***Original Research Article***

# Control of Peanut (*Arachis hypogaea* L.) Foliar and Soil-Borne Diseases Using Bixafen Plus Flutriafol


## ABSTRACT

**Aim:** Evaluate bixafen plus flutriafol when used in various fungicide programs for peanut foliar and soilborne disease control and yield response when using Georgia M-13 and Georgia 09B peanut varieites.
**Study design:** Randomized complete block.
**Place and Duration of Study:** Field studies were conducted from 2018 through 2020 in south-central Texas near Yoakum (29.276$^o$ N, 97.123$^o$ W).
**Methodology:** Fungicides were applied with a $CO_2$-propellant sprayer. The spray boom was equipped with three D2-23 hollow-cone spray nozzles per row with the middle nozzle centered over each plant in the row and another nozzle located as such to spray on each side of the plant to provide thorough coverage with a spray volume was 187 L $ha^{-1}$. All studies included a non-treated control and a comparison treatment of chlorothalonil only at 1.26 kg $ha^{-1}$. Each plot consisted of four rows spaced 97 cm apart and 7.9 m long.
**Results:** The primary foliar disease was early leaf spot, caused by *Cercospora arachidicola* S. Hori. Bixafen + flutriafol applied twice in a 4 to 5 fungicide spray program in combination with chlorothalonil provided early leaf spot control as good as or better than the standard of chlorothalonil alone or chlorothalonil + azoxystrobin plus benzovindiflupyr. Fungicide treatments which included bixafen + flutriafol reduced southern blight caused by *Sclerotium rolfsii* Sacc. disease incidence up to 85%. The level of soilborne and foliar disease control exhibited with each fungicide program influenced peanut yield response as those programs which provided the best control also produced the highest yield.
**Conclusion:** These studies show the ability of bixafen plus flutriafol to provide control of foliar and soilborne diseases found in southwest peanut production.



*Keywords: Cercospora arachidicola, early leaf spot, Sclerotium rolfsii, white mold, southern blight, peanut yield.*


## 1. INTRODUCTION

The systemic demethylation inhibitor (DMI) fungicides are used in all the peanut growing regions of the US for management of foliar leafspot diseases of peanut (*Arachis hypogaea* L.) including early leafspot, caused by *Cercospora arachidicola* (Hori), and late leaf spot caused by *Nothopassalora personata* (Beck. & M. A. Curtis) S.A. Khan & M. Kamal (formerly *Cercosporidium personatum* [Beck. & M. A. Curtis] Deighton) [1]. These fungicides are also used to control soil-borne diseases including southern stem rot (southern blight) caused by *Sclerotium rolfsii* (Sacc.) and Rhizoctonia limb rot, caused by *Rhizoctonia solani* (Kuhn) [1.2]. Diseases caused by these organisms lead to significant reductions in peanut yield and quality throughout the world [1,2].

Tebuconazole, a DMI fungicide, is one of the most widely used fungicides in peanut in the US [1]. In the southeastern US, the typical labeled use pattern has been four consecutive applications of tebuconazole following one or two applications of chlorothalonil or a mixture of chlorothalonil plus propiconazole, or pyraclostrobin. The subsequent consecutive applications of tebuconazole are initiated approximately 60 days after planting (DAP) [2]. In the southwest peanut growing region, a maximum of five fungicide applications are generally made during the growing season depending on weather conditions [3-6]..

The succinate dehydrogenase (SDHI) fungicides (FRAC Group 7) have been on the market since the late 1960's [7]. All fungicides in FRAC Group 7 inhibit complex II of the fungal mitochondrial respiration by binding and blocking SDH-mediated electron transfer from succinate to ubiquinone. The SDHI fungicides work much like the FRAC group 11 fungicides, just at a different site in the mitochondrial respiration. Also like the FRAC group 11 fungicides, they are at-risk for fungicide resistance development because of their specific modes of action. Research has shown there are numerous single point mutations that can lead to resistance development to FRAC group 7 fungicides [7].

