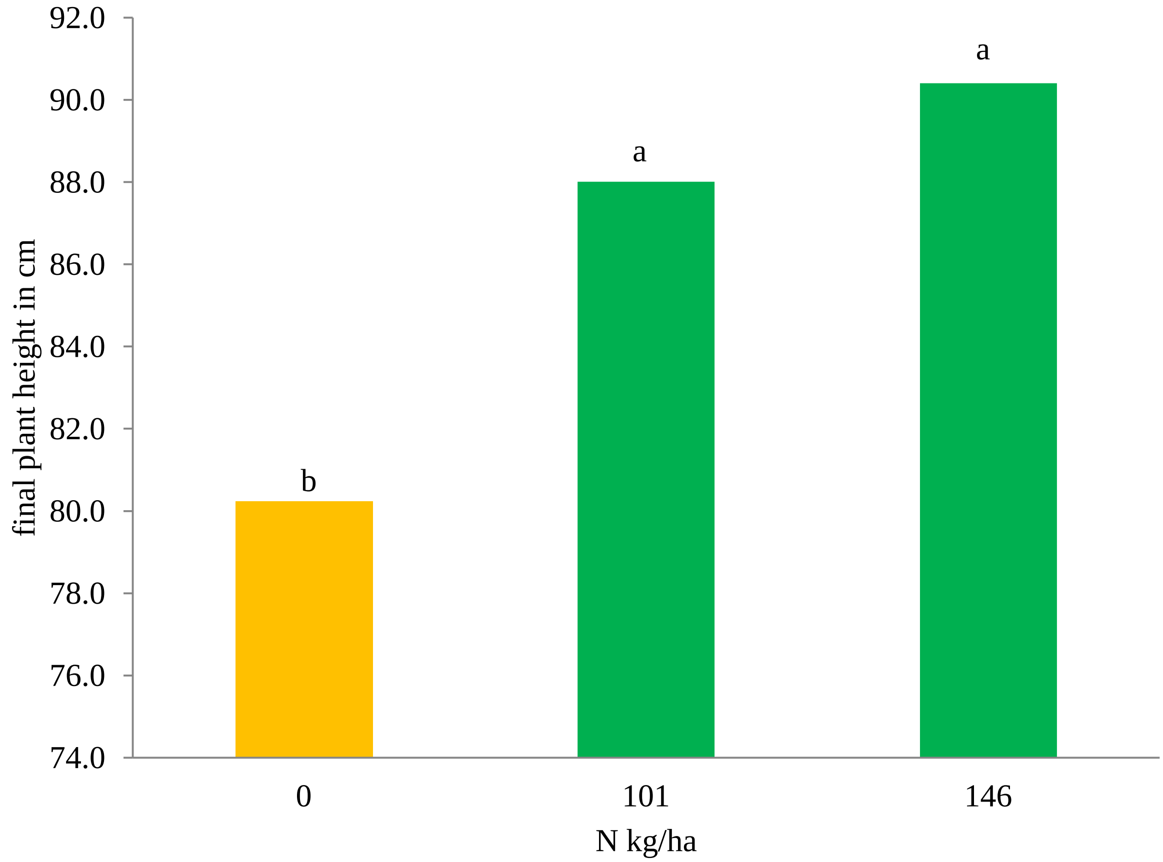


Figure 4.2. Plant heights (cm) taken after defoliation during final plant map across nitrogen rates for the small plots across years 2009 and 2010. LSD, *(P≤0.05)*

