Tank Mix Combinations of Propiconazole and Chlorothalonil for Control of Leaf Spot Diseases of Peanut

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ABSTRACT

Field experiments were conducted in one location in 1993 and two locations in 1994 to determine the effects of propiconazole and chlorothalonil tank mix combinations on severity of early (*Cercospora arachidicola*) and late (*Cercosporidium personatum*) leaf spot diseases of peanut (*Arachis hypogaea* L.). In all tests, 10 treatments consisted of 0 and 63 g a.i./ha of propiconazole and 0, 0.315, 0.63, 0.945, and 1.26 kg a.i./ha of chlorothalonil arranged factorially. In 1993, final leaf spot intensity ratings decreased according to nonlinear quadratic functions of chlorothalonil concentrations applied with and without propiconazole. No improvement in leaf spot control was evident with the addition of more than 0.945 kg a.i./ha of chlorothalonil with 63 g a.i./ha of propiconazole. In 1994, conditions were more conducive for leaf spot development. At the Plains location, final leaf spot intensity ratings decreased according to non-linear quadratic functions of chlorothalonil concentrations alone. Leaf spot intensity ratings decreased linearly with increasing rates of chlorothalonil when applied with 63 g a.i./ha of propiconazole. At Tifton, final leaf spot intensity ratings decreased linearly with increasing rates of chlorothalonil with or without propiconazole. Leaf spot intensity ratings were lower on plants treated with tank mixes of chlorothalonil and propiconazole compared to those treated with chlorothalonil alone. Pod yields increased linearly or according to quadratic functions of rates of chlorothalonil with or without propiconazole in both years and all locations. Across all rates of chlorothalonil, yields were higher from plants treated with propiconazole than those treated with the respective rates of chlorothalonil alone.

Key Words: Chemical control, DMI, ergosterol biosynthesis inhibitor, EBI, fungicide sterol demethylation inhibitor, resistance management.

For over 20 years, control of early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot (*Cercosporidium personatum* (Berk. & Curt.) Deighton) of peanut (*Arachis hypogaea* L.) in the southeastern U. S. has been dependent largely upon intensive applications of the protectant fungicide chlorothalonil. In 1994, the sterol demethylation-inhibiting (DMI) fungicides, propiconazole and tebuconazole, were registered for use on peanut in the U. S. The DMIs have activity against many different fungal pathogens of various plants, animals, and humans (14). Several DMI fungicides have shown great potential for control of major foliar and soilborne diseases of peanut (1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 18). Propiconazole is active against *C. arachidicola* and *C. personatum* and provides some suppression of southern stem rot (*Sclerotium rolfsii* Sacc.) on peanut (4).

Several different application techniques and schedules have been evaluated in efforts to utilize this fungi-

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cide optimally for disease control and to prevent or delay development of pathogen populations with reduced sensitivity. Several factors must be considered for determining use patterns for propiconazole. First, the maximum legal allowable dosage is 504 g a.i./ha per season. Divided equally across seven or eight applications, this rate of propiconazole alone would not be sufficient to control late leaf spot on peanut cultivars typically grown in the southeastern states (18). Furthermore, propiconazole alone, even at higher rates, does not control peanut rust (*Pucinnia arachidis* Speg.) (18). Finally, full season use of any DMI alone is not recommended because of the risk of developing pathogen populations with reduced sensitivity to these fungicides (15).

The use of propiconazole in tank mix combinations with chlorothalonil may enhance disease control and overcome some of the potential problems associated with use of propiconazole alone. Tank mix combinations or cyproconazole and chlorothalonil have shown excellent potential for improved control of late leaf spot compared to chlorothalonil alone (8, 10). Use of tank mix combinations of 126 g a.i./ha of propiconazole and 1.26 kg a.i./ha of chlorothalonil would be cost-prohibitive for most peanut growers. The purpose of this study was to determine the effects of full season applications of tank mix combinations of reduced rates of propiconazole and chlorothalonil on intensity of leaf spot diseases of peanut.