A common resistance management strategy is to use fungicide mixtures with more than one mode of action in the mixture [8.9]. These fungicides are often categorized as low-risk or high-risk for resistance, depending on whether resistant pathogen strains exist in the population and the likelihood of developing resistance amongst other factors [10]. In practice, fungicide mixtures often contain two fungicides that are high-risk for development of resistance. These mixtures are of increasing relevance since there are few low-risk fungicides available and the high risk options are typically of higher efficacy [11]. Low-risk (multi-site) fungicides are increasingly rare. As an example, chlorothalonil has been banned for use by the EU since 2019 due to environmental concerns [12]. Previous modeling studies have found fungicide mixtures to be more effective as a resistance management strategy than alternating use of fungicides [13]. or spatially concurrent applications where different fields receive treatments from different modes of action [8].

Pathogen isolates with reduced sensitivity to fungicides may be present in a population due to natural mutations and are not necessarily the result of fungicide application. Applying a fungicide will select for these mutants and they will proportionally increase as part of the population that is still sensitive to the fungicide. Therefore this will eventually lead to a pathogen population that has reduced sensitivity or is resistant to the fungicide [14].

Bixafen is a systemic SDHI fungicide that functions by inhibiting succinate dehydrogenase, an enzyme Involved in the citric acid cycle and mitochondrial electron transport chain, which in turn disrupts energy production [15]. It is registered in the US in combination with other fungicides for use on corn (*Zea mays* L.), soybean (*Glycine max* L.), sugar beet (*Beta vulgaris*), potato (*Solanum tuberosum* L.), cereal grains, and other crops [15].

Flutriafol is a systemic DMI fungicide that can be used curative or as a preventative treatment. It inhibits the specific enzyme, C14-demethylase, a fungal cytochrome P450 which plays a role in sterol production. Sterols are needed for fungal membrane structure and function and are essential for the development of functional cell walls [16].

The combination of bixafen + flutriafol is marketed in the US under the trade name Lucento® and was registered for use in 2019 on corn, soybeans, sugar beet, peanut (*Arachis hypogaea* L.), wheat (*Triticum aestivum* L.), triticale (x *Tritocosecalen Wittm*. Ex. A. Camus), and grain sorghum [*Sorghum bicolor* (L.) Moench] [17,18]. Due to the two modes of action for disease management there is a lot of interest in the efficacy of this product for foliar and soil borne diseases of peanut. Therefore, the objective of this research project was to determine the effectiveness of bixafen plus flutriafol for control of peanut foliar and soilborne diseases and subsequent yield response in the south Texas peanut growing area.

## 2. MATERIAL AND METHOD

**2.1 Field studies.** Studies were conducted in 2018 through 2020 at the Texas A&M AgriLife Research Site near Yoakum (29.276$^{o}$ N, 97.123$^{o}$ W) in south-central Texas to determine peanut disease control and yield response to applications of the premix of bixafen plus flutriafol applied at various application timings during the growing season. These studies were in the same general area within a field but were moved each year to different locations within the field. Two studies were conducted in 2018 and 2019 and are labeled as Test 1 and Test 2 with one study conducted in 2020. Soil type was a Tremona loamy fine sand (thermic Aquic arenic Paleustalfs) with less than 1% organic matter and pH 7.1 to 7.4. Other details of the study including peanut variety, planting and harvest date are presented in Table 1.

**2.2 Plot maintenance.** All test areas were maintained weed-free with preemergence (flumioxazin, pendimethalin, S-metolachlor) and postemergence (clethodim, imazapic, 2,4-DB) herbicides commonly used to control weeds in peanut. Sprinkler irrigation was applied on a 1- to 2-wk schedule throughout the growing season as needed.

