Peanut Cultivar Response to Damage from Tobacco Thrips and Paraquat

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ABSTRACT

Virginia market-type peanut cultivars in North Carolina vary in the number of days following emergence required to reach optimum maturity, and concern over cultivar response to interactions of tobacco thrips (*Frankliniella fusca* Hinds) damage in absence of in-furrow insecticide and injury from paraquat exist with respect to cultivar selection. Experiments were conducted during 2007 and 2008 to determine if cultivars vary in response to interactions of the insecticide aldicarb (no aldicarb or aldicarb applied in the seed furrow at planting) and the herbicide paraquat (no paraquat or paraquat applied 24 to 28 d after peanut emergence, DAE). The cultivar VA 98R expressed more damage from tobacco thrips than the cultivars Gregory, Perry, or Phillips. Although vegetative growth parameters varied among cultivar, aldicarb, and paraquat treatments, pod yield and market grade characteristics were not affected by the interaction of experiment, cultivar, aldicarb, and paraquat or the interaction of cultivar, aldicarb, and paraquat. Damage from tobacco thrips in absence of aldicarb affected pod yield more than injury from paraquat. The combination of tobacco thrips damage in absence of aldicarb and injury from paraquat lowered pod yield compared with aldicarb-treated peanut either with or without paraquat regardless of cultivar. These data suggest that recommendations on use of aldicarb for tobacco thrips control or paraquat for early season weed control should not vary based on cultivar selection when considering pod yield and market grade characteristics.

Virginia market-type peanut grown in North Carolina and Virginia can vary by as much as 15 d from emergence to optimum maturity and require a minimum of 2500 growing degree days (13°C base and 35°C ceiling) to reach maturity (Jordan, 2009a). While peanut grown in the lower southeastern United States has additional time during the growing season to reach optimum maturity compared with North Carolina and Virginia, the production window in North Carolina is limited to early May through early October (Carley et al., 2008; Mozingo et al., 1991). In some years, peanut pods do not reach optimum maturity due to limited heat unit accumulation and combinations of biotic and abiotic stress even when planted timely (Carley et al., 2009; Mozingo et al., 1991; Sholar et al., 1995). Determining interactions of cultivar selection and plant stress can be important in formulating pest management strategies for peanut.

Damage from feeding by tobacco thrips can limit early season peanut growth and reduce yield in North Carolina (Brandenburg et al., 1998; Carley et al., 2009; Herbert et al., 2007). Several insecticides are registered for use in peanut to control tobacco thrips and minimize early-season damage (Brandenburg, 2009; Johnson et al., 1993). Aldicarb {*O*-[(methylamino) carbonyl]oxime} is the most popular insecticide applied in-furrow in North Carolina to control tobacco thrips (Rhodes et al., 2008). Paraquat (1,1′-dimethyl-4,4′-bipyridinium ion) can be applied within 28 DAE to control small annual broadleaf weeds and grasses (Senseman, 2007; Wilcut et al., 1995). Application later than 28 d after emergence is discouraged due to the potential for crop injury with less time for plant recovery (Johnson et al., 1993).

Concern about effects of tobacco thrips damage combined with injury from paraquat has been expressed, and determining interactions among these variables is important when formulating appropriate management strategies for weeds present early in the season and protection from tobacco thrips damage in peanut. Blenk et al. (1991) reported that thrips-induced injury reduced pod yield of the Virginia market-type cultivar NC 7, while paraquat did not affect yield and there was no cumulative effect of damage from tobacco thrips feeding and injury from paraquat. Herbert et al. (1991) suggested that the combined impact of tobacco thrips damage and herbicide injury could delay development of NC 7 sufficiently to reduce yield in Virginia and northeastern North Carolina. Brecke et al. (1996) and Funderburk et al. (1998) reported that cumulative increases in stress from thrips damage, herbicide injury, or soil moisture conditions that limit recovery from early-season stress resulted in delayed pod development and reduced yield of the runner market-types Florunner and Southern Runner. More recently, Carley et al. (2009) reported that interactions between aldicarb and paraquat treatment were noted for the

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Abbreviations: DAE, days after peanut emergence; ELK, extra large kernels; FP, farmer stock fancy pods; MP, mature pods; SMK, sound mature kernels; SS, sound splits; TSMK, total sound mature kernels.

