Use of Resistant Peanut Cultivars and Reduced Fungicide Inputs for Disease Management in Strip-Tillage and Conventional Tillage Systems

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Abstract
Field experiments were conducted in 2000 and 2001 to determine the effects of the number of fungicide applications and resistant cultivars on early leaf spot (Cercospora arachidicola) of peanut (Arachis hypogaea) grown in strip-tillage versus conventional tillage. Split-plot experiments with four replications of cultivars and fungicide treatments were conducted in commercial fields using strip-tillage and conventional-tillage practices in Worth Co., GA. Main treatments consisted of cultivars Georgia Green and Florida MDR-98 in both years with the addition of C-99R in 2001. Sub-plot treatments were two fungicide treatments: (i) azoxystrobin (AZO) 0.33 kg/ha (sprays 3 and 5) and chlorothalonil (CHL) 1.26 kg/ha (all other sprays), applied at 14-day intervals; and (ii) AZO 0.33 kg/ha (sprays 2 and 4) and CHL 1.26 kg/ha (all other sprays), applied at 21- to 28-day intervals. Leaf spot ratings were 2.3 and 4.4 for Georgia Green and 1.9 and 3.3 for Florida MDR-98 (LSD = 0.4) for treatments 1 and 2, respectively, in conventional-tillage plots, and 2.1 and 2.9 for Georgia Green and 2.3 and 1.7 for Florida MDR (LSD = 0.2) in strip-tillage plots, respectively, in 2001. Lower levels of leaf spot severity in large strip-tilled plots of resistant cultivars were similar to results observed in small plot experiments. Leaf spot control in reduced fungicide regimes in strip-till was comparable to leaf spot control in the standard 14-day fungicide regimes. Thus, strip-tillage may reduce fungicide requirements for leaf spot control on Georgia Green, and should allow for even better leaf spot control when combined with resistant cultivars such as Florida MDR-98 or C-99R. Utilization of precision agriculture technologies aided in visualizing and explaining some of treatment differences for leaf spot, stem rot, tomato spotted wilt, and yield in 2000 and 2001.

Introduction
Peanut (Arachis hypogaea) production in the southeastern United States has changed dramatically over the last decade. Long-used intensive tillage practices have been replaced in many instances with reduced or conservation tillage practices. In Georgia, this conversion was due largely to suppressed crop prices, reduced labor force, and increased fuel prices. These factors have forced producers to evaluate new production practices to lower production costs. In a reduced tillage system, a producer typically utilizes cover crops and rarely uses any tillage implement except for a strip-tillage implement to till a narrow seedbed. The standard tillage system may involve tilling the soil six to seven times with implements such as disk harrows, moldboard plows, rotor tillers, and
"bedders" to form a clean seedbed in which to plant. The use of reduced tillage in peanuts is growing each year. In Georgia, peanut acreage utilizing strip-tillage increased from 6% to 22.9% from 1997 to 2003 (1,19).

Among the most important and costly peanut diseases in Georgia are early and late leaf spots caused by Cercospora arachidicola Hori and Cercosporidium personatum. Direct losses to leaf spot diseases and costs of disease control account for an annual loss of up to $63 million for Georgia producers (2,20,21). If not managed adequately, leaf spots can cause up to 70% reduction in yield (16). Two other important peanut diseases that producers are faced with each year in Georgia are tomato spotted wilt, caused by the topivirus Tomato spotted wilt virus (TSWV), and stem rot, caused by Sclerotium rolfsii (6,7).

In previous research trials, the severity of leaf spot was lower in reduced tillage plots than in conventional tillage plots (17). Similar trends in peanut leaf spot disease development were observed in reduced-tillage (strip-till) peanut trials conducted by Monfort et al. (15), and by Cantonwine et al. in small plots (4). However, evaluations in larger plots are needed to determine if the combined effects of resistant cultivars and tillage on peanut diseases that will be consistent when peanuts are produced under more typical large-scale production practices. This research was undertaken to evaluate the effects of reduced tillage and conventional tillage systems on performance of recommended and reduced fungicide regimes on peanut cultivars having multiple resistance to leaf spot, stem rot, and TSWV. A secondary objective of these on farm trials was to evaluate the potential value of precision agriculture technologies in helping to understand spatial differences within and among tillage, cultivars, and fungicide treatments for leaf spot, stem rot, TSWV, and yield.