**Table 1. Variables with each study at Yoakum, TX.**

| Year | Study | Variety | Planting date | Harvest date |
|---|---|---|---|---|
| 2018 | Test 1 | Georgia M-13 | 26 June | 12 Dec |
| | Test 2 | Georgia M-13 | 26 June | 12 Dec |
| 2019 | Test 1 | Georgia 09B | 26 June | 3 Dec |
| | Test 2 | Georgia 09B | 26 June | 3 Dec |
| 2020 | Test 1 | Georgia 09B | 1 July | 8 Dec |

**2.3 Fungicide application.** In all studies, fungicides were applied with a $CO_2$-propellant sprayer. The spray boom was equipped with three D2-23 hollow-cone spray nozzles per row with the middle nozzle centered over each plant in the row and another nozzle located as such to spray on each side of the plant in a row to provide thorough coverage. Spray volume was 187 L $ha^{-1}$. The experimental design was a randomized complete block with four replications. Some studies included a non-treated control while others included chlorothalonil only at 1.26 kg $ha^{-1}$ as the comparison treatment. Each plot consisted of four rows spaced 97 cm apart and 7.9 m long. The two middle rows were sprayed while the outside row on each side were buffers to prevent spray drift from affecting adjacent plots and also to serve as inoculum source for foliar disease(s).

**2.4 Disease history and assessment.** The trial locations had a history of early leafspot, *Rhizoctonia* limb and pod rot, and southern blight disease pressure due to being in continuous peanut production for over 40 yrs. and in all instances these studies relied on natural inoculum for infection. Peanut phytotoxicity ratings were taken 7 to 14 d after treatment at all locations. Peanut injury, if present, was visually estimated on a scale of 0 to 100 (0 indicating no leaf chlorosis or necrosis and 100 indicating complete peanut kill), relative to the non-treated control. Severity of leaf spot was rated in the center two rows of each plot using the Florida leaf spot 1-10 index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead [19-21]. The leaf spot rating was taken several days prior to peanut digging. Soil borne disease incidence was assessed immediately after peanut plants were inverted by counting 31 cm or less of segment of the row with symptomatic plants infected with *Rhizoctonia solani* or *S. rolfsii* [22] and is expressed as percent infection.

**2.5 Peanut maturity and data analysis.** Plants were dug based on pod maturity [23]. Peanut yields were obtained after digging each plot separately, air-drying in the field for 4 to 7 d, and harvesting pods from each plot with a combine. Weights were recorded after drying to 10% moisture and cleaning to remove soil and plant debris.

Data were subjected to ANOVA and analyzed using SAS PROC MIXED with locations and years designated as random effects in the model [24]. Treatment means were separated using Fisher's Protected LSD at $P \leq 0.05$. Since fungicide treatments and application timings varied for years, trials were evaluated separately and no attempt was made to consolidate data.

## 3. RESULTS AND DISCUSSION

No peanut phytotoxicity was noted with any bixafen plus flutriafol treatments (data not shown). In all studies chlorothalonil at 1.26 kg ai ha$^{-1}$ was included with each fungicide spray program. Chlorothalonil is the foundation of peanut leaf spot control programs because it is the only fungicide proven to have multiple modes of action to the reduce the risk of developing leaf spot resistance [25]. Alternating or tank mixing chlorothalonil with other fungicides can delay development of resistance towards these alternative fungicides. Chlorothalonil in the last spray can also help prevent resistant leaf spot strains from overwintering and causing infection in the following year [25].

**Table 2. Bixafen plus flutriafol spray programs for leafspot and southern blight control in 2018[a] (Test 1).**

| | | **Early leafspot** | **Southern blight** | |
|---|---|---|---|---|
| **Fungicides and application timings[b,c]** | | **Florida scale[d]** | **Infection** | **Yield** |
| Chlorothalonil | Bixafen + flutriafol | 1-10 | % | Kg ha$^{-1}$ |
| A-E | - | 3.1 | 2.7 | 3347 |
| A,E | B, C, D | 1.9 | 2.6 | 3304 |
| B,D | A,C,E | 2.2 | 2.0 | 3143 |
| A,C,E | B,D | 1.7 | 2.2 | 3191 |
| A,E | B,D | 1.9 | 2.6 | 3078 |
| A,E | B,C | 1.9 | 2.1 | 3152 |
| A,C,E | B,D,E | 1.8 | 2.6 | 3074 |
| A,C,E | A,C,E | 1.9 | 3.0 | 3006 |
| - | - | 6.7 | 11.5 | 2576 |
| LSD (0.05) | | 0.7 | 2.4 | 529 |

