Peanut Tolerance to Paraquat as Influenced by Seed Size [1]

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ABSTRACT

Studies were conducted over a 2-year period at Headland, Ala. and Jay, Fla. to evaluate the relationship between peanut seed size and tolerance of the resultant crop to normal and excessive rates of the herbicide paraquat (1,1'-dimethyl-4,4'-bipyridinium ion). Three seed sizes, termed small (3340 seeds/kg), medium (2615 seeds/kg), and large (1820 seeds/kg), were planted to achieve a common plant population. While seedling size at emergence reflected seed size, no interaction between seed size and herbicide treatment was detected for crop growth measured as the increase in canopy diameter over a 5-week period following herbicide application. None of the seed sizes resulted in seedlings that were either uniquely sensitive or abnormally tolerant of paraquat. Two sequential applications of paraquat at 0.14 kg ai/ha each was consistently the most damaging treatment as measured in growth reduction, however yield was reduced in only one of four trials. Seed size had an effect on yield in only two of the four trials, and within these two trials the average yield improvement from large seed relative to medium and small seed was only 10 and 12%, respectively. Net return generally was independent of seed size. However, medium-sized seed resulted in maximum net return in two out of the four experiments.

Key Words: Herbicides, peanut growth, growth rate, net returns.

Studies examining the relationship between seed size and seedling performance have been conducted for a number of legume crops, including soybean [*Glycine max* (L.) Merr.] (5,9,11,16,18), sweet clover [*Melilotus officinalis* (L.) Lam.] (14), alfalfa (*Medicago sativa* L.) (7), and peanut (*Arachis hypogaea* L.) (13,17). In these studies larger seed size generally was associated with superior performance during emergence and subsequent development. However, this early-season benefit was not consistently reflected in yield. In soybean, Smith and Camper (20) reported that larger seed resulted in greater yield in 5 of 6 years; however, Johnson and Luedders (16) found no relationship between seed size and yield.

Larger seed size in peanut has been associated with higher seed protein, more rapid emergence and overall larger and more vigorous seedlings (6,13,17,19). Yield and grade responses are generally inconsistent but generally favor larger seed (17). Gorbet (13) reported that larger seed size resulted in more rapid seedling emergence, better overall seedling vigor, and greater yield in 2 of 3 years.

Few studies focusing on seed size and seedling vigor and their relationship to herbicide tolerance have been conducted. Cargil and Santelmann (6) evaluated the tolerance of seedlings from four seed sizes of Spanish peanut (cultivar Starr) to trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl) benzenamine] and chloramben (3-amino-2,5-dichlorobenzoic acid) under greenhouse and field conditions. Under greenhouse conditions, seedlings from larger seed exhibited greater tolerance of both herbicides as indicated by seedling root and shoot dry weights, taken 10 days after treatment. Under field production, plants from larger seed exhibited greater vegetative growth and improved herbicide tolerance. However, this was not reflected in yield.

A considerable amount of weed control in peanut is obtained with herbicides that are applied between crop emergence (termed 'ground cracking') and the initiation of flowering. This places additional importance on seedling vigor. For many years, the primary herbicide applied at ground cracking was dinoseb [2-*sec*-butyl-4,6-dinitrophenol(2-(1-methylpropyl)-4,6-dinitrophenol)] (4,15). Peanut tolerance of dinoseb has been attributed to relatively high levels of nutrients contained within the seed which allows seedlings to overcome herbicide-induced injury (18). The Environmental Protection Agency canceled all registrations for the herbicide dinoseb in October 1986 due to toxicological considerations (2). Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was registered for use in peanut 2 years after this cancellation. Prior to registration, paraquat had been evaluated for the control of annual grasses in peanut (21). In several later studies, paraquat controlled various broadleaf weeds in the cultivar Florunner (23).

Paraquat is gaining acceptance as a useful tool for weed control in peanut production in the southeastern United States. To reduce the risk of crop injury, the use rate is relatively low ($\leq$0.14 kg ai/ha). Even with correct use, foliar injury does occur. Normally this injury does not reduced yield (21, 23).

The potential for significant injury from early season applications of paraquat, and the marketing of smaller seed sizes has renewed interest in the effect of varying seed sizes on the tolerance of young peanut plants to herbicides. Specifically, it was questioned whether plants from smaller seed are less tolerant of paraquat. The objective of this research was to evaluate crop tolerance of registered and excessive rates of paraquat as affected by seed size.

Materials and Methods

Field experiments were conducted during 1989 and 1990 at the Wiregrass Substation of Auburn University, located at Headland AL., and the Agricultural Research and Education Center of the University of Florida, located at Jay, FL. The soil type at Headland was a Dothan sandy loam (fine-loamy, siliceous, thermic plinthic paleudults) with 1.3% organic matter and a pH of 6.5. The soil at Jay was a Red Bay sandy loam (fine-loamy, siliceous, thermic rhodic kandiudults) with 2.1% organic matter and pH of 5.8. Following a winter cover crop of rye (*Secale cereale* L.), the experimental areas were moldboard plowed in the spring. Separate test areas were used each year of the experiment. Since the focus of the study was crop response, the experimental areas were maintained weed free. Annual grasses and small-seeded broadleaf weeds were controlled with a broadcast, preplant-incorporated application of benefin [*N*-butyl-*N*-ethyl-2,6-dinitro-4-

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[3] X-77 (a mixture of alkylaryl-polyoxyethylene glycols, free fatty acids, and isopropanol). Valent USA Corp., P. O. Box 8025, Walnut Creek, CA 94596-8025.