Virginia market-types NC-V 11 and VA 98R. However, these cultivars were not compared in the same experiment. Additional research is needed to determine if cultivar response to tobacco thrips damage is influenced by interactions of aldicarb and paraquat when cultivars express a wide range of days required to reach optimum pod maturity after emergence. Therefore, research was conducted to determine if vegetative and reproductive growth and market grade characteristics of peanut varied when Gregory, Perry, Phillips, and VA 98R were planted in the same experiment and were damaged by tobacco thrips feeding and injured from paraquat.

MATERIALS AND METHODS

The experiment was conducted in North Carolina during 2007 and 2008 at the Peanut Belt Research Station located near Lewiston-Woodville on a Norfolk loamy sand soil (fine-loamy, siliceous, thermic, Typic Paleudults) and at the Upper Coastal Plain Research Station near Rocky Mount on a Goldsboro sandy loam (fine-loamy, siliceous, thermic Aquic Paleudalts). Peanut was seeded in conventionally-prepared raised seedbeds at a rate needed to establish in-row plant density of 13 plants m^{-1} on 3 May 2007 and 2 May 2008 at Lewiston-Woodville and 14 May 2007 and 18 May 2008 at Rocky Mount. Plot size was two rows spaced 91 cm apart by 12 m. Seeds were placed 5 to 8 cm deep depending on soil moisture. Peanut was irrigated occasionally at a rate of 1.5 cm with sprinkle irrigation. Fields at Lewiston-Woodville during both years were fumigated with metam sodium at 18 L ha^{-1} at planting to control Cylindrocladium black rot (caused by *Cylindrocladium crotalaria* Bell and Sobers) (CBR) and suppress plant parasitic nematodes. Metam sodium was injected during the subsoiling and bedding process 30 cm below seed placement 2 wk before planting. Fields at Rocky Mount did not have a history of CBR or nematodes and were not fumigated. All other production and pest management practices were held constant across the experiment and were based on Cooperative Extension Service recommendations (Brandenburg, 2009; Jordan, 2009a, 2009b; Shew, 2009).

Treatments consisted of four levels of cultivar, two levels of aldicarb, and two levels of paraquat. Cultivars included Gregory (Isleib et al., 1999), Perry (Isleib et al., 2003), Phillips (Isleib et al., 2006), and VA 98R (Mozingo et al., 2000). Aldicarb treatments included no aldicarb or granular aldicarb (Temik 15G insecticide, Bayer CropScience, Research Triangle Park, NC) at 1.1 kg a.i. ha^{-1} applied in the seed furrow before seed drop. Paraquat treatments included no paraquat or paraquat (Gramoxone INTEON, Syngenta Crop Protection, Greensboro, NC) at 0.14 kg a.i. ha^{-1} applied 24 to 28 DAE. Paraquat was applied with nonionic surfactant at 0.125% (v/v) (Induce nonionic surfactant, Helena Chemical Co., Memphis, TN) using a CO$_2$–pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} using regular flat fan nozzles (Spraying Systems Co., Wheaton, IL). Entire test areas were maintained weed free by applying pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] (Prowl herbicide, BASF Corp., Research Triangle Park, NC) at 1.1 kg a.i. ha^{-1} preplant incorporated and *S*-metolachlor [*S*-2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] (Dual Magnum herbicide, Syngenta Crop Protection, Greensboro, NC) at 1.1 kg a.i. ha^{-1} preemergence. Acifluorfen [5-(2-chloro-*α*,*α*,*α*-trifluoro-*P*-tolyloxy)-2-nitrobenzoic acid] at 0.38 kg a.i. ha^{-1} plus bentazon [3-(1-methylethyl)-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one-2,2-dioxide] at 1.1 kg a.i. ha^{-1} plus 2,4-DB [4-(2,4-dichlorophenoxy)butyric acid] at 0.28 kg a.i. ha^{-1} plus nonionic surfactant (Induce nonionic surfactant, Helena Chemical Co., Memphis, TN) at 0.25% (v/v) followed by clethodim {(*E*)-(+)-2-[1-[[(3-chloro-2-propenyl)oxy]imino] propyl-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} (Select 2EC herbicide, Valent USA Corp., Walnut Creek, CA) at 0.14 kg a.i. ha^{-1} plus crop oil concentrate (Agri-Dex crop oil concentrate, Helena Chemical Co., Memphis, TN) at 1.0% (v/v) were applied approximately 6 wk after peanut emergence to control escaped broadleaf and grass weeds.