[a] Peanuts dug when 162 days old.
[b] Spray schedule: A, 48 days after planting (DAP); B, 68 DAP; C, 83 DAP; D, 101 DAP; E, 120 DAP.
[c] Fungicide rates: Chlorothalonil, 1.26 kg ai ha$^{-1}$; bixafen, 0.142 kg ai ha$^{-1}$ + flutriafol, 0.243 kg ai ha$^{-1}$.
[d] Leaf spot assessed using the Florida leaf spot index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead.

### 3.1 Early leaf spot control.

#### 3.1.1 2018.

***3.1.1.1 Test 1.*** Under heavy foliar disease pressure based on the untreated check (lesions numerous and very evident on upper canopy with 50 to 75% defoliation), the chlorothalonil only treatment improved leafspot control over the untreated while all bixafen plus flutriafol treatments improved leafspot control over the chlorothalonil only treatment (Table 2). No differences were noted with application timing when using bixafen plus flutriafol. The use of bixafen plus flutriafol at the first timed application (48 DAP) did not improve leaf spot control over bixafen plus flutriafol applied at the second timed application (68 DAP).

***3.1.1.2 Test 2.*** Again, under heavy foliar disease pressure, chlorothalonil only reduced leaf spot 60% compared with the untreated check (Table 3). Bixafen plus flutriafol applied B + C or C + D reduced leaf spot disease 15 to 35% when compared with the chlorothalonil only treatment while the addition of tebuconazole (D) to bixafen plus flutriafol (B + C) reduced leaf spot 35%. Azoxystrobin plus benzovindiflupyr applied B + C only reduced leaf spot incidence 8% over chlorothalonil alone while the addition of cyproconazole (C + E) to azoxystrobin plus benzovindiflupyr (C + E) improved leaf spot control 31% over chlorothalonil alone. Strobilurins such as azoxystrobin can move across the leaf surface and into the waxy cuticle of the leaf (locally systemic) and may even move into the cuticle on the underside of the leaf (translaminar activity) [26]. Also, some azoxystrobin may move into the xylem and be transported upwards [27]; however, little of the azoxystrobin moves down to the roots [28,29].

**Table 3. Bixafen plus flutriafol spray programs for leafspot and southern blight control in 2018[a] (Test 2).**

| | | | **Early leafspot** | **Southern blight** | |
|---|---|---|---|---|---|
| **Fungicides and application timings[b,c]** | | | **Florida scale[d]** | **Infection** | **Yield** |
| | | | 1-10 | % | Kg ha$^{-1}$ |
| Chlorothalonil A-E | - | - | 2.6 | 3.2 | 2336 |
| Chlorothalonil A,B,E | Bixafen + flutriafol C,D | - | 2.2 | 2.8 | 2360 |
| Chlorothalonil A,D,E | Bixafen + flutriafol B,C | - | 1.8 | 4.7 | 2284 |
| Chlorothalonil A,E | Bixafen + flutriafol B,C | Tebuconazole D | 1.7 | 2.0 | 2479 |
| Chlorothalonil A,D,E | Azoxystrobin + benzovindiflupyr B,C | - | 2.4 | 2.5 | 2108 |
| Chlorothalonil A,B,D | Azoxystrobin + benzovindiflupyr C,E | Cyproconazole C,E | 1.8 | 3.8 | 2477 |
| - | - | - | 6.5 | 17.9 | 1269 |
| LSD (0.05) | | | 0.6 | 2.5 | 360 |

[a] Peanuts dug when 162 days old.
[b] Spray schedule: A, 48 days after planting (DAP); B, 68 DAP; C, 83 DAP; D, 101 DAP; E, 120 DAP.
[c] Fungicide rates: Chlorothalonil, 1.26 kg ai ha$^{-1}$; bixafen, 0.142 kg ai ha$^{-1}$ + flutriafol, 0.243 kg ai ha$^{-1}$; tebuconazole, 0.227 kg ai ha$^{-1}$; azoxystrobin, 0.019 kg ai ha$^{-1}$ + benzovindiflupyr, 0.001 kg ai ha$^{-1}$; cyproconazole, 0.048 kg ai ha$^{-1}$.
[d] Leaf spot assessed using the Florida leaf spot index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead.