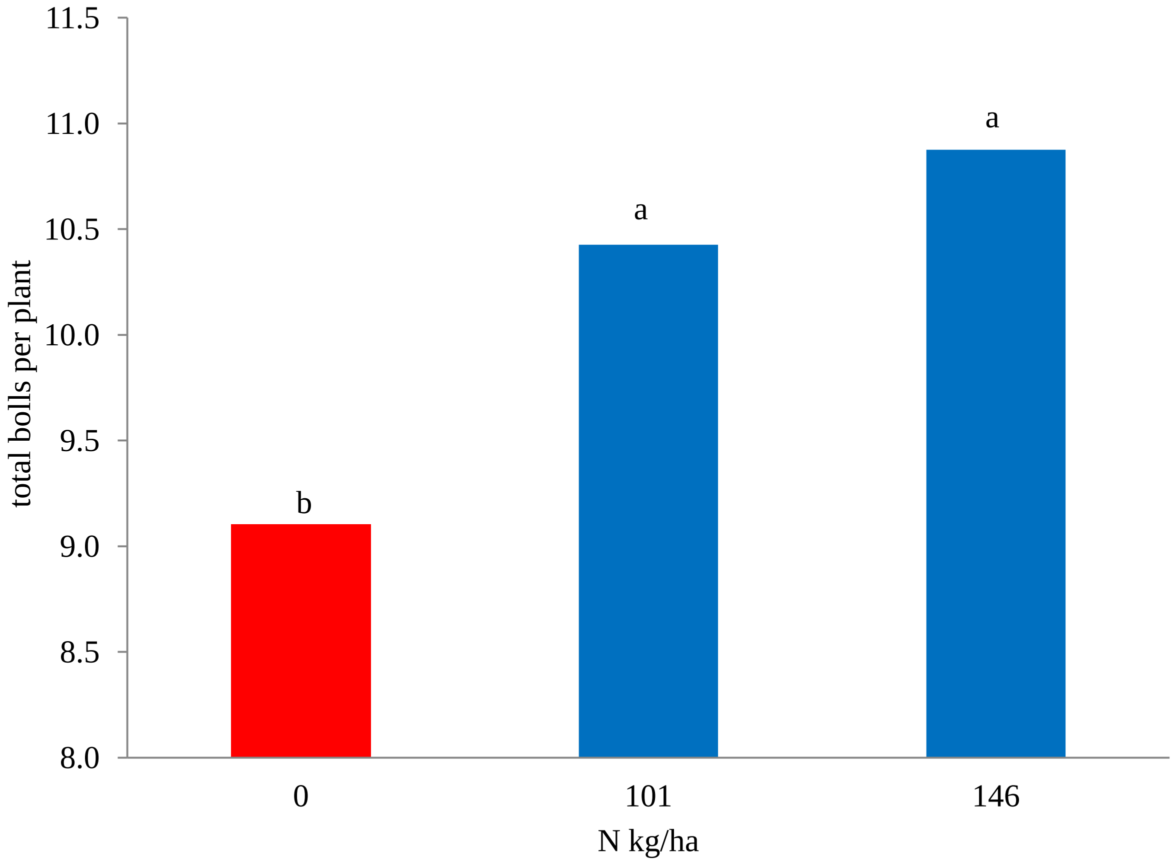


Figure 4.3. Total bolls per plant at harvest across nitrogen rates for small plots across years 2009 and 2010. LSD, *(P≤0.05)*

APPENDIX C

Appendix C, Table 1. Probability values for spring reniform and total bolls for microplots 2009, 2010.

Effect	Spring reniform/100cm^3	Total Bolls at harvest
Nematicide [a]	0.3057	0.6895
Fertilizer [b]	0.4671	0.0147
Nematicide*Fertilizer	0.5422	0.325

[a] 1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b] Nitrogen fertilizer rates of 0, 101, and 146 kg/ha

Appendix C, Table 2. Probability values for plant height for microplots 2009, 2010.

	Weekly Beginning at Pinhead Square				
	1	2	3	4	5
Effect	Plant height (cm)				
Nematicide [a]	0.1485	0.1969	0.279	0.222	0.3203
Fertilizer [b]	0.5848	0.4656	0.5381	0.6321	0.3306
Nematicide*Fertilizer	0.3857	0.3305	0.9334	0.7036	0.6219

[a] 1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b] Nitrogen fertilizer rates of 0, 101, and 146 kg/ha

Appendix C, Table 3. Probability values for dry matter weights and percent total nitrogen in plant tissue for microplots 2009, 2010.

	dry weight (g)			%Total Nitrogen[c]		
Effect	Fruit	Stem	Leaves	Fruit	Stem	Leaves
Nematicide [a]	0.4137	0.4618	0.7374	0.2145	0.3605	0.1015
Fertilizer [b]	0.3142	0.0104	0.0077	0.0182	0.0109	0.0002
Nematicide*Fertilizer	0.8122	0.7711	0.484	0.6897	0.8267	0.8116

[a] 1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b] Nitrogen fertilizer rates of 0, 101, and 146 kg/ha

[c] % total nitrogen by combustion with elementar rapid N

Appendix C, Table 4. Probability values seedcotton yields by position for microplots 2009, 2010.

	Seedcotton (g)			
Effect	Position 1	Position 2	Position 3/other	Total
Nematicide[a]	0.2882	0.6918	0.7951	0.661
Fertilizer[b]	0.4395	0.9801	0.2499	0.4201
Nematicide*Fertilizer	0.5957	0.3041	0.9594	0.6809

[a]1,3-dichloropropene (Telone II®) applied at 28 l/ha 6 weeks pre-plant

[b]Nitrogen fertilizer rates of 0, 101, and 146 kg/ha

Appendix C, Table 5. Seed cotton yield means harvested by boll position for nematicide and fertilizer for microplots 2009, 2010.

	Seedcotton (g)			
	Position 1	Position 2	Position 3/other	Total
0 Nematicide[a]	106.218[c]	61.7	80.9225	248.84
Fertilizer[b]				
0	101.591	60.8263	66.6438	229.061
101	110.144	67.1875	84.7113	262.043
146	106.919	57.0863	91.4125	255.418
28 Nematicide[a]	117.054	65.8332	77.918	260.806
Fertilizer[b]				
0	110.45	68.0722	65.5803	244.102
101	113.469	58.9575	76.96	249.386
146	127.245	70.47	91.2138	288.929

[a]l/ha of 1,3-dichloropropene (Telone II®) applied six weeks pre-plant

[b]Nitrogen rates in kg/ha

[c]means in any combination were not significantly different for seed cotton $P \leq 0.05$ by LSD

CONCLUSION

The relationship between nitrogen fertility and 1,3-dichloropropene use was not clearly demonstrated. Inconsistent growth patterns, possibly related to climate, resulted in high year to year variability. Nematicide impacts were seen in plant height and H:N early in the season but did not carry throughout growing season. Nematicide by year interactions occurred for height, total nodes, H:N, NAWF, and 3rd/other position yield. Differences in growth parameters due to fertilizer treatments were common. Fertilizer alone impacted NAWF, total nodes, height, H:N, total bolls, and yields. Most differences were between the lowest rate and all other rates. A fertilizer by nematicide interaction occurred for only one observation, total nodes during the reniform trial and a three way interaction occurred for only for one observation of total nodes out of all data collected. Neither input caused the excessive growth previously reported by farmers. Most differences although statistically significant, were small numerically. Neither input had major effects on final yields, although interestingly the plants seemed to produce more outside bolls with lower fertility during the reniform large plot trials. Differences in microplots data continued the trend of control versus any fertilizer rate. Nematicide had no effect. Lack of consistency across years implies that the idea of automatically reducing nitrogen fertilizer if 1,3-dichloropropene is utilized is incorrect. This study suggests that maintaining fertility within reasonable ranges is beneficial whether or not nematodes are controlled. In future research, this subject would benefit from controlling the variability inherent in this type of situation. Traditionally this could be done by extending it to cover more years, but it is believed this may be better suited as a spatial study.