Management of Peanut Diseases in Conventional and Reduced Tillage Systems

Field tests were conducted in fields of Tifton loamy sand at Sutton Farms and Brooks Farms in 2000, and Young Farms, Worth Co., GA in 2001. Field sites had been planted to cotton (Gossypium hirsutum L.) the previous year. Both the Sutton and Young field sites were planted to a cover crop consisting of a mixture of wheat (Triticum aestivum) and rye (Secale cereale) at a seeding rate of 104.4 kg/ha in the fall prior to spring planting.

A split-plot design with four replications was used in all experiments. Cultivars were main plots and fungicide regimes were sub-plots. In 2000, the conventional tillage and reduced tillage systems were conducted in two fields that were ~ 800 m apart. For 2001, the two tillage treatments were represented in contiguous halves of the same field (Fig. 1).

Sub plots were 375 to 450 m long by 3.6 m wide in 2000 and 240 m long by 3.6 m wide in 2001. All cultivars were planted in both tillage plots at 13 to 20 seed/m of row in 91-cm row spacings on 16 May 2000 and 18 May 2001. Plots received aldicarb (Temik 15G, Bayer Crop Science, Research Triangle Park, NC) at a rate of 1.12 kg a.i./ha in furrow at planting. Applications of plant nutrients
and pesticides other than fungicides were based on the individual producer’s needs and production practices. Peanut cultivar Georgia Green, a leaf spot susceptible cultivar, and Florida MDR-98 (9) and C-99R (8) with moderate levels of partial resistance to C. personatum and C. arachidicola were used in these experiments (only MDR-98 in 2000). All three cultivars have moderate levels of field resistance to TSWV, and MDR-98 and C-99R have some resistance to S. rolfsii (7,8,9). Fungicide treatment regimes consisted of: (i) applications of chlorothalonil (Bravo Weatherstik, Syngenta Crop Protection Inc., Greensboro, NC) 1.26 kg a.i./ha, sprays 1, 2, 4, 6 and 7, and azoxystobin (Abound 2.08 F, Syngenta) 0.33 kg a.i./ha, sprays 3 and 5, applied at planned 14-day intervals; and (ii) applications of chlorothalonil at 1.26 kg a.i./ha, sprays 1 and 4, and azoxystobin at 0.33 kg a.i./ha, sprays 2 and 3, applied at planned 21- to 28-day intervals.

In 2000, fungicide applications were made 37, 51, 64, 79, 93, 107, and 126 days after planting (DAP) for the 14-day schedule, and 37, 59, 79, and 107 DAP for the extended schedule. In 2001, applications were made 34, 45, 62, 77, 90, 106, and 120 DAP for the 14-day schedule and 34, 56, 77, and 106 DAP for the extended schedule. Fungicide applications were made using a tractor-mounted hydraulic sprayer. The spray boom was equipped with three D3-23 hollow-cone spray nozzles per row. Fungicides were applied in water at 114 liter/ha at a pressure of 345 kPa.

Leaf spot intensity (severity and defoliation) was assessed at 10 m intervals for entire plots by use of the Florida 1 to 10 scale where 1 = no leaf spot, and 10 = plants completely defoliated and killed by leaf spots (5). Leaf spot intensity ratings were made 85, 100, 118, and 135 DAP in 2000, and 128 and 142 DAP in 2001. Early leaf spot was the predominant foliar disease in both years. Although the tillage treatment was not replicated, there was a significant location (tillage) effect on leaf spot intensity in both years. Cultivar × treatment interactions were significant ($P \leq 0.05$) for leaf spot intensity ratings in 2001 in the conventional-tillage plots; therefore fungicide treatments were compared within each cultivar. In 2000, leaf spot intensity was higher for in Georgia Green than in MDR-98 across both fungicide treatments (Fig. 2). In 2001, C-99R had the lowest leaf spot disease ratings (Fig. 2). Leaf spot intensity was typically higher in most of the 21- to 28-day fungicide regimes compared to the 14-day fungicide regime for each cultivar (Fig. 2).
Plants in each plot were evaluated at 10-m intervals for severe symptoms of TSWV at 99 DAP in 2001 and 96 DAP in 2000. Incidence of TSWV was determined as the percent of row length affected by spotted wilt (9). Similar suppressive effects of tillage on TSWV across all cultivars in the large farm plots were also noted when compared to small plot experiments in 2000 and 2001 (Figs. 3 and 4) (15). There were no significant fungicide effects or cultivar × fungicide treatment interactions on incidence of spotted wilt. Across fungicide treatments, incidence of TSWV was 8.1% for Georgia Green and 9.6% for MDR-98 in conventional-tillage (LSD = 2.5), and 5.4% for Georgia Green and 1.1% for MDR-98 in strip-tillage (LSD = 1.1) in 2000; and 14.6% for Georgia Green, 20.8% for MDR-98, and 24.1% for C-99R in conventional-tillage (LSD = 2.0), and 9.6% for Georgia Green, 16.6% for MDR-98, and 18.2% C-99R in strip-tillage (LSD = 2.1) in 2001.
Fig. 3. Spatial map of TSWV incidence on peanut in on-farm trials conducted in Worth Co., GA in 2000. Fungicide treatments are denoted at margin of each block as: (1) Georgia Green at 14-day intervals, (2) Georgia Green at 21- to 28-day intervals, (3) MDR 98 at 14-day intervals, and (4) MDR 98 at 21- to 28-day intervals. TSWV incidence was mapped based on percentage of 31-cm sections of row infected on 10-m interval blocks within each plot for both tillage practices. Each block represents a 2-m by 10-m plot.

