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Research Article

Peanut (*Arachis hypogaea*) Response to Fungicides and Herbicides Applied using Different Spray Nozzles

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Abstract

Late leaf spot [caused by *Nothopassalora personata* (Berk. & M.A. Curtis) U. Braun, C. Nakash, Videira & Crous] is an economically important disease in peanut (*Arachis hypogaea* L.) and fungicides are used routinely to protect peanut from infection and the resulting yield loss. Herbicides are an important component of effective weed management in peanut. Concern over particle drift of pesticides exists in the farming community, especially after stewardship issues associated with synthetic auxin application in herbicide resistant crops in the United States. Spray nozzles that deliver larger droplets that are less prone to drift is a possible solution to this issue. However, fungicides may be less effective in penetrating the crop canopy and covering foliage for protection from pathogens with these nozzles compared with nozzles delivering smaller droplets. Research was conducted to compare suppression of late leaf spot disease when chlorothalonil, prothioconazole plus tebuconazole, azoxystrobin, pyraclostrobin, and chlorothalonil were applied sequentially every 14 days using hollow cone nozzles (fine droplet size), regular flat fan nozzles (medium droplet size), air induction flat fan nozzles (coarse droplet size), and turbo teejet induction nozzles (ultra-coarse droplet size). Regular flat fan and hollow cone nozzles were slightly more effective in delivering fungicides based on canopy defoliation at harvest compared with turbo teejet induction nozzles and in some cases air induction nozzles. However, suppression of pathogens by fungicides applied using all four nozzle types prevented canopy defoliation adequately to protect peanut from yield loss. In a separate experiment, peanut yield and control of common ragweed (*Ambrosia artemisiifolia* L.) and late leaf spot did not differ at harvest when herbicides and fungicides were applied with air induction or turbo teejet induction nozzles throughout the cropping cycle. These results indicate that farmers can apply fungicides and herbicides to peanut using nozzles that limit potential for particle drift with minimal concern over reduced pesticide efficacy and protection of yield from pests.

Introduction

Late leaf spot [caused by *Nothopassalora personata* (Berk. & M.A. Curtis) U. Braun, C. Nakash, Videira & Crous] and southern stem rot (caused by *Athelia rolfsii* Sacc.) are important diseases that can reduce yield of peanut *(Arachis hypogaea* L.*)* in North Carolina [1,2]. Fungicides are routinely applied beginning at the R-3 stage of peanut development [3] and continuing on a 14-day schedule through September to protect peanut from these diseases [2]. Adequate weed control is also important in optimizing peanut yield in many fields, and herbicides often the most effective management tool for weed control [1].

Uniform distribution of fungicide in the peanut canopy is needed to ensure protection from disease. Growers often apply fungicides using spray nozzles that deliver small droplets that can penetrate the canopy and provide greater coverage of leaves Zhu et al. [4] reported that a solution of water and fluorescent dye penetrated the peanut canopy less when applied with flat fan nozzles compared with hollow cone, air induction, or twin jet nozzles. Using a similar approach, Buosi et al. [5] reported greater spray solution deposition throughout the peanut canopy with nozzles designed to deliver small droplets compared with nozzles delivering larger droplets. Kucharek et al. [6] reported that efficacy of fungicides was similar when applied using flat fan and hollow cone nozzles for leaf spot disease in peanut. More recently, Virk et al. [7] reported similar pest control (e.g., diseases, insects, and weeds) when pesticides were applied using non-air induction and air induction nozzles delivering a range of droplet sizes. While deposition in the canopy was lower when larger droplets were delivered, leaf spot control with fungicides was not compromised.

Particle drift associated with synthetic auxin herbicides used in cotton (*Gossypium hirsutum* L.) and soybean [*Glycine max* (L.) Merr.] is a major stewardship challenge for farmers in the United States [8-10]. To minimize particle drift to susceptible plants, including those registered as endangered, synthetic auxin herbicides are applied using spray nozzles that deliver large droplets that are less prone to drift [11,12]. Nozzle selection is not currently dictated for fungicides and herbicides used in peanut in a manner similar to synthetic auxin herbicides in cotton and soybean. However, determining if control of leaf spot and weeds is compromised when fungicides and herbicides are applied with nozzles that deliver larger droplets that are less prone to drift but may not penetrate the peanut canopy as effectively, could help farmers develop strategies that increase pesticide stewardship. Therefore, research was conducted to determine the effect of applying fungicides using four nozzles delivering a broad distribution droplet size on canopy defoliation caused by leaf spot disease and peanut yield. Research was also conducted to determine if common ragweed control and protection of peanut from late leaf spot disease differed when pesticides were applied with air induction nozzles and turbo teejet induction nozzles throughout the cropping cycle.

