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Research Article

Peanut Response to Injury Caused by Tobacco Thrips and Pesticide Combinations

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Abstract

Thrips (*Frankliniella* spp.) can reduce peanut (*Arachis hypogaea* L.) yield by injuring peanut tissue and by vectoring tomato spotted wilt orthotospovirus (family Tospoviridae, genus Orthotospovirus). Pathogens early in the cropping cycle can cause disease, and weeds that escape herbicide applications prior to or at planting can interfere with crop yield if not controlled. To suppress these pests, farmers often apply pesticides either individually or as tank mixtures. For logistical reasons when pests are present at the same time, farmers would prefer to apply pesticides simultaneously. Three different experiments were conducted from 2012-2017 in North Carolina to determine peanut response to herbicides as a result of injury caused by tobacco thrips (*Frankliniella fusca* Hinds) or the implications of co-applying herbicides with insecticide or fungicide to suppress this insect pest and protect peanut from disease. In one experiment, stunting of peanut caused by a combination of injury from paraquat plus bentazon alone or with *S*-metolachlor and feeding by tobacco thrips was not affected by co-application with the fungicide prothioconazole. In a second experiment, stunting of peanut by co-application of the herbicides lactofen plus bentazon plus 2,4-DB or lactofen plus imazapic plus 2,4-DB alone and with *S*-metolachlor was not affected by thrips injury in presence of the insecticide phorate applied in the seed furrow at planting or when these herbicides were co-applied with acephate. In a third experiment, peanut stunting after co-application of acetochlor or pyroxasulfone was not affected when phorate was applied in the seed furrow at planting or when these herbicides were co-applied with acephate. Peanut yield was not affected by injury caused by herbicides applied alone or with acephate. However, in most cases peanut yield was greater when phorate was applied in the seed furrow at planting as a result of thrips suppression by this insecticide regardless of herbicide or acephate treatment following peanut emergence. Acephate did not affect yield regardless of co-applied pesticide or phorate treatment at planting.

Introduction

Tobacco thrips (*Frankliniella fusca* Hinds) feeding early in the cropping cycle can reduce peanut (*Arachis hypogaea* L.) yield if not controlled in North Carolina [1-3]. This insect pest also vectors tomato spotted wilt orthotospovirus (family Tospoviridae, genus Orthotospovirus) [1,4-6]. Systemic insecticides including aldicarb, imidacloprid, oxamyl, and phorate can be applied in the seed furrow at planting to suppress tobacco thrips [1]. When injury from thrips is visible on emerged plants, farmers often apply acephate to further suppress this insect and prevent yield loss [1].

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 economically important diseases of peanut in North Carolina [7,8]. While farmers often apply fungicides on a 14-day schedule beginning at the R-3 stage of peanut development [9], research [10] indicates that in some fields application of prothioconazole earlier in the cropping cycle can increase disease suppression.

Interference from weeds early in the cropping cycle can reduce peanut yield [11,12], and farmers often apply herbicides prior to planting, to the soil surface immediately after planting, and after peanut and weeds have emerged [13]. Co-application of paraquat plus bentazon is recommended within 3 weeks after peanut and weed emergence to control weeds that have escaped application of herbicides at planting [13]. Herbicides with residual activity in soil are often co-applied with these contact herbicides to extend weed control further into the cropping cycle [13]. Imazapic and lactofen are also herbicides that can be applied after peanut and weeds have emerged [13].

Timing of application of herbicides to control emerged weeds, the insecticide acephate for suppression of tobacco thrips, and use of prothioconazole to proactively protect peanut from late leaf spot often coincide [13]. Farmers prefer to co-apply these pesticides if pest control is not compromised or peanut injury does not increase. The compatibility of contact herbicides co-applied with acephate and prothioconazole has not been defined in the peer-reviewed literature. Additionally, peanut response to herbicides applied alone or with acephate has not been defined for some of the herbicides used in peanut, most notably when phorate is applied in the seed furrow at planting. Therefore, research was conducted to define interactions of pesticide combinations that influence both suppression of tobacco thrips, protection from pathogens that cause disease, and herbicides that can injure peanut.

Materials and Methods

Methods common to all experiments

The experiments were conducted in the field in North Carolina at the Peanut Belt Research Station located near Lewiston-Woodville, at the Upper Coastal Plain Research Station near Rocky Mount, and in Virginia at the Tidewater Agricultural Research and Extension Center near Suffolk. Soil at Lewiston-Woodville was a Norfolk sandy loam soil (fine-loamy, siliceous, thermic, Aquic Paleudult) with 0.8 to 1.2% organic matter and pH 5.9. Goldsboro loamy sand soil (fine loamy, mixed, semiactive, thermic, Typic Hapludult) with 1.4% organic matter and pH 6.1 was at Rocky Mount. Soil at Suffolk was a Suffolk loamy sand (Fine-loamy, siliceous, semiactive, thermic Typic Hapludults). Experiments were conducted in conventionally-prepared, raised seedbeds. Plot size was 2 or 4 rows spaced 96-cm apart by 9 m. Peanut cultivar Bailey [14] was planted at a depth of 4 to 5 cm at all locations at a rate designed to achieve final in-row populations of 4 plants/m. Production, irrigation, and pest management practices other than specific treatments were standard for peanut production in the region [13].