Damage from tobacco thrips feeding was recorded approximately 3 wk after peanut emergence and before paraquat application using a scale of 0 to 5, where 0 = no damage, 1 = noticeable feeding but no stunting, 2 = noticeable feeding and 25% stunting, 3 = feeding with blackened terminals and 50% stunting, 4 = severe feeding and 75% stunting, 5 = severe feeding and 90% stunting. Peanut stunting was recorded 45 and 75 DAE using a scale of 0 to 100%, where 0 = no stunting and 100 = plant death. Width of peanut rows was recorded 75 DAE as the average width of five plants per plot. The number of days from peanut emergence to row closure was also recorded. Percentages of pods with brown and black pod mesocarp color were recorded in mid September by removing a total of 100 pods from three plants in each plot and subjecting pods to mesocarp color determination (Williams and Drexler, 1981; Williams et al., 2004). Pods in the brown and black color categories are considered mature, and Virginia market-type peanut is often dug and vines inverted when the combined percentage of brown and black pods is 65% (referred to as percentage of mature pods, %MP)(Jordan et al., 2005). In 2007 at Rocky Mount, the percentage of the peanut canopy expressing damage from two-spotted spider mite (*Tetranychus urticae* Koch) was recorded using a visual scale of 0 to 100%, where 0 = no damage and 100 = plant death. For each cultivar, aldicarb, and paraquat combination, peanut was dug and vines inverted when approximately 65% of pods were in the brown and black category based on pod mesocarp color (Jordan et al., 2005). Digging peanut separately for each combination of cultivar, aldicarb, and paraquat allowed a comparison of yield and market grade characteristics at optimum maturity. Peanut was threshed 4 to 7 d after digging and dried to final moisture of 8%. Percentages of sound mature kernels (SMK), sound splits (SS), total sound mature kernels (TSMK), extra large kernels (ELK), and farmer stock fancy pods (FP) were determined using Federal and State Cooperative grading criteria (USDA, 2005).

The experimental design was a randomized complete block with a split plot arrangement of treatments. Cultivar served as whole plot units and the combination of aldicarb and paraquat were considered subplot units. Data for visual estimates of tobacco thrips damage, plant stunting 45 DAE and 75 DAE, and damage from two-spotted spider mite; days from emergence to row closure; percentages of pods with brown and black mesocarp color in mid September; pod yield; and percentages of SMK, SS, TSMK, OK, ELK, and FP were subjected to ANOVAs for a four (experiment) by four (cultivar) by two

Table 1. *P* > *F* for tobacco thrips damage, plant stunting, peanut canopy width, days from emergence to row closure (DAE), and two-spotted spider mite damage.

Treatment factor	Tobacco thrips damage	Peanut stunting 45 DAE	Peanut stunting 75 DAE	Peanut width	Days from emergence to row closure	Spider mite damage
	1–5 scale	%	%	cm	d	%
Experiment (Exp)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	–
Cultivar (Cul)	0.0188	0.2887	0.0631	0.3604	0.5681	0.9330
Exp × Cul	0.0608	0.5834	0.0034	0.6555	0.556	–
Aldicarb (Ald)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0018
Paraquat (Para)	–	<0.0001	<0.0001	0.0042	0.0099	0.5867
Exp × Ald	<0.0001	<0.0001	<0.0001	0.0384	0.0002	–
Exp × Para	–	<0.0001	<0.0001	0.3842	0.0134	–
Ald × Para	–	<0.0001	0.1571	0.8189	0.943	0.2799
Ald × Cul	0.5593	0.5211	0.1035	0.6197	0.5901	0.1566
Para × Cul	–	0.1870	0.0334	0.1056	0.4093	0.7689
Exp × Ald × Para	–	<0.0001	<0.0001	0.8275	0.7343	–
Exp × Ald × Cul	0.2357	0.3394	0.0029	0.5624	0.8713	–
Exp × Para × Cul	–	0.8734	0.0122	0.9371	0.8214	–
Ald × Para × Cul	–	0.5834	0.1408	0.6759	0.2664	0.7849
Exp × Ald ×Para × Cul	–	0.4522	0.4623	0.6612	0.5937	–