Materials and Methods

Late Leaf Spot Control with Fungicides Applied with Different Nozzles

Two different experiments were conducted in North Carolina from 2017-2019 at the Peanut Belt Research Station near Lewiston-Woodville, at the Upper Coastal Plain Research Station near Rocky Mount, and at the Border Belt Research Station near Whiteville on sandy loam and loamy sand soils typical for peanut production in the North Carolina coastal plain. The cultivar Bailey [13] was planted in conventionally-prepared, raised seedbeds in rows spaced 91 cm apart. Plot size was four rows wide by 9 m long. In the experiment with four different nozzles, only the two center rows received the fungicides. In the experiment with only two nozzles, all four rows were treated with fungicide. With the exception of fungicides applied for late leaf spot control, all other production and pest management practices were the same across the entire experiment [14].

At two locations in 2017 (Lewiston-Woodville and Whiteville) and one location in 2019 (Lewiston-Woodville), chlorothalonil, prothioconazole plus tebuconazole, azoxystrobin, pyraclostrobin, and chlorothalonil were applied sequentially every 14 days beginning at the R-3 stage of peanut development [3] using:

a) air induction nozzles (Teejet AIXR 11002, Spraying Systems Co., Wheaton, IL) delivering coarse droplets
b) turbo teejet induction nozzles (Teejet TTI 02, Spraying Systems Co., Wheaton, IL) delivering ultra coarse droplets.

In the second experiment conducted in 2017 (Lewiston-Woodville, two separate fields at Rocky Mount, and Whiteville), the same fungicide regime was applied. The following two additional nozzles were included:

a) regular flat fan nozzles (Teejet FF 11002, Spraying Systems Co., Wheaton, IL) delivering medium droplets
b) hollow cone nozzles (TXVK-12 ConeJet, Spraying Systems Co., Wheaton, IL) delivering fine droplets.

Fungicides were delivered using a CO_2-pressurized backpack sprayer calibrated to deliver 145 L/ha at pressures ranging from 265 to 280 kPa at a ground speed of 5 km/h.

A third experiment was conducted at Lewiston-Woodville (2020 and 2021) and Rocky Mount (2021) to compare common ragweed control, peanut canopy defoliation caused by late leaf spot, and peanut yield when herbicides and fungicides were applied with air induction or turbo teejet nozzles throughout the cropping cycle. *S*-metolachlor (1.1 kg ai/ha) was applied immediately after planting followed by paraquat (0.14 kg ai/ha) plus bentazon (0.56 kg ai/ha) applied 3 weeks after planting, and clethodim (0.28 kg ai/ha) and lactofen (0.22 kg ai/ha) applied sequentially 5 to 6 weeks after planting. The fungicide regime included chlorothalonil at 1.4 kg/ha (6 weeks after planting) followed by pydiflumetofen (44 g ai/ha) plus the commercial mixture of azoxystrobin plus benzovindiflupyr (0.30 kg ai/ha) (8 weeks after planting) followed by prothioconazole plus tebuconazole at 0.49 kg ai/ha (12 weeks after planting) followed by chlorothalonil at 1.4 kg/ha (14 weeks after planting).

Data Collected and Statistical Analyses

In all experiments, percent canopy defoliation caused by late leaf spot was recorded on a scale of 0 to 100% where 0 = no defoliation and 100 = complete defoliation within one week prior to digging pods and inverting vines. In the experiment where herbicides and fungicides were applied with air induction and turbo teejet nozzles, the number of common ragweed plants per plot was recorded within one week prior to digging pods and inverting vines. Peanut pods were dug and vines inverted at optimum maturity based on pod mesocarp color [15]. Pod yield was adjusted to 8% moisture. The experimental design was a randomized complete block with treatments replicated four times. Data for number of common ragweed plants, canopy defoliation caused by late leaf spot, and pod yield were subjected to analysis of variance using the GLIMMIX procedure in SAS (SAS Institute, Cary, NC). Site-year combinations and replications were considered random effects. Nozzle selection was considered a fixed effect. Means were separated using Fishers Protected LSD test at $\alpha = 0.05$ pooled over site-year combinations.

Results and Discussion

In the experiment with air induction and turbo teejet induction nozzles, applying fungicides with either nozzle type over the cropping cycle resulted in canopy defoliation that was 3-4% (Table 1). Canopy defoliation for non-treated peanut was 66%. Peanut yield was also similar regardless of nozzle selection. Applying fungicides using either nozzle type resulted in peanut yields exceeding yield of non-treated peanut.

Table 1: Peanut canopy defoliation within one week prior to digging pods and inverting vines and peanut yield when fungicides were applied with spray nozzles delivering droplets at various sizes.[a,b]

Spray nozzle	Peanut defoliation	Peanut pod yield
	%	kg/ha
No fungicide	66 a	4,920 b
Turbo TeeJet Induction	4 b	5,630 a
Air Induction	3 b	5,790 a

[a]Fungicide program consisted of sequential applications of chlorothalonil, prothioconazole plus tebuconazole, azoxystrobin, pyraclostrobin, and chlorothalonil applied at 1.4, 0.49, 0.32, 0.11, and 1.4 kg/ha, respectively, on 14-day intervals.
[b]Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over two locations in 2017 and one location in 2019.

In the experiment where four different nozzles were compared, canopy defoliation was similar when fungicides were applied with turbo teejet induction, air induction, and regular flan fan nozzles (Table 2). Canopy defoliation was lower when fungicides were applied using hollow cone nozzles compared with air induction and turbo teejet Induction nozzles; similar defoliation was observed when fungicides were applied with regular flat fan and hollow cone nozzles. There was no difference in yield regardless of spray nozzles used to deliver fungicides.