All experimental areas were kept weed-free by combining hand removal with herbicides applied preplant incorporated and preemergence. Pendimethalin at 1.13 kg ai/ha was applied preplant incorporated. *S*-metolachlor and flumioxazin were applied at 1.3 and 0.07 kg ai/ha, respectively. Clethodim at 130 g ai/ha and 2,4-DB at 0.28 kg ai/ha were applied to control escaped weeds late in the season. Visual estimates of peanut stunting were determined 2 weeks after pesticide combinations were applied using a scale of 0 to 100 where 0 = no stunting and 100 = plant death. Peanut pods were dug and vines inverted based on pod mesocarp color for peanut in the experiment not extensively damaged by thrips feeding or herbicides to obtain optimum yield [15]. Pod yield was determined 4 to 7 d after digging with final yield adjusted to 8% moisture content.

Experiment 1. Interactions of Insecticides, Herbicides, and Prothioconazole

The experiment was conducted at Lewiston-Woodville and Rocky Mount during 2012. Treatments consisted of a factorial arrangement of 2 levels of phorate (no phorate vs. phorate applied in the seed furrow at planting), 3 levels of herbicide (no herbicide, paraquat plus bentazon, and paraquat plus bentazon plus *S*-metolachlor), 2 levels of acephate (no acephate vs. acephate applied 10-14 days after peanut emergence), and 2 levels of fungicide (no fungicide and prothioconazole applied 10-14 days after peanut emergence). Paraquat, bentazon, and *S*-metolachlor were applied at 0.14, 0.28, and 1.0 kg/ha, respectively. Phorate was applied at 1.1 kg ai/ha while acephate was applied at 0.56 kg ai/ha. Prothioconazole was applied at 0.56 kg ai/ha. Nonionic surfactant at 0.125% (v/v) was applied with all treatments.

Experiment 2. Interactions of Insecticides with Herbicide Treatments Containing Imazapic and Lactofen

The experiment was conducted at Lewiston-Woodville and Rocky Mount during 2013. Treatments consisted of a factorial arrangement of 2 levels of phorate (no phorate vs. phorate applied in the seed furrow at planting), 3 levels of herbicide (no herbicide, lactofen plus bentazon plus 2,4-DB, and lactofen plus imazapic plus 2,4-DB), 2 levels of *S*-metolachlor (no *S*-metolachlor vs. *S*-metolachlor), and 2 levels of acephate (no acephate vs. acephate applied 10-14 days after peanut emergence). *S*-metolachlor and phorate were applied at the rates described previously. Bentazon, lactofen, imazapic, and 2,4-DB were applied at 1.1, 0.22, 0.07, and 0.28 kg ai/ha, respectively. Treatments were applied with nonionic surfactant at 0.25% (v/v).

Experiment 3. Interactions of Insecticides with Acetochlor and Pyroxasulfone

Field experiments were conducted at Lewiston-Woodville in 2015 and 2016 and Rocky Mount in 2017. The experiment was also conducted at Suffolk in 2017. Treatments consisted of a factorial arrangement of 2 levels of phorate (no phorate vs. phorate applied in the seed furrow at planting), 4 levels of herbicide (no herbicide, paraquat plus bentazon, paraquat plus bentazon plus acetochlor, and paraquat plus bentazon plus pyroxasulfone), and 2 levels of acephate (no acephate vs. acephate applied 10-14 days after peanut emergence). Acetochlor and pyroxasulfone were applied at 1.7 and 0.13 kg ai/ha, respectively.

Statistical Analyses

The experimental design was a randomized complete block with treatments replicated four times in all experiments. Data for peanut stunting 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. Levels of phorate, acephate, foliar-active herbicides with residual activity, and prothioconazole were considered a fixed effect. Means were separated using Tukey's HSD test at $\alpha = 0.05$ pooled over site-year combinations.

Results and Discussion

Experiment 1. Interactions of Insecticides, Herbicides, and Prothioconazole

Main effects of phorate, herbicide, acephate, and prothioconazole were significant for peanut stunting. Interactions of phorate × herbicide, herbicide × acephate, and herbicide × prothioconazole were also significant for peanut stunting. All other two-way and three-way interactions were not significant. Peanut yield was affected only by the main effect of phorate.