**<u>3.1.2 2019.</u>**

***3.1.2.1 Test 1.*** Under moderate leaf spot pressure (lesions noticeable on the upper canopy and 20 to 50% defoliation), the chlorothalonil only treatment reduced leaf spot from the untreated check 62% while all bixafen plus flutriafol treatments reduced leaf spot disease 67 to 73% (Table 4). Applying bixafen plus flutriafol at the first application, 50 DAP (A) reduced leaf spot disease incidence up to 39% when compared with bixafen plus flutriafol applied 69 (B) and 104 (D) DAP. Applying tebuconazole 122 DAP actually resulted in leaf spot incidence comparable with the chlorothalonil only treatment. The performance of tebuconazole for leaf spot control has changed drastically within 10 years of the registration of tebuconazole in the US with tebuconazole frequently less effective than chlorothalonil for leaf spot control [30,31].

**3.1.2.2 Test 2.** With moderate pressure, the bixafen plus flutriafol treatments controlled leaf spot more effectively (< 1.8 on the Florida scale) than treatments which contained chlorothalonil only, chlorothalonil plus tebuconazole, or chlorothalonil plus tebuconazole plus pyraclostrobin (Table 5).

***3.1.3 2020.*** With moderate leaf spot pressure, all fungicide treatment reduced leaf spot disease incidence when compared with the untreated check (Table 6). Chlorothalonil alone performed as well as bixafen plus flutriafol or azoxystrobin plus benzovindiflupyr treatments while bixafen plus flutriafol applied 48 (A) plus 82 (C) DAP without azoxystrobin, tebuconazole, or pyraclostrobin, had the greatest amount of early leaf spot of all fungicide treatments. In another study, azoxystrobin plus benzovindiflupyr provided early leaf spot control comparable to prothioconazole plus tebuconazole and other fungicide programs [5].

**Table 4. Bixafen plus flutriafol spray programs for leafspot and southern blight control in peanut in 2019 (Test 1).**

| Fungicides and application timings[a,b] | | | Early leafspot | Southern blight | |
|---|---|---|---|---|---|
| **Chlorothalonil** | **Bixafen + flutriafol** | **Tebuconazole** | **Florida scale[c]** | **Infection** | **Yield** |
| | | | **1-10** | **%** | **Kg ha$^{-1}$** |
| A-E | - | - | 2.1 | 5.4 | 4156 |
| B,D,E | A,C | - | 1.5 | 3.8 | 4372 |
| A,C,E | B,D | - | 1.6 | 6.7 | 3909 |
| A,B,D | C,E | - | 1.8 | 3.3 | 4285 |
| B,E | A,C | D | 1.4 | 2.9 | 3977 |
| A,C | B,D | E | 2.0 | 5.0 | 4087 |
| A,B | C,E | D | 1.6 | 6.3 | 3925 |
| C,E | B,D | - | 1.8 | 5.8 | 3796 |
| B,D | C,E | - | 1.8 | 3.8 | 3951 |
| C | B,D | E | 2.3 | 3.3 | 3744 |
| A,B,D,E | C,E | D | 1.6 | 3.3 | 4218 |
| - | - | - | 5.4 | 17.5 | 2485 |
| LSD (0.05) | | | 0.6 | 5.1 | 740 |

[a] Spray schedule: A, 50 days after planting (DAP); B, 69 DAP; C, 86 DAP; D, 104 DAP; E, 122 DAP.

[b] Fungicide rates: Chlorothalonil, 1.26 kg ai ha$^{-1}$; bixafen, 0.142 kg ai ha$^{-1}$ + flutriafol, 0.243 kg ai ha$^{-1}$; tebuconazole, 0.227 kg ai ha$^{-1}$.