Materials and Methods

Field experiments were conducted at one location (Plains, GA) in 1993 and two locations (Plains and Tifton, GA) in 1994. Fields at Plains were located on The University of Georgia Southwest Branch Station. Both fields were Greenville sandy clay loam soil (clayey, kaolinitic, thermic Rhodic Kandiudults; pH = 5.8) and were planted to peanut the previous year. The field at Tifton was located on the Black Shank Farm at the Coastal Plain Experiment Station. The soil type was a Fuquay loamy sand (loamy siliceous, thermic Arenic Plinthic Kandiudults; pH = 5.8) and was planted to cotton (*Gossypium hirsutum* L.) the previous year.

The peanut cultivar Florunner was planted at 112 kg seed/ha on 7 May 1993 and 16 April 1994 at Plains and on 17 May 1994 at Tifton. Aldicarb (1.1 kg a.i./ha, Temik 15G) was applied in-furrow at planting to all plots for control of thrips (*Frankliniella* spp.). Plots in all tests consisted of two rows on beds 1.8 m wide and 7.6 m long. At Plains, rows were 0.76 m apart on the bed and 1.04 m apart between the beds, whereas rows at Tifton were 0.9 m apart. Experimental plots were separated by two nonsprayed border rows and 2.4 m fallow alleys.

A randomized complete block design with four replications was used in all experiments. The 10 treatments consisted of 0 and 63 g a.i./ha of propiconazole (Tilt 3.6 E, Ciba, Greensboro, NC) and 0, 0.315, 0.63, 0.945, and 1.26 kg a.i./ha of chlorothalonil (Bravo 720, ISK Biosciences, Mentor, OH) in a 2 x 5 factorial arrangement. Propiconazole was used at 63 g a.i./ha or one-eighth of the 504 g a.i./ha maximum amount. This rate represents one-half of the standard rate for propiconazole used alone. The 1.26 kg a.i./ha of chlorothalonil represents the recommended rate for control of early and late leaf spot diseases. Treatments that included both fungicides were applied as tank mix combinations.

Fungicides were scheduled for application on a 14-d calendar schedule. Treatments were applied 39, 55, 67, 83, 95, 109, and 129 d after planting (DAP) in 1993; 50, 63, 83, 96, 106, 117, and 131 DAP in 1994 at Plains; and 29, 45, 57, 70, 84, 98, and 112 DAP in 1994 at Tifton. Fungicides were applied using a multiple-boom tractor-mounted CO_2-propellant sprayer. Each boom was equipped to deliver 187 L/ha at 310 kPa with three D3-23 hollow-cone spray nozzles per row. Leaf spot intensity ratings were made 127 and 143 DAP in 1993; 124 and 147 DAP in 1994 at Plains, and 118 and 143 DAP at Tifton in 1994. Ratings were made using the Florida 1-10 scale, where 1 = no leaf spot and 10 = plants completely defoliated and killed by leaf spot (5).

Plants were dug and inverted 144 DAP in 1993, 147 DAP in 1994 at Plains, and 146 DAP in 1994 at Tifton. Immediately after plants were inverted, incidence of southern stem rot was determined in each plot or 15.2 m of row. Disease loci included one or more diseased plant(s) in up to 31 cm of linear row (17). Plants were dried in windrows for 4-10 d and pods were harvested mechanically and weighed. Data were subjected to analysis of variance. Regression analysis was used to evaluate leaf spot intensity ratings, and pod yield responses to increasing rates of chlorothalonil. Fisher's protected least significant differences were calculated for mean separation of main effects by propiconazole.

Results

In 1993, leaf spot intensity was low throughout most of the season, but epidemics developed rapidly during late season. In 1994, leaf spot epidemics were extremely severe at both locations. Early leaf spot was the prevalent foliar disease in all experiments, with late leaf spot epidemics developing late in the season.