(aldicarb treatment) by two (paraquat treatment) factorial treatment structure using appropriate error terms for fixed and random effects (Carmer et al., 1989; SAS Institute, 2006). Data for visual estimates of tobacco thrips damage were subjected to a four (experiment) by four (cultivar) by two (aldicarb treatments) factorial treatment structure. Paraquat was not a component of the treatment structure when tobacco thrips damage was recorded. Data for visual estimates of damage from two-spotted spider mite were subjected to a four (cultivar) by two (aldicarb treatments) by two (paraquat treatment) factorial treatment structure. Two-spotted spider mite damage was observed only at Rocky Mount during 2007. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

The interaction of experiment × aldicarb treatment and the main effect of cultivar were noted for early season damage from tobacco thrips feeding (Table 1). Significant damage from tobacco thrips was noted when aldicarb was not applied compared with aldicarb in the seed furrow at both locations during each year (data not presented in tables). On a scale of 0 to 5, where 5 represents severe damage, damage in absence of aldicarb ranged from 2.3 to 2.4 at Lewiston-Woodville during both years (data not shown). At Rocky Mount, damage was 1.3 in 2007 and 0.4 in 2008 (data not shown). More damage at Lewiston-Woodville may have been associated with planting date when comparing the two locations. Peanut was planted in early May at Lewiston-Woodville compared with mid to late May planting at Rocky Mount. Hurt et al. (2005) reported that peanut was damaged more by tobacco thrips when emerging in early to mid May compared with emergence in late May or early June. Aldicarb reduced damage at all locations to 0.7 or less (data not shown). When pooled over aldicarb treatments, VA 98R expressed greater damage from tobacco thrips feeding (1.9) compared with values of 0.8 to 0.9 for Gregory, Perry, and Phillips (data not shown). Differential response of peanut cultivars to damage from tobacco thrips has been reported previously (Hurt et al., 2004, 2005, 2006).

Table 2. Influence of peanut injury caused by paraquat and peanut damage from tobacco thrips on peanut stunting 45 and 75 days after peanut emergence (DAE).

Aldicarb rate	Paraquat rate	Lewiston-Woodville 2007	Lewiston-Woodville 2008	Rocky Mount 2007	Rocky Mount 2008
kg ha^{-1}	kg ha^{-1}	% peanut stunting			
Stunting 45 DAE					
0	0	0c†	51b	0b	0c
0	0.14	33a	74a	20a	22a
1.1	0	0c	2d	0b	0c
1.1	0.14	28b	9c	20a	19b
Stunting 75 DAE					
0	0	43a	33b	32a	19b
0	0.14	43a	58a	31a	28a
1.1	0	0c	0d	2b	6d
1.1	0.14	8b	8c	4b	13c

† Means within a location and year combination and for stunting 45 or 75 DAE followed by the same letter are not significantly different according to Fisher's Protected LSD test at $P \leq 0.05$. Data are pooled over cultivars.

Interactions of experiment × aldicarb and experiment × cultivar × paraquat were significant for peanut stunting 45 DAE (Table 1). However, the interaction of cultivar × aldicarb × paraquat was not significant. Additionally, the interaction of experiment × aldicarb × paraquat was significant for peanut stunting at this time during the season. At Lewiston-Woodville during 2007, peanut stunting was higher when paraquat was applied regardless of aldicarb treatment, with no stunting attributed to early season damage from tobacco thrips (Table 2). Peanut was stunted more when paraquat followed tobacco thrips damage in absence of aldicarb compared with paraquat following aldicarb. During 2008 at this location, peanut was stunted 51% in absence of aldicarb and paraquat compared with only 2% when aldicarb was applied in absence of paraquat. Applying paraquat increased stunting to 74% when aldicarb was not applied and 9% when aldicarb was included. At Rocky Mount, stunting from paraquat was similar in 2007 irrespective of aldicarb treatment while in 2008 slightly higher stunting was noted when paraquat was applied when aldicarb was to applied to control tobacco thrips.

Peanut stunting 75 DAE was also affected by the interaction of experiment, aldicarb, and paraquat irrespective of cultivar

(Table 1). When pooled over cultivars, peanut stunting was 43% at Lewiston-Woodville in 2007 in absence of aldicarb irrespective of paraquat treatment (Table 2). At this location during 2008, stunting was higher when aldicarb was not applied and paraquat was applied (58%) compared with 33% stunting when aldicarb and paraquat were not applied. During both years at this location, stunting was 8% or less when aldicarb was applied regardless of paraquat treatment. At Rocky Mount, stunting was 31 to 32% when aldicarb was not applied and 4% or less when aldicarb was applied irrespective of paraquat treatment. Similar to results at Lewiston-Woodville during 2008, peanut stunting was greatest when aldicarb was not applied, and stunting was exacerbated when paraquat was included irrespective of aldicarb treatment.