[c] Leaf spot assessed using the Florida leaf spot index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead.

**3.2 Southern blight control.** Warm, wet weather has been associated with increased occurrence of southern blight [3,4,32,33,34]. However, dry conditions also play a role in disease development. Fluctuations in soil moisture have been shown to promote germination of sclerotia and lead to greater disease development [35]. Date of planting can also play a role in disease development. In the southeastern US, the incidence of southern blight has been found to be lower in later- than in earlier planted peanuts [32,34,36] while in the south Texas growing area southern blight usually develops later in the growing season [3,4].

**3.2.1 2018.**

***3.2.1.1 Test 1.*** Under light disease pressure based on the untreated (11.5% infection), all fungicide treatments resulted in less southern blight disease development than the untreated check (Table 2). There was no difference in control with any fungicide treatments including chlorothalonil. Chlorothalonil has no activity against any soil borne diseases commonly found in peanut [3,4,3738].

***3.2.1.2 Test 2.*** Under moderate disease pressure (17.9%), all fungicide treatments resulted in less disease incidence than the untreated check (Table 3). The addition of tebuconazole to bixafen plus flutriafol applied 68 (B) and 83 (C) DAP did not improved southern blight control over bixafen plus flutriafol alone applied 68 (B) and 83 (C) DAP. Bixafen plus flutriafol applied 68 (B) and 83 (C) DAP or azoxystrobin plus benzovindiflupyr applied 83 (C) plus 120 (E) improved southern blight control over chlorothalonil alone. Applying bixafen plus flutriafol 83 (C) plus 101 (D) DAP or azoxystrobin plus benzovindiflupyr applied 68 (B) plus 83 (C) DAP did not improve southern blight control over chlorothalonil alone.

***3.2.2 2019.***

***3.2.2.1 Test 1.*** With moderate disease pressure (17.5% infection) all fungicide treatments effectively controlled southern blight and no differences were noted between fungicide treatments with all fungicides resulting in 2.9 to 6.7% infection (Table 4).

**Table 5. Bixafen plus flutriafol combinations for leafspot and southern blight control in peanut in 2019 (Test 2).**

| Fungicides and application timings[a,b] | | | Early leafspot Florida scale[c] | Southern blight Infection | Yield |
|---|---|---|---|---|---|
| | | | 1-10 | % | Kg ha$^{-1}$ |
| Chlorothalonil A-E | - | - | 2.4 | 23.3 | 3408 |
| Chlorothalonil A,C,E | Tebuconazole B,D | - | 2.4 | 5.5 | 3725 |
| Chlorothalonil B,D,E | Bixafen + flutriafol A,C | - | 1.5 | 7.2 | 3399 |
| Chlorothalonil A,C,E | Bixafen + flutriafol B,D | - | 1.6 | 7.2 | 4420 |
| Chlorothalonil A | Bixafen + flutriafol B,D | Tebuconazole C,E | 1.8 | 4.6 | 3948 |
| Chlorothalonil A | Tebuconazole C,E | Pyraclostrobin B,D | 2.7 | 8.8 | 3879 |
| - | - | - | 5.5 | 30.8 | 2343 |
| LSD (0.05) | | | 0.7 | 8.0 | 889 |

[a] Spray schedule: A, 50 days after planting (DAP); B, 69 DAP; C, 86 DAP; D, 104 DAP; E, 122 DAP.
[b] Fungicide rates: Chlorothalonil, 1.26 kg ai/ha; bixafen, 0.142 kg ai/ha + flutriafol, 0.243 kg ai/ha; tebuconazole, 0.227 kg ai/ha.
[c] Leaf spot assessed using the Florida leaf spot index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead.

***3.2.2.2 Test 2.*** Under heavy disease pressure (30.8%), all tebuconazole and bixafen plus flutriafol treatments

resulted in a 71 to 85% reduction in disease incidence over the untreated check (Table 5). The chlorothalonil only treatments resulted in disease incidence not different from the untreated check. The addition of tebuconazole to bixafen plus flutriafol applied 69 (B) and 104 (D) DAP did numerically lessen southern blight severity.