Fig. 4. Spatial map of TSWV incidence on peanut in on-farm trials conducted in Worth Co., GA in 2001. Fungicide treatments are denoted at margin of each block as: (1) Georgia Green at 14-day intervals, (2) Georgia Green at 21-day intervals, (3) MDR 98 at 14-day intervals, (4) MDR 98 at 21-day intervals, (5) C99R at 14-day intervals, (6) C99R at 14-day intervals. TSWV incidence was mapped based on percentage of 31-cm sections of row infected on 10-m interval blocks within each plot for both tillage practices. Each block represents a 2-m by 10-m plot.
Immediately after plants were inverted at harvest, loci of stem rot were counted at 10-m intervals within each plot, where a locus represented 31 cm or less of linear row with one or more plants showing symptoms of stem rot and/or signs of the pathogen. Incidence of stem rot was calculated as the percentage of 31-cm sections of row with stem rot. Incidence of stem rot was generally higher in strip-tillage than conventional tillage in 2000 (Fig. 5) and 2001 (Fig. 6). There were no significant cultivar × fungicide treatment interactions in 2000 or 2001 for stem rot. Across all other factors, mean incidence of stem rot was 3.2% for Georgia Green and 3.5% for MDR-98 (LSD = 3.8) in the conventional-tillage field; and 6.7% for Georgia Green and 4.8% for MDR-98 in the strip-tillage (LSD = 1.6) in 2000. In 2001, incidence of stem rot was and 15.1% for Georgia Green, 11.0% for MDR-98, and 15.7% for C-99R in conventional-tillage (LSD = 4.2); and 20.7% for Georgia Green, 10.8% for MDR-98, and 17.8% for C-99R in strip-tillage (LSD = 4.8) in 2001. Stem rot incidence was typically higher, but not always significant, in most of the 21- to 28-day expanded fungicide regimes compared to the 14-day fungicide regime (Figs. 5 and 6).

Fig. 5. Spatial map of stem rot incidence on peanut in on-farm trials conducted in Worth Co., GA in 2000. Fungicide treatments are denoted at margin of each block as: (1) Georgia Green at 14-day intervals, (2) Georgia Green at 21- to 28-day intervals, (3) MDR 98 at 14-day intervals, (4) MDR 98 at 21- to 28-day intervals. Stem rot incidence was mapped based on percentage of 31-cm sections of row infected on 10-m interval blocks within each plot for both tillage practices. Each block represents a 2-m by 10-m plot.
Reduced Tillage and Fungicide Regime Effects on Cultivar Yield

All cultivars were dug and inverted at 147 DAP in 2000, whereas in 2001 inverting was at 130 DAP for Georgia Green and 150 DAP for MDR-98 and C-99R. Plants were dried in wind-rows, and pods were harvested at 151 DAP in 2000 for both cultivars and 133 DAP for Georgia Green and 154 DAP for the MDR-98 and C-99R in 2001. Plots were harvested using a two-row KMC peanut combine (Kelly Manufacturing Company, Tifton, GA) equipped with a peanut yield monitor developed in the Biological and Agricultural Engineering Department at The University of Georgia Coastal Plain Experiment Station, Tifton, GA. Pod yields were determined for each plot after harvested pods were dried and adjusted to 12% w/w moisture for treatment comparisons. Data for the two years were analyzed independently by analysis of variance using SAS statistical software (SAS Institute Inc., Cary, NC) (18). Fisher’s protected least significant differences were calculated for comparison of cultivars and treatment effects. Subsequent reference to significant differences among means indicates significance at $P \leq 0.05$ unless otherwise stated.