When pooled over acephate and prothioconazole treatments, peanut stunting was lowest when phorate was applied in absence of herbicide treatment (Table 1). This stunting was caused by minor levels of feeding by tobacco thrips earlier in the season. In absence of phorate and herbicide, 22% stunting was observed. Absence of systemic insecticide applied in the seed furrow at planting often results in significant stunting of peanut and yield loss [1-3]. When paraquat plus bentazon was applied alone or with *S*-metolachlor, stunting ranged from 31 to 37% regardless of phorate treatment.

Table 1: Peanut stunting caused by a combination of feeding by tobacco thrips based on phorate performance and herbicides applied after peanut emergence in Experiment 1.[a]

Phorate applied in the seed furrow at planting[b]	Herbicides applied 21 days after planting[c]	Peanut stunting %
No	No	22 c
Yes	No	7 d
No	Paraquat plus bentazon	35 a
Yes	Paraquat plus bentazon	36 a
No	Paraquat plus bentazon plus *S*-metolaochlor	31 a
Yes	Paraquat plus bentazon plus *S*-metolaochlor	37 a

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2012, acephate treatments, and prothioconazole treatments.

[b]Phorate applied at 1.1 kg/ha.

[c]Paraquat, bentazon, and *S*-metolachlor applied at 0.14, 0.28, and 1.0 kg/ha, respectively.

When pooled over phorate and prothioconazole treatments, no difference in peanut stunting was noted regardless of acephate treatment in absence of herbicide treatment (Table 2). Similarly, acephate did not affect peanut stunting when paraquat plus bentazon was applied. However, when paraquat plus bentazon plus *S*-metolachlor was applied, peanut stunting was lower when acephate was included in the tank mixture.

Table 2: Peanut stunting caused by a combination of feeding by tobacco thrips based on acephate performance and herbicides applied after peanut emergence in Experiment 1.[a]

Acephate applied 21 days after planting[b]	Herbicides applied 21 days after planting[c]	Peanut stunting %
No	No	14 c
Yes	No	14 c
No	Paraquat plus bentazon	36 a
Yes	Paraquat plus bentazon	34 ab
No	Paraquat plus bentazon plus *S*-metolaochlor	36 a
Yes	Paraquat plus bentazon plus *S*-metolaochlor	33 b

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2012, phorate treatments, and prothioconazole treatments.
[b]Acephate applied at 0.56 kg/ha.
[c]Paraquat, bentazon, and *S*-metolachlor applied at 0.14, 0.28, and 1.0 kg/ha, respectively.

When pooled over phorate and acephate treatments, co-applying prothioconazole with acephate did not affect peanut stunting in absence of herbicides (Table 3). However, peanut stunting was greater when prothioconazole was applied with acephate when paraquat plus bentazon was included in the mixture. Peanut stunting was similar when comparing prothioconazole treatments when paraquat plus bentazon plus *S*-metolachlor was applied.

Table 3: Peanut stunting following co-application of prothioconazole and herbicides applied after peanut emergence in Experiment 1.[a]

Prothioconazole applied 21 days after planting[b]	Herbicides applied 21 days after planting[c]	Peanut stunting %
No	No	14 d
Yes	No	14 d
No	Paraquat plus bentazon	33 c
Yes	Paraquat plus bentazon	38 a
No	Paraquat plus bentazon plus S-metolaochlor	32 bc
Yes	Paraquat plus bentazon plus S-metolaochlor	36 ab

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2012, acephate treatments, and phorate treatments.
[b]Prothioconazole applied at 0.56 kg/ha.
[c]Paraquat, bentazon, and *S*-metolachlor applied at 0.14, 0.28, and 1.0 kg/ha, respectively.

Peanut yield was affected only by the main effect of phorate, with peanut yield in absence of phorate being 7,990 kg/ha compared with a yield of 8,530 kg/ha when phorate was applied. The positive yield response to phorate most likely resulted from injury from tobacco thrips during the first 14 to 21 days after planting when this insect pest was not controlled by phorate. These results also suggest that even though higher levels of stunting were noted with other treatment factors, response did not affect peanut yield.

Experiment 2. Interactions of Insecticides with Herbicide Treatments Containing Imazapic and Lactofen

Main effects of phorate, foliar active herbicide, acephate, and *S*-metolachlor as well as interactions of herbicide × *S*-metolachlor and phorate × acephate were significant for peanut stunting. In this experiment, peanut yield was not affected by main effects of phorate, herbicide, acephate, and *S*-metolachlor or interactions of these treatment factors.

No difference in peanut stunting was observed when *S*-metolachlor was applied alone or with lactofen plus bentazon plus 2,4-DB (Table 4). However, greater stunting of peanut was noted when *S*-metolachlor was applied with imazapic plus lactofen plus 2,4-DB compared with imazapic plus lactofen plus 2,4-DB alone (32% vs. 24%).