Propiconazole, chlorothalonil, and propiconazole x chlorothalonil effects on initial leaf spot intensity ratings were significant ($P \leq 0.01$) in all tests; therefore, regressions of leafspot intensity ratings on rate of chlorothalonil are reported within propiconazole treatments (Fig. 1). In all experiments, initial leaf spot intensity ratings decreased linearly or according to quadratic functions with increasing rates of chlorothalonil. Propiconazole and chlorothalonil main effects on final leaf spot intensity ratings were significant ($P \leq 0.01$) in all experiments, but propiconazole x chlorothalonil interaction effects were significant ($P \leq 0.01$) only in 1993.

Regression of leaf spot intensity ratings on chlorothalonil rates, however, was performed within propiconazole treatments to illustrate effects of both fungicides (Fig. 2). In 1993, final leaf spot intensity ratings decreased according to quadratic functions of rate of chlorothalonil with or without propiconazole treatments. Leaf spot intensity ratings for propiconazole and no propiconazole converged as chlorothalonil rates approached 1.26 kg a.i./ha.

In 1994, final leaf spot intensity ratings at Plains decreased according to a quadratic function of rates of chlorothalonil alone, and according to linear functions when applied with propiconazole. Across chlorothalonil treatments, final leaf spot intensity ratings were 5.7 (±0.6) and 7.2 (±1.0) (LSD = 0.3; $P \leq 0.05$) for plots treated with and without propiconazole, respectively. Disease intensity ratings decreased linearly with as rates

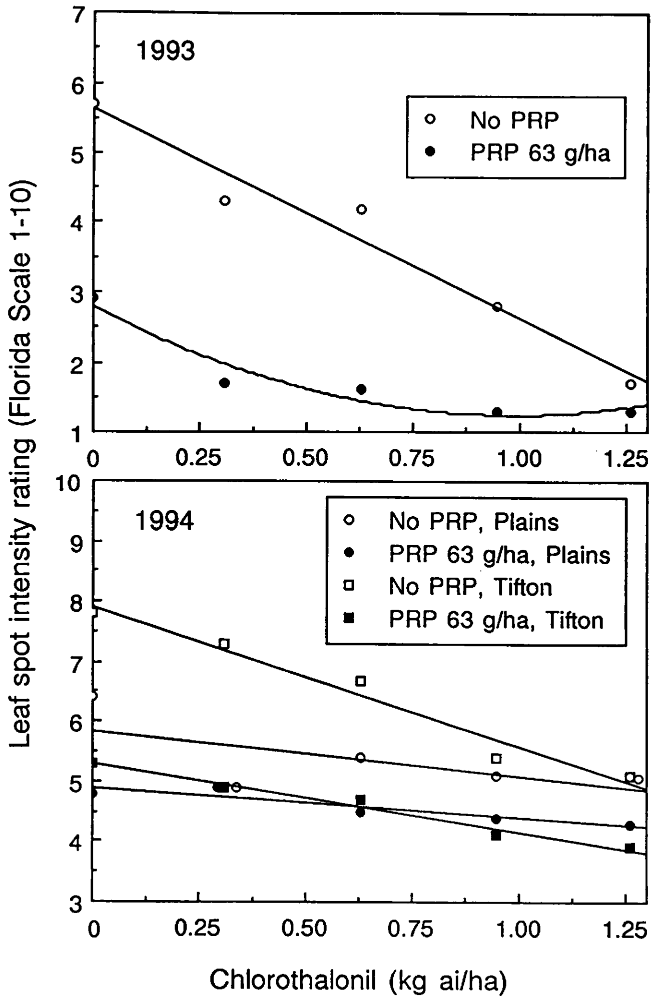

Fig. 1. Effects of chlorothalonil (CHL) alone and tank mixed with propiconazole (PRP) (0.63 g a.i./ha) on initial leaf spot intensity (LS) on peanut in 1993 and 1994. Circles and squares represent actual means. Lines represent predicted values. 1993: PRP 0, LS = 7.6(± 0.32) - 3.1(± 0.34)CHL, R^2 = 0.78; PRP 63, LS = 2.8(±0.23) - 3.2(±0.87)CHL + 1.6(±0.66)CHL^2, R^2 = 0.61. 1994 Plains: PRP 0, LS = 6.2(±0.21) - 2.4(±0.69)CHL + 1.2(±0.44)CHL^2, R^2 = 0.51; PRP 63, LS = 4.9(±0.11) - 0.4(±0.13)CHL, R^2 = 0.34. 1994 Tifton: PRP 0, LS = 7.9(±0.29) - 1.9(±0.31)CHL, R^2 = 0.68; PRP 63, LS = 5.3(±0.10) - 0.95(±0.11)CHL, R^2 = 0.79. Numbers in parentheses are standard errors.