Table 2: Influence of four different nozzles delivering various droplet sizes of fungicide spray solution on peanut canopy defoliation within one week prior to digging pods and inverting vines and peanut yield.[a,b]

Spray nozzle	Peanut defoliation	Peanut pod yield
	%	kg/ha
No fungicide	80 a	3,290 b
Turbo TeeJet Induction	58 b	4,670 a
Air Induction	61 b	4,800 a
Regular Flat Fan	54 bc	4,840 a
Hollow Cone	47 c	4,890 a

[a]Fungicide program consisted of sequential applications of chlorothalonil, prothioconazole plus tebuconazole, azoxystrobin, pyraclostrobin, and chlorothalonil applied at 1.4, 0.49, 0.32, 0.11, and 1.4 kg/ha, respectively, on 14-day intervals.
[b]Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over four locations in 2017.

Peanut defoliation was relatively high (47 to 58%) in 2017 with fungicides when nozzles were compared. The high level of defoliation most likely was caused by inoculum from border rows moving into the plots. In this experiment, only two rows out of four were treated with fungicide. Presence of evolved resistance to the quinone outside inhibiting (QOL) fungicides at these locations also contributed to high levels of defoliation [1,2,16]. Azoxystrobin and pyraclostrobin are expected to be essentially ineffective in protecting peanut from epidemics of late leaf spot at this location. These fungicides were applied sequentially for sprays 3 and 4 at a time when the pathogen causing late leaf spot was active. These results demonstrate that even under high incidence of disease, the four nozzles used in this research delivered adequate and most likely similar levels of fungicide in the peanut canopy.

In the experiment where herbicides and fungicides were applied with air induction or turbo teejet induction nozzles throughout the cropping cycle, the number of common ragweed plants, canopy defoliation caused by late leaf spot disease, and pod yield did not differ based on nozzle selection (Table 3). These results are similar to those reported by

Virk et al. [7] indicating that control of weeds and disease was similar when pesticides were delivered with air induction or turbo teejet Induction nozzles.

Table 3: Common ragweed population and peanut canopy defoliation caused by late leaf spot disease within one week prior to digging pods and inverting vines and peanut yield when herbicides and fungicides were applied with spray nozzles delivering droplets at various sizes over the cropping cycle.[a,b]

Spray nozzle	Common ragweed density	Peanut defoliation	Peanut pod yield
	No./plot	%	kg/ha
Turbo TeeJet Induction	0a	3a	4,960 a
Air Induction	1a	1a	4,990 a

[a]S-metolachlor (1.1 kg/ha) was applied immediately after planting followed by paraquat (0.14 kg/ha) plus bentazon (0.56 kg/ha) applied 3 weeks after planting, and clethodim (0.28 kg/ha) and lactofen (0.22 kg/ha) applied sequentially 5 to 6 weeks after planting. The fungicide regime included chlorothalonil at 1.4 kg/ha (6 weeks after planting) followed by pydiflumetofen (44 g/ha) plus the commercial mixture of azoxystrobin plus benzovindiflupyr (0.30 kg/ha) (8 weeks after planting) followed by prothioconazole plus tebuconazole at 0.49 kg ai/ha (12 weeks after planting) followed by chlorothalonil at 1.4 kg/ha (14 weeks after planting).

[b]Means within a column followed by the same letter are not significantly different based on Fishers Protected LSD test at $\alpha = 0.05$. Data are pooled over three site-year combinations in 2020 and 2021.

Conclusion

Results from these experiments indicate that fungicide efficacy is only marginally affected when applied with nozzles that deliver large droplets compared with those delivering smaller droplets. While minor differences in canopy defoliation were noted when comparing hollow cone, regular flat fan, air induction, and turbo teejet induction nozzles, these differences did not translate into differences in peanut yield. With the exception of chlorothalonil, the fungicides used in these experiments are systemic fungicides that are absorbed into leaves to protect against pathogens. This phenomenon would make coverage of foliage less critical for these fungicides (e.g., azoxystrobin, prothioconazole plus tebuconazole, and pyraclostrobin) while coverage is more important for contact fungicides that are not readily absorbed and forms a layer of protection from pathogens on the leaf surface (e.g., chlorothalonil). Virk et al. [7] reported that disease control, including late leaf spot, did not differ when fungicides were applied with range of nozzles similar to the range used in our experiment. Similar to our findings, weed control with herbicides was not affected by nozzle selection over the cropping cycle.

Collectively, these data suggest that fungicides can be applied using a range of nozzles without sacrificing efficacy. However, with the exception of chlorothalonil, fungicides used in the present study were systemic, and nozzle selection most likely less critical. A more detailed study with herbicides and fungicides representing all modes of action and/or systemic movement with the nozzles used in our study would be informative, especially in North Carolina to corroborate or refute the findings of Virk et al. [7]. Depending on constraints growers may have in their communities, application using nozzles that deliver large droplets is an effective practice to avoid particle drift.

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