Table 4: Peanut stunting following co-application of S-metolachlor and herbicides with foliar activity in Experiment 2.[a]

S-metolachlor applied 21 days after planting[b]	Herbicides applied 21 days after planting[c]	Peanut stunting %
No	No	21 d
Yes	No	19 d
No	Lactofen plus bentazon plus 2,4-DB	26 bc
Yes	Lactofen plus bentazon plus 2,4-DB	28 b
No	Lactofen plus imazapic plus 2,4-DB	24 c
Yes	Lactofen plus imazapic plus 2,4-DB	32 a

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2013, phorate treatments, and acephate treatments.
[b]*S*-metolachlor applied at 1.0 kg/ha.
[c]Lactofen, bentazon, imazapic, and 2,4-DB applied at 0.22, 1.1, 0.07, and 0.28 kg/ha, respectively.

When pooled over herbicide treatment factors, the greatest peanut stunting was occurred when phorate and acephate were not applied (Table 5). In absence of phorate, peanut treated with acephate were stunted 30%. Phorate and phorate followed by acephate decreased stunting to no more than 15%.

Table 5: Peanut stunting caused by a combination of feeding by tobacco thrips based on insecticide performance in Experiment 2.[a]

Phorate[b]	Acephate[c]	Peanut stunting %
No	No	40 a
Yes	No	16 c
No	Yes	30 b
Yes	Yes	15 c

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2013, *S*-metolachlor, and herbicides with foliar activity.
[b]Phorate applied at 1.1 kg/ha.
[c]Acephate applied at 0.56 kg/ha.

Even though differences in peanut stunting were noted when comparing herbicide and insecticide treatments, no differences in peanut yield were observed regardless of any of the treatment factors in this experiment. Although phorate increased peanut yield regardless of insecticide, yield response to systemic insecticides applied in the seed furrow at planting can be variable [1-3].

Experiment 3. Interactions of Insecticides with Acetochlor and Pyroxasulfone

Main effects of phorate and acephate and the interaction of phorate × acephate were significant for peanut stunting. The main effect of residual herbicide treatment was not significant for peanut stunting and the interaction of this treatment factor with phorate or acephate was also not significant. The main effect of phorate was significant for peanut yield; no other main effect or interactions were observed for peanut yield.

Peanut stunting did not differ when herbicides were not applied or when paraquat plus bentazon was applied alone or with acetochlor or pyroxasulfone, regardless of phorate or acephate treatment (data not shown). Peanut stunting was affected by the interaction of phorate × acephate (Table 6). As expected, the greatest stunting occurred when insecticide was not applied while the least amount of stunting was noted when both phorate and acephate were applied. Acephate applied after peanut emergence was less effective in preventing stunting than phorate applied in the seed furrow at planting. This was expected because acephate was not applied until approximately 3 weeks after planting while phorate protected peanut from thrips feeding during this period of time. Protection of peanut from thrips feeding during the first few weeks of the season translated into an increase in yield regardless of herbicide or acephate treatments. When pooled over other treatment factors, peanut yield was 4,600 kg/ha in absence of phorate and 5,020 kg/ha when phorate was applied (data not shown).

Table 6: Peanut stunting caused by a combination of feeding by tobacco thrips based on insecticide performance in Experiment 3.[a]

Phorate[b]	Acephate[c]	Peanut stunting %
No	No	39 a
Yes	No	17 c
No	Yes	24 b
Yes	Yes	12 d

[a]Means followed by the same letter are not significantly different based on Tukey's HSD at $\alpha = 0.05$. Data are pooled over two locations in 2015 and one location in both 2016 and 2017, *S*-metolachlor, and herbicides with foliar activity.

[b]Phorate applied at 1.1 kg/ha.
[c]Acephate applied at 0.56 kg/ha.

Conclusion

The objective of our study was to define interactions of pesticide combinations that influence both suppression of tobacco thrips, protection from pathogens that cause disease, and herbicides that can injure peanut. We found that some combinations of herbicides and insecticides or injury prior to application from tobacco thrips can interact with respect to stunting of peanut. However, stunting from co-application of pesticides or application of herbicides, acephate, and prothioconazole or applying these combinations after phorate was applied or when it was not applied did not result in differences in peanut yield. The only treatment factor that affected peanut yield was phorate, and the positive response to this insecticide was observed in 2 of the 3 experiments regardless of variation in peanut stunting caused by herbicide injury, protection of peanut from thrips injury with acephate, or prothioconazole applied alone or with herbicides or acephate. These results underscore the importance of protecting peanut from injury caused by tobacco thrips during the first few weeks of the cropping cycle. These results also indicate that many of the pesticides used in peanut after crop emergence will not adversely affect peanut yield even though early season stunting of peanut can occur. These results also demonstrate that while acephate will reduce stunting caused by tobacco thrips, a positive response may not occur.

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