Peanut stunting was lower during both years at each location when aldicarb was applied to Perry, Phillips, and VA 98R when data were pooled over paraquat treatments (Table 3). Aldicarb decreased peanut stunting of the cultivar Gregory at Lewiston-Woodville during both years and at Rocky Mount in 2007. However, stunting did not differ between aldicarb treatments for this cultivar during 2008 at Rocky Mount. Considerable variation in peanut stunting was noted when comparing cultivars with or without paraquat. At Lewiston-Woodville during 2007, Gregory and Phillips were stunted by paraquat; Perry and VA 98R were not affected. Stunting of all cultivars was noted at this location during 2008, while no significant stunting was caused by paraquat during 2007 at Rocky Mount. Phillips and VA 98R were stunted by paraquat in 2008 at Rocky Mount. Phillips was stunted in three of four experiments, while Perry was stunted in only one experiment.

Damage caused by two-spotted spider mite was noted at Rocky Mount during 2007, but not in 2008 or during either year at Lewiston-Woodville. At Rocky Mount in 2007, damage was affected by the main affect of aldicarb treatment, but not by cultivar or paraquat or the interaction these factors, or by interactions of aldicarb with other treatment factors (Table 1). When pooled over cultivar and paraquat treatments, damage was 22% when aldicarb was not applied, and 8% when aldicarb was applied (data not shown). Incidence of two-spotted spider mite often is associated with dry weather and canopy humidity (Brandenburg and Kennedy, 1987). When aldicarb was not applied, the peanut canopy was stunted 75 DAE and most likely canopy humidity was lower compared with humidity in the canopy when aldicarb was applied and less stunting was observed. The canopy with lower humidity most likely was more conducive to populations of two-spotted spider mite increasing and subsequently damaging peanut (Brandenburg and Kennedy, 1987).

Table 3. Peanut stunting 45 days after emergence as influenced by interactions of cultivar with tobacco thrips damage in absence of aldicarb and cultivar with paraquat treatment.

Treatment factors		Lewiston-Woodville		Rocky Mount	
Cultivar	Aldicarb or paraquat	2007	2008	2007	2008
	kg ha^{-1}	% peanut stunting			
	Aldicarb				
Gregory	0	42*	46*	33*	12
Gregory	1.1	5	5	4	7
Perry	0	46*	44*	31*	27*
Perry	1.1	5	6	3	9
Phillips	0	48*	43*	29*	34*
Phillips	1.1	4	4	3	15
VA 98R	0	38*	48*	33*	22*
VA 98R	1.1	3	3	2	8
	Paraquat				
Gregory	0	21	18	17	18
Gregory	0.14	26*	33*	20	18
Perry	0	24	16	18	18
Perry	0.14	27	34*	16	18
Phillips	0	23	18	16	19
Phillips	0.14	28*	29*	16	30*
VA 98R	0	19	16	16	13
VA 98R	0.14	22	34*	18	18

* Indicates significance within a cultivar and year comparison for the interaction of cultivar, aldicarb, and experiment and the interaction of cultivar, paraquat, and experiment at $P \leq 0.05$. Data are pooled over levels of remaining treatment factors.

Peanut canopy width 75 DAE, days from peanut emergence to row closure, and %MP were affected by the interaction of experiment × aldicarb (Tables 1 and 4). Peanut plants were wider when aldicarb was applied regardless of cultivar or paraquat treatment at both locations during each year (Table 5). Additionally, the number of days required to reach row closure was fewer when aldicarb was applied during both years at Lewiston-Woodville and during 2007 at Rocky Mount. Surprisingly, the %MP in mid September was higher in absence of aldicarb at both locations during 2007, but not at either location during 2008. The stress caused by tobacco thrips feeding would be expected to

Table 4. *P* > *F* for pod yield and percentages of pods with brown and black mesocarp color considered mature pods (%MP), sound mature kernels (%SMK), sound splits (%SS), total sound mature kernels (%TSMK), other kernels (%OK), extra large kernels (%ELK), and fancy pods (%FP).