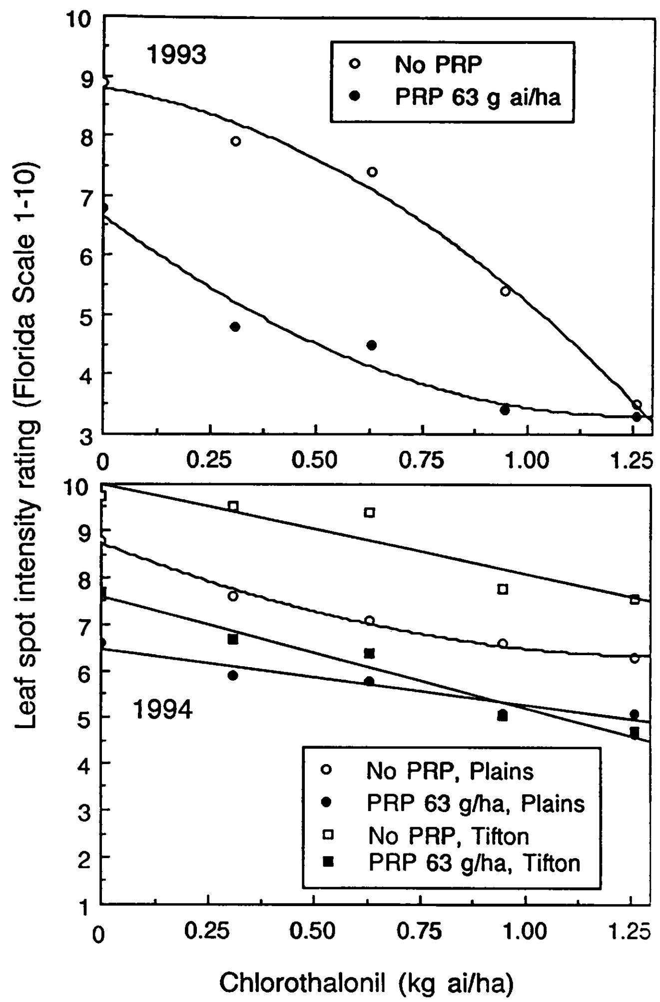

Fig. 2. Effects of chlorothalonil (CHL) alone and tank mixed with propiconazole (PRP) (0.63 g a.i./ha) on final leaf spot intensity (LS) on peanut in 1993 and 1994. Circles and squares represent actual means. Lines represent predicted values. 1993: PRP 0, LS = 8.9(± 0.32) - 1.6(± 1.2)CHL - 2.2(±0.93)CHL^2, R^2 = 0.90; PRP 63, LS = 6.7(±0.34) - 5.5(±1.3)CHL + 2.2(±0.96)CHL^2, R^2 = 0.78. 1994 Plains: PRP 0, LS = 8.7(±0.22) - 2.9(±0.7)CHL + 0.88(±0.46)CHL^2, R^2 = 0.79; PRP 63, LS = 6.4(±0.13) - 0.98(±0.15)CHL, R^2 = 0.72. 1994 Tifton: PRP 0, LS = 10.0(±0.24) - 1.6(±0.27)CHL, R^2 = 0.67; PRP 63, LS = 7.6(± 0.32) - 2.0(± 0.34)CHL, R^2 = 0.67. Numbers in parentheses are standard error values.

of chlorothalonil were increased at Tifton. Across chlorothalonil treatments, leaf spot intensity ratings were 6.1 (±1.4) and 8.8 (±1.1) (LSD = 0.4; P ≤ 0.05) with and without propiconazole, respectively.