There were no significant cultivar by fungicide treatment interactions in either year. Yield of Georgia Green was highest in both fields in 2000 (Fig. 7). Across all other factors, the mean yield was 4491 kg/ha for Georgia Green and 3959 kg/ha for MDR-98 in the conventional-tillage field and 4750 kg/ha for Georgia Green and 4230 kg/ha for MDR-98 in the strip-tillage field (LSD = 404) in 2000. However, yield of MDR-98 was highest among the three cultivars in 2001 (Fig. 7). In 2001, across all other factors, the average yield was 4788 kg/ha for Georgia Green, 4806 kg/ha for MDR-98, and 4318 kg/ha for C-99R for conventional-tillage (LSD = 349); and 4221 kg/ha for Georgia Green, 4684 kg/ha for MDR-98, and 4124 kg/ha for C-99R for strip-tillage (LSD = 363).
Spatial Evaluations of Disease and Yield among Cultivars and Tillage Treatments

Incidence of leaf spot, stem rot, and spotted wilt were mapped in each field at 10-m intervals within each plot using a Global Positioning System (Trimble GPS, Sunnyvale, CA) and Farm Site Mate mapping software (Farm Works Software, Hamilton, IN). For determining the accuracy of utilizing a peanut yield monitor for yield comparisons in research trials, peanuts harvested from each plot were weighed with commercial truck scales (Intercomp Company, Minneapolis, MN) and compared back to the weights recorded by the peanut yield monitor. Along with disease and yield data, aerial photography and topography data were collected using a Beeline tractor guidance system (Beeline Technologies Inc., Fresno, CA) in 2001. After data were collected site-specifically with Farm Site Mate, spatial interpolation maps were constructed in the geographic information systems software, SSTool box (Site-Specific Technology Development Group Inc., Stillwater, OK) to aid in evaluating potential differences in disease and/or yield across and within treatments.

In 2000, the spatial evaluations of TSWV, stem rot, and leaf spot showed minimal variation in disease within tillage and fungicide treatments (Figs. 3, 5, and 8). The highest level of variation was noted between tillage practices for TSWV and leaf spot (Figs. 3 and 8). Although there were little differences spatially in the trials in 2000, spatial evaluations of the collected data helped explain the variations in both disease and yield in 2001. Like the previous year, TSWV and leaf spot incidence was higher in the conventional tillage (Figs. 4 and 9). However, the single block in conventional tillage had an increased level of TSWV and a decreased level of leaf spot visually compared to the block in strip-tillage, which could have impacted the overall results.

**Fig. 7.** Effects of cultivars and fungicide application regimes on peanut yield, Worth Co., GA in 2000 and 2001. Averages within each treatment were calculated based on yield data collected via a GPS integrated peanut yield monitor designed by The University of Georgia Department of Engineering. A single asterisks (*) indicates statistical significance (LSD) between cultivars within select tillage systems.
Fig. 8. Spatial map of Conventional-till and strip-till plots for early leaf spot intensity in peanut caused by *Cercospora arachidicola* Hori in on-farm trials conducted in Worth Co., GA in 2000. Fungicide treatments are denoted at margin of each block as: (1) Georgia Green at 14-day intervals, (2) Georgia Green at 21- to 28-day intervals, (3) MDR 98 at 14-day intervals, (4) MDR 98 at 21- to 28-day intervals. Leaf spot intensity was mapped on 10-m interval blocks based on Florida 1 to 10 scale where 1 = no leafspots and 10 = plants completely defoliated. Each block represents a 2-m by 10-m plot.