***3.2.3 2020.***

***3.2.3.1*** Under moderate pressure (14.4%), all fungicide treatments (including chlorothalonil) resulted in less disease development than the untreated check (Table 6). However, azoxystrobin plus benzovindiflupyr applied 65 (B) and 100 (D) DAP and bixafen plus flutriafol applied 48 (A) plus 82 (C) DAP or 65 (B) plus 100 (D) DAP plus azoxystrobin resulted in less disease than bixafen plus flutriafol alone applied 65 and 100 DAP.

The lack of differences between fungicides that have soil borne disease activity and chlorothalonil which has no soil borne disease activity may be attributed to control of early leaf spot and the disease cycle of the fungus. Conditions that favor growth of the southern blight fungus include high moisture, warm to hot temperatures, and the presence of dead plant litter on the soil surface [39]. Leaf litter arising from leafspot infections, natural leaf aging, and weed or old crop residues stimulate germination of sclerotia and serve as a food source for the fungus. In all instances, chlorothalonil provided a 54 to 69% reduction in leaf spot incidence compared with the untreated check. Also, the use of chlorothalonil delayed disease development. Therefore, the lack of a food source for the *Scleotium rolfsii* limited its development during the growing season.

**Table 6. Bixafen plus flutriafol combinations for leafspot and southern blight control in peanut in 2020.**

| Fungicides and application timings[a,b,c] | | | Early leafspot | Southern blight | |
|---|---|---|---|---|---|
| | | | Florida scale[d] | Infection | Yield |
| | | | 1-10 | % | Kg $ha^{-1}$ |
| Chlorothalonil (A-E) | - | - | 1.8 | 9.3 | 2383 |
| Chlorothalonil (A,C,E) | Azoxystrobin + benzovindiflupyr (B,D) | - | 1.8 | 2.9 | 3504 |
| Chlorothalonil (B,D,E) | Bixafen + flutriafol (A,C) | - | 2.3 | 3.6 | 2742 |
| Chlorothalonil (A,C,E) | Bixafen + flutriafol (B,D) | - | 2.0 | 6.5 | - |
| Chlorothalonil (A,E) | Bixafen + flutriafol (B,D | Tebuconazole (C ) | 1.7 | 4.9 | 2470 |
| Chlorothalonil (B,E) | Bixafen + flutriafol (A,C) | Tebuconazole (D) | 1.8 | 3.2 | 2911 |
| Chlorothalonil (A,E) | Bixafen + flutriafol (B,D) | Pyraclostrobin (C) | 1.7 | 7.2 | 2871 |
| Chlorothalonil (B,E) | Bixafen + flutriafol (A,C) | Pyraclostrobin (D) | 2.0 | 3.8 | - |
| Chlorothalonil (A,E) | Bixafen + flutriafol (B,D) | Azoxystrobin (C) | 1.6 | 2.7 | 2679 |
| Chlorothalonil (D,E) | Bixafen + flutriafol (A,C) | Azoxystrobin (B) | 2.0 | 2.9 | - |
| - | - | - | 5.7 | 14.4 | 2626 |
| LSD (0.05) | | | 0.5 | 3.6 | 279 |