The effect of propiconazole on incidence of southern stem rot was significant (P ≤ 0.05) in 1993, but chlorothalonil and interaction effects were not. Across all chlorothalonil treatments, incidence of stem rot was 6.6 (±3.1) and 8.6 (±3.3) % (LSD = 2.0; P ≤ 0.05) for plots treated with and without propiconazole, respectively. The incidence of stem rot was not affected (P > 0.05) by treatments in either experiment in 1994. Disease incidence of stem rot averaged 18.0 (±8.6) and 18.8 (±7.4) % at Plains, and 3.2 (±3.1) and 3.4 (±2.5) % at Tifton for plots treated with and without propiconazole, respectively.

The effect of propiconazole and chlorothalonil on pod yield was significant (P ≤ 0.05) in all tests. There was no significant chlorothalonil x propiconazole interaction in any test. Within propiconazole or no propiconazole treatments, pod yield increased linearly with increasing rates of chlorothalonil (Fig. 3). Across all treatments in 1993, pod yields were 4665 (±641) and 3901 (±579) kg/ha (LSD = 257, P ≤ 0.05) with and without propiconazole, respectively. In 1994, pod yields at Plains increased according to quadratic functions of rate of chlorothalonil with or without propiconazole (Fig. 3). Across all treatments, pod yields averaged 3503 (±782) and 2664 (±874) kg/ha (LSD = 427, P ≤ 0.05) with and without propiconazole, respectively. Yields at Tifton increased

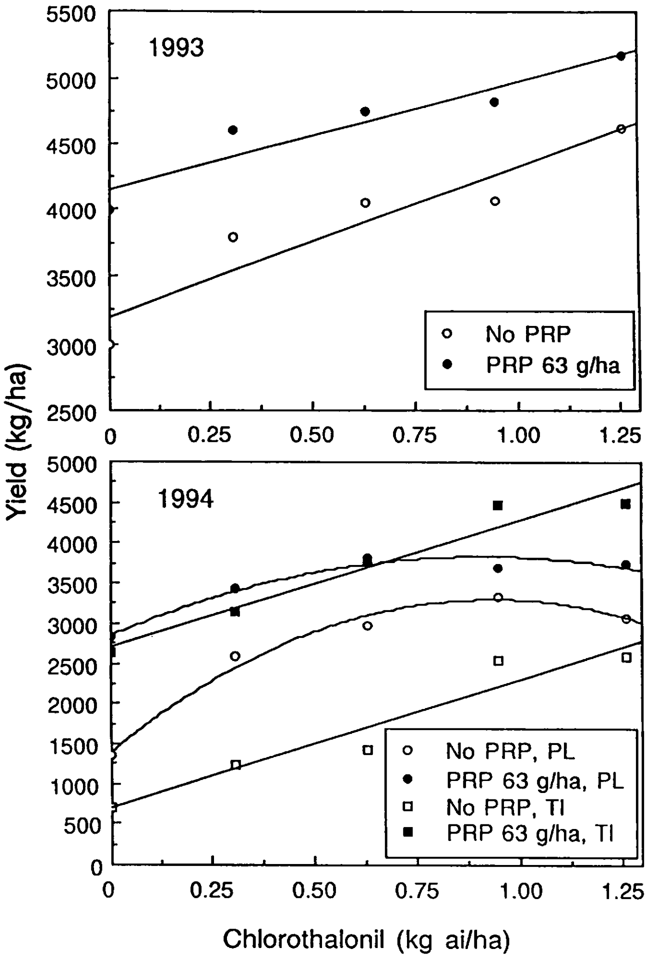

Fig. 3. Effects of chlorothalonil (CHL) alone and tank mixed with propiconazole (PRP) (0.63 g a.i./ha) on peanut pod yield in 1993 and 1994. Circles and squares represent actual means. Lines represent predicted values. 1993: PRP 0, Y = 3193(±106) + 1134(±139)CHL R^2 = 0.79; PRP 63, Y = 4152(±208) + 821(±271)CHL, R^2 = 0.34. 1994 Plains: PRP 0, Y = 1391(±252) + 3422(±795)CHL -1533(±508) CHL^2, R^2 = 0.67; PRP 63, Y = 2844(±343) + 1808(±1084)CHL -827(±693) CHL^2, R^2 = 0.22. 1994 Tifton: PRP 0, Y = 687(±231) + 1352(±251)CHL, R^2 = 0.62; PRP 63, Y = 2694(±221) + 1339(±240)CHL, R^2 = 0.63. Numbers in parentheses are standard error values.