Fig. 9. Spatial map of peanut leaf spot intensity in on-farm trials conducted in Worth Co., GA in 2001. Fungicide treatments are denoted at margin of each block as: (1) Georgia Green at 14-day intervals, (2) Georgia Green at 21- to 28-day intervals, (3) MDR 98 at 14-day intervals, (4) MDR 98 at 21- to 28-day intervals, (5) C99R at 14-day intervals, (6) C99R at 21- to 28-day intervals. Leaf spot intensity was mapped 10 m interval blocks based on Florida 1 to 10 scale where 1 = no leafspots and 10 = plants completely defoliated. Each block represents a 2 m by 10 m plot.
The advantage in evaluating the data collected spatially was observed in both yield and stem rot in 2001. There was an increase in stem rot in strip tillage that was not previously observed in small or large plot research trials conducted on strip-till peanuts (Fig. 6). Furthermore, a reduction in yield was also noted in the same area with strip-tillage (Figs. 6 and 10). Examination of the field’s layout and topography showed that the strip-till area of the field had a 1.8 m drop in elevation and had terraces in place to reduce erosion (Figs. 1 and 10). The reduction in elevation and terraces were found to promote water retention thus potentially increasing stem rot incidence and yield loss in the strip-till area. Although the average stem rot incidence was found to be higher for the entire strip-till area, disease incidence was lower in the strip-till areas not affected by the terraces visually compared to the conventional tillage plots. The increase in stem rot incidence also translated into lower yields near the terraces. Finally, yields calculated by the peanut yield monitor were highly correlated to truck scale weights ($R^2 = 0.96, P < 0.05$) (Fig. 11).

Fig. 10. Interpolated yield map in kilograms per hectare (kg/ha) overlayed onto a 3-D topographical map illustrating the effects of topography on yield using a Beeline Tractor Guidance System and ArcGIS 8. X and Y coordinates are GPS latitude and longitude while the Z coordinate is meters above mean sea level.

Fig. 11. Correlation between actual truck scale weights and weights calculated by a GPS integrated yield monitor of peanuts harvested on Young Farms in Worth Co., GA in 2001.
Summary

In this study, reduced leaf spot was observed in strip-tillage in all cultivar and fungicide treatment regimes when compared to conventional-tillage. This trend of reduced leaf spot in strip-till agrees with previously published results of replicated small plot research (15). Although leaf spot epidemics did not reach severe levels in either year, the leaf spot epidemics were generally more severe in conventional tilled fields, especially for the cultivar Georgia Green.

Suppression of leaf spot epidemics can be further enhanced by planting leaf spot resistant cultivars like MDR-98 and C-99R (15). Although Georgia Green is the predominant cultivar grown in Georgia, newer cultivars like C-99R would enable producers to better control certain diseases as well as aid in managing harvest intervals by planting cultivars with varying days of maturity. The results from this study indicated that fungicide usage could be reduced when resistant cultivars are planted in strip-till fields. Leaf spot severity was typically higher in plots receiving the 21- to 28-day fungicide application schedule than in the 14-day schedule. However, in both years, disease severity in the 21- to 28-day fungicide schedule and strip-tillage system was comparable to that of the 14-day fungicide regimes in conventional-tillage in the respective cultivars (Figs. 2, 8 and 9). The ability to adequately control leaf spot with an expanded schedule could reduce the input cost of producing peanuts and reduce unnecessary fungicide applications. Based on elimination of three applications of chlorothalonil in the extended spray schedule used in this study, the reduction in fungicide applications could cut production costs by an average $49.40/ha (2000 estimated average fungicide cost) (A. K. Culbreath, personal communication).

Results from this study support those of previous studies indicating that incidence of TSWV is suppressed in peanuts under a reduced tillage system and that stem rot is not consistently affected by reduced tillage (10,11,12,13,14,15).

Yields of both cultivars tended to be higher in strip-tilled fields than in the conventional-tilled fields in 2000. However, yields were higher in the conventional-tilleage system than in the strip-tilled fields for all three cultivars in 2001. Lower yields (Fig. 7) in the strip-tilled area in 2001 may have been due to an increase in stem rot and water retention that occurred due to the terraces (Figs. 1 and 10). Evaluation of the data collected using precision agriculture technologies may have prevented an erroneous conclusion. Along with utilizing precision agriculture technologies to aid in explaining results, use of these technologies (i.e., yield monitors) in field research can increase the efficiency and effectiveness of data collection in large plot research trials.

Integrating reduced tillage practices into peanut would allow producers to eliminate unnecessary tillage implements. This adaptation may translate into less overhead and labor costs, along with a reduction in management time. These reductions combined with potential savings from fungicide inputs from utilizing a reduced tillage practice in peanut production could potentially outweigh small yield reductions in strip-till compared conventional-tillage. Those comparisons are currently being examined. Furthermore, utilization of a reduced tillage practice like strip-tillage may potentially reduce soil erosion, nutrient runoff, and pesticides as well as enhancing water utilization (3,4).

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Literature Cited