Treatment factor	%MP	Yield	%SMK	%SS	%TSMK	%OK	%ELK	%FP
Experiment (Exp)	0.0002	0.0056	<0.0001	<0.0001	<0.0001	0.0696	<0.0001	<0.0001
Cultivar (Cul)	0.0652	<0.0001	0.9182	0.0041	0.4313	0.0591	0.0030	<0.0001
Exp × Cul	0.4106	0.0466	0.0883	0.0594	0.2974	0.8613	0.2639	0.3719
Aldicarb (Ald)	0.3386	<0.0001	0.0996	0.1149	0.3384	0.1534	0.8861	0.0298
Paraquat (Para)	0.2329	0.0395	0.0896	0.3497	0.1879	0.5446	0.0955	0.0966
Exp × Ald	0.0023	<0.0001	0.1334	0.8505	0.2290	0.6096	0.0769	0.6521
Exp × Para	0.5465	0.0058	0.4139	0.2458	0.8624	0.2851	0.1830	0.3771
Ald × Para	0.7007	0.0066	0.9725	0.3309	0.6170	0.7044	0.3716	0.1408
Ald × Cul	0.4094	0.1605	0.7974	0.4209	0.8224	0.4016	0.7869	0.2727
Para × Cul	0.3947	0.0760	0.2828	0.5003	0.1939	0.8450	0.1241	0.9550
Exp × Ald × Para	0.5616	0.3937	0.2744	0.9597	0.2599	0.3023	0.0659	0.0085
Exp × Ald × Cul	0.8463	0.0816	0.4882	0.6787	0.3369	0.7200	0.4657	0.0518
Exp × Para × Cul	0.0998	0.5366	0.1332	0.9644	0.1971	0.8060	0.0267	0.3139
Ald × Para × Cul	0.9303	0.0560	0.2525	0.6550	0.4955	0.8225	0.2074	0.6536
Exp × Ald × Para × Cul	0.6103	0.9923	0.1674	0.9987	0.1732	0.8543	0.3365	0.2620

Table 5. Peanut canopy width, days from peanut emergence to row closure, and percentages of pods with brown and black mesocarp color (%MP) as influenced by tobacco thrips damage in absence of aldicarb.

Aldicarb	Lewiston-Woodville 2007	Lewiston-Woodville 2008	Rocky Mount 2007	Rocky Mount 2008
kg ha^{-1}	Canopy width, cm			
0	48	64	58	61
1.1	58*	74*	64*	66*
	Row closure, d			
0	106*	83*	90*	68
1.1	96	73	80	67
	Mature pods, %			
0	66*	61	31*	23
1.1	60	65	23	27

* Indicates a difference at $P \leq 0.05$. Data are pooled over cultivars and paraquat treatments.

delay plant development and possibly cause pod maturation to be delayed compared with plants not experiencing damage from tobacco thrips.

Paraquat affected peanut canopy width independent of experiment, cultivar, or aldicarb (Table 1). When pooled over the other treatment factors, peanut canopy width was 64 cm when paraquat was applied compared with 67 cm in absence of paraquat (data not shown). Additionally, the number of days from peanut emergence to row closure at Lewiston-Woodville increased from 98 to 104 (2007) and 76 to 80 (2008) (data not shown). However, at Rocky Mount, no difference in the number of days to reach row closure was noted when comparing paraquat treatments (data not shown).

Peanut pod yield was affected by interactions of aldicarb × paraquat, experiment × aldicarb, and experiment × paraquat (Table 4). However, the interaction of cultivar with these treatment factors was not significant, nor was the interaction of experiment × aldicarb × paraquat. When pooled over experiments and cultivars, pod yield was higher when aldicarb was applied regardless of paraquat treatment when compared with the no-aldicarb control (Table 6). No difference in pod yield was noted between paraquat treatments when aldicarb was applied. In contrast, applying paraquat in absence of aldicarb lowered pod yield compared with no aldicarb or aldicarb with or without application of paraquat. These data suggest that, when tobacco thrips damage is minimized by aldicarb, pod yield will not be affected by paraquat. However, when tobacco thrips damage occurs, further stress on peanut due to paraquat injury may exacerbate loss of pod yield.