linearly with increasing rate of chlorothalonil (Fig. 3). Across all treatments, pod yields were averaged 3699 (±915) and 1700 (±936) kg/ha (LSD = 352, $P \leq 0.05$) with and without propiconazole, respectively.

Discussion

Data from these studies indicate that tank mixes of propiconazole at 0.63 kg a.i./ha and chlorothalonil at 0.72 to 1 kg a.i./ha applied on approximately 14-d schedules improves control of leaf spot diseases and increases pod yields in comparison to standard rates of chlorothalonil alone. The advantages of tank mixes for leaf spot control compared to chlorothalonil alone were more evident when environmental conditions were extremely conducive for development of leaf spot epidemics.

This study did not address the effect of the various treatments on the proportion of late leaf spot and early leaf spot lesions. From general observation in previous experiments, propiconazole typically has been more effective against early leaf spot than late leaf spot. Use of propiconazole might represent a directional selection mechanism against *C. arachidicola*. Studies are in progress to characterize the proportion of late and early leaf spot lesions in these treatment regimes. Also, it is not known whether similar advantages in control compared to chlorothalonil alone would result if late leaf spot were the predominant foliar disease involved.

Trends toward higher pod yields in treatments of 1.125 and 1.26 kg of chlorothalonil with propiconazole than those from corresponding rates of chlorothalonil alone could not be explained by differences in leaf spot control in 1993. When more intense leaf spot epidemics occurred, pod yield differences most likely were due largely to differences in leaf spot control. Only minimal effects of propiconazole on incidence of southern stem rot were observed in 1993 and no effects were observed in 1994. However, our assessments did not include the severity associated with each locus of stem rot. Reduction in severity of stem rot could be a factor in yield increases, but more research is needed to prove this hypothesis. Propiconazole also has shown suppression of Rhizoctonia limb rot (*Rhizoctonia solani* Kühn AG-4) (4). Although limb rot was not severe in these tests, propiconazole may have reduced peg infections that otherwise would have reduced yields. Peanut rust was not observed in any of these tests.

The risk of developing populations of *C. arachidicola* or *C. personatum* with reduced sensitivity is not known. Differences among isolates of *C. arachidicola* have been reported for *in vitro* sensitivity to 1 ppm of propiconazole (12). Considering the high reproductive potential of *C. arachidicola* and *C. personatum* and the potential benefits the peanut industry could realize from extended use of several DMI fungicides, a very conservative approach to resistance management is warranted.

Although tank mix combinations of propiconazole and chlorothalonil were very efficacious in this study, the effectiveness of chlorothalonil as a companion fungicide for preventing or managing reduced fungicide sensitivity in *C. arachidicola* or *C. personatum* has not been determined. Tank mix combinations of fungicides are a means of preventing or delaying development of pathogen populations with reduced sensitivity to at-risk fungicides (6). Limitations with the use of a conventional fungicide such as chlorothalonil for resistance management were discussed by Köller and Scheinpflug (13). Currently, chlorothalonil is the only viable non-DMI option for use as a companion fungicide or for use in an alternating schedule. An alternative to use of tank mixes is to use maximum rates of a DMI fungicide as a block of sprays between those with a non-DMI fungicide. Köller and Scheinpflug (13) indicated that there was no clear preference for the use of alternate sprays or tank mixes. In a review of DMI sensitivity, Staub (19) stated that if efficacy for controlling disease and preventing development of pathogen populations are equal, use of mixtures is much easier to enforce. This may be of particular pertinence in situations with growers who are inclined to overuse a new product. In addition, Phipps (16) suggested that pre-mixes are also much easier to incorporate into environment driven spray advisories which are becoming more prevalent.

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