[a] Spray schedule: A, 48 days after planting (DAP); B, 65 DAP; C, 82 DAP; D, 100 DAP; E, 118 DAP.
[b] Fungicide rates: Chlorothalonil, 1.26 kg ai $ha^{-1}$; bixafen, 0.142 kg ai $ha^{-1}$ + flutriafol, 0.243 kg ai $ha^{-1}$; tebuconazole, 0.227 kg ai $ha^{-1}$; azoxystrobin, 0.019 kg ai $ha^{-1}$ + benzovindiflupyr, 0.001 kg ai $ha^{-1}$; azoxystrobin, 0.34 kg ai $ha^{-1}$.
[c] Induce at 0.25% v/v added to the Elatus treatment.
[d] Leaf spot assessed using the Florida leaf spot index where 1 = no leaf spot and 0% defoliation; 2 = very few lesions and none on the upper canopy with 0% defoliation; 3 = few lesions and very few on the upper canopy with 0% defoliation; 4 = some lesions with more on upper canopy and 5% defoliation; 5 = lesions noticeable even on upper canopy and 20% defoliation; 6 = lesions numerous and very evident on upper canopy with 50% defoliation; 7 = lesions numerous on upper canopy with 75% defoliation; 8 = upper canopy covered with lesions with 90% defoliation; 9 = very few leaves remaining and those covered with lesions, some plants completely defoliated; and 10 = plants completely defoliated or dead.

### *3.3 Peanut yield.*

***3.3.1 2018.***

***3.3.1.1 Test 1.*** Chlorothalonil applied 48 (A) and 120 (E) DAP plus bixafen plus flutriafol applied 68 (B) and 101 (D) DAP or chlorothalonil applied A, 83 (C) DAP, and E plus bixafen plus flutriafol applied either B, D, and E or A, C, and E resulted in peanut yield that was not different from the untreated check (Table 2). The chlorothalonil only treatment produced the highest yield. Light southern blight disease pressure helped to account for a lack of greater difference in yield between fungicide treatments and the untreated.

***3.3.1.2 Test 2.*** All fungicide treatments resulted in 66 to 95% yield increases over the untreated check (Table 3). A fairly high level of leaf spot occurance coupled with southern blight disease development which was 56% greater in this study than in Test 1 helped account for the yield differences noted between fungicide treatments and the untreated check. Shokes and Culbreath [40] reported on studies in Alabama which showed that early and late leaf spot can reduce yield by as much as 50%.

***3.3.2 2019.***

***3.3.2.1 Test 1.*** Peanut yields with fungicides increased yields over the untreated check by 51 to 76% (Table 4). No yield differences were noted between any fungicide treatments.

***3.3.2.2 Test 2.*** All fungicide treatments increased yield over the untreated check (Table 5). The combination treatment of chlorothalonil applied 50 (A), 86 (C), and 122 (E) DAP and bixafen plus flutriafol applied 69 (B) and 104 (D) DAP produced the highest yield while chlorothalonil alone and the combination treatment of chlorothalonil applied B, D, and E and bixafen plus flutriafol applied A and C resulted in 23% less yield.

***3.3.3 2020.***

***3.3.3.1*** Plots from bixafen plus flutriafol applied 65 (B) and 100 (D) DAP and bixafen plus flutriafol applied 48 (A) and 82 (C) DAP plus either pyraclostrobin applied 100 (D) DAP or azoxystrobin applied B were not harvested for yield because of excessive deer (*Odocoileus virginianus*) damage after peanuts were dug which prevented an accurate assessment of yield (Table 6). Chlorothalonil applied A, C, and E plus azoxystrobin plus benzovindiflupyr applied B and D resulted in the highest yield and a 33% increase over the untreated check and was greater than all other fungicide treatments.

## 4. CONCLUSION

Fungicide spray programs comprised of multiple modes of action are recommended for resistance disease management [1,10,21,41-43]. The premix of bixafen plus flutriafol combines a SDHI fungicide with a DMI fungicide having systemic activity to help combat resistance issues. Also, sequential applications using azoxystrobin, azoxystrobin plus benzovindiflupyr, pyraclostrobin and/or tebuconazole provide great help in disease resistant management.

Data regarding the performance of bixafen plus flutriafol in a peanut fungicide program for disease control in the southwestern US has been lacking. These results provide a basis of comparison of bixafen plus flutriafol in various fungicide programs to chlorothalonil. Bixafen plus flutriafol represents a new broad-spectrum fungicide that producers can use in developing management strategies for foliar as well as soilborne peanut diseases. These studies show that when used in a fungicide spray program that bixafen plus flutriafol is highly effective against early leaf spot and southern blight thus making this premix an important tool for disease resistance management.

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