When comparing aldicarb and paraquat treatments across experiments, pod yield was lower in three of four experiments when aldicarb was not applied and in one of four experiments when paraquat was applied (Table 7). Damage from tobacco thrips was generally higher at Lewiston-Woodville during both years and at Rocky Mount during 2007 when compared with damage at Rocky Mount during 2008, and this may explain lack of a yield response to aldicarb at Rocky Mount during 2008. Tobacco thrips damage was considerably higher at Lewiston-Woodville during 2008 compared with other experiments, and may explain a yield reduction following paraquat treatment in this experiment compared with other experiments. Data for pod yield associated with the interaction of aldicarb and paraquat indicate that damage from both stresses can result in greater yield loss compared with either stress alone. Therefore, damage from tobacco thrips should be a greater concern for peanut growers than injury from paraquat. The higher level of tobacco thrips damage at Lewiston-Woodville during 2008 may explain partially the yield loss at this location due to paraquat.

Table 6. Peanut pod yield as influenced by the interaction of tobacco thrips damage in absence of aldicarb and crop injury in presence of paraquat.†

Aldicarb rate	Paraquat rate	Pod yield
kg ha^{-1}		
0	0	4550b†
0	0.14	4230c
1.1	0	5120a
1.1	0.14	5150a

† Means followed by the same letter are not significantly different according to Fisher's Protected LSD test at $P \leq 0.05$. Data are pooled over experiments and cultivars.

With the exception of %ELK and %FP, main effects and interactions of aldicarb and paraquat did not affect market grade characteristics regardless of experiment or cultivar treatment (Table 4). The %ELK was similar regardless of aldicarb or paraquat treatment at Lewiston-Woodville during 2007 and at Rocky Mount during 2008 (data not shown). However, the lowest %ELK in 2008 at Lewiston-Woodville was noted when aldicarb was not applied followed by application of paraquat (data not shown). Surprisingly, the lowest %ELK was noted in 2007 at Rocky Mount when aldicarb was applied and paraquat was not applied (data not shown). The %FP was affected by the main effect of aldicarb with a higher %FP noted when aldicarb was applied compared with no aldicarb regardless of experiment or cultivar treatment (data not shown). A higher %ELK and %FP often reflect more advanced pod maturation (Jordan, 2009a; Knauft et al., 1990).

These experiments indicate that while considerable differences in vegetative growth may be a result of interactions among experiment, cultivar, aldicarb, and paraquat, these differences do not always translate into effects on pod yield and market grade characteristics. Peanut yield and market grade response to aldicarb and paraquat were not affected by cultivar selection. Therefore, recommendations on early-season tobacco thrips management and use of paraquat to control weeds early in the season most likely will not need to be altered due to cultivar selection. In these experiments, peanut was dug based on pod maturity using mesocarp

Table 7. Peanut pod yield as influenced by tobacco thrips damage (main effect of aldicarb treatment) and crop injury (main effect of paraquat treatment).

Treatment factors	Lewiston-Woodville 2007	Lewiston-Woodville 2008	Rocky Mount 2007	Rocky Mount 2008
	kg ha^{-1}			
Aldicarb, kg ha^{-1}				
0	4090	5000	4550	3930
1.1	4670*	6090*	5620*	4160
Paraquat, kg ha^{-1}				
0	4490	5730	4960	4130
0.14	4270	5350*	5210	3960

* Indicates significance within a location and year combination for both aldicarb and paraquat at $P \leq 0.05$. Data are pooled over levels of other cultivars and levels of the other treatment factor.

color as an indicator for each combination of cultivar, aldicarb, and paraquat in an effort to allow differences in maturation to be minimized and not be an artifact of the experiment. In previous research (Carley et al., 2009), peanut receiving various treatments of aldicarb and paraquat were dug simultaneously based on maturity of peanut treated with aldicarb but not paraquat. Results from research by Carley et al. (2009) may have reflected greater differences in pod yield and market grade characteristics because later-maturing peanut, possibly due to damage from tobacco thrips or paraquat injury, did not have sufficient time to recover. Data from our study most likely reflect greater resolution on the effects of tobacco thrips damage and paraquat injury on Virginia market-type peanut production in North Carolina because peanut for each combination of cultivar, aldicarb, and paraquat were dug independently at optimum maturity.

Even though paraquat can be applied up to 28 DAE, the effect of paraquat on peanut growth and yield most likely would be reduced if bentazon was applied with paraquat or if paraquat alone or paraquat plus bentazon were applied closer to peanut emergence (Johnson et al., 1993; Jordan et al., 2003). These data also suggest that growers should scout fields for tobacco thrips damage and apply insecticide if damage exceeds established thresholds to minimize risk of yield loss (Brandenburg, 2009).

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