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(trifluoromethyl)benzenamine] at 1.7 kg ai/ha. Weeds escaping this treatment were removed by hand on a weekly basis. Experiments were irrigated on an 'as-needed' basis so as to eliminate drought stress as a confounding factor.

Three peanut seed sizes of the cultivar Florunner were used. The first size passed through a screen with 6.4- mm openings, and was retained by a screen with 5.9- mm openings (8). The second size passed through a 6.7-mm screen and was retained by a 6.4-mm screen. The third size passed through a 9.5-mm screen and was retained by a 6.4-mm screen. The 5.9-, 6.4-, 6.7-, and 9.5-mm screens correspond to the 15/16-, 16/64-, 17/64- and 24/64- inch screens, respectively, as used in the peanut seed industry (8). For convenience, these sizes are referred to as 'small', 'medium' and 'large', respectively. The average numbers of seeds per kilogram were 3340, 2615, and 1820 for the three sizes. Seed of each size were planted in rows spaced 91 cm apart with conventional equipment so as to obtain an equal seed spacing of 20 seeds per meter of row. This resulted in a seeding rate of 64, 82, and 118 kg/ha for the small, medium and large seed, respectively. A common planting depth of 3 to 4 cm was used. This depth was judged to be adequate for the large seed, yet sufficiently shallow so as to not inhibit emergence of the small seed.

The first two treatments were paraquat applied at 0.14 and 0.28 kg ai/ha, respectively. The currently-registered single-application rate is 0.14 kg/ha. Both treatments were applied at 7 to 10 days after emergence. The third treatment consisted of two applications of paraquat both at 0.14 kg/ha; the first at 7 to 10 days after emergence, the second was 10 days later. The fourth treatment was a nontreated check. A nonionic surfactant[3] at 0.25% (v/v) was included with all herbicide treatments.

Plots consisted of four 91-cm rows, 6.1 m in length. Herbicide applications were made with a tractor-mounted, compressed-air sprayer that delivered 140 L/ha at 220 kPa. A split-plot design with four replications was used, with seed size assigned to whole plots and herbicide treatments assigned to subplots.

Stand counts were taken (1991 only) to confirm that an equal population had been achieved. Crop canopy diameter was measured just prior to herbicide application and five times thereafter on a weekly basis so that growth of the crop during and after herbicide treatment could be graphed. In addition, the first and last measurements were used to calculate the percent increase in canopy diameter (termed 'cumulative growth') during this 5-week period. Preliminary statistical analysis revealed that crop canopy measurements, as well as the cumulative growth data, did not vary significantly between individual year-location experiments. Consequently, data for each seed size were pooled across experiments for further analysis and for graphical presentation. An $LSD_{0.05}$ was calculated for each seed size.

Peanut was harvested 140 to 150 days after planting using conventional harvesting equipment, and subsequently graded. Treatment variables had no effect on grade, consequently only yield data will be presented. Preliminary statistical analysis revealed that yield varied significantly between individual year-location experiments. Consequently, data for each experiment were analyzed separately. In none of the experiments was the interaction between seed size and herbicide treatment significant ($p \leq 0.05$) with respect to yield. Consequently, the main effect means for each experiment were separated by Duncan's multiple range test at the 5% level.

Treatment means for each location were also used in net return calculations. A more indepth analysis using individual plot data was deemed inappropriate since herbicide effect was a experimental variable, yet weeds had been removed by hand. The cost of peanut seed during the 2-year period that these studies were conducted averaged $1.78/kg regardless of size. The economic incentive for using small seed is that fewer kilograms are required to plant a given area. Average value of farmer-stock peanuts during this same period was $0.71/kg. It is assumed that all remaining variable and fixed costs were $1,360/ha (1).

Results and Discussion

General observations. Observations by the authors revealed that the rate of seedling emergence and the resultant plant population were not affected by seed size (data not shown). However seedling size (cotyledons and first true leaves) reflected seed size. By the time that the herbicides were scheduled to be applied, seedlings from small, medium and large seed averaged 13, 14, and 16 cm in diameter, respectively.

Growth subsequent to herbicide application. Analysis of cumulative growth data indicated that growth was influenced by seed size and herbicide treatment, however in none of the four experiments was the interaction of these two variables significant. During the first 2 weeks after herbicide applications, canopy diameters of the nontreated controls continued to reflect the initial relationship to seed size, reaching 20, 23 and 27 cm for small, medium and large seed, respectively (Fig. 1). Rate of growth appeared to be essentially identical as indicated by the near parallel nature of the growth lines. Between the second and third week, the crop canopy from large seed increased at a greater rate than the canopy from small and medium seed, resulting in a significantly greater canopy diameter. This difference continued for the remainder of the observational period. Growth of seedlings from medium and small seed remained nearly equivalent during the 5- week period. By the end of the observational period, canopy width was 50 (small), 50 (medium), and 61 cm (large), compared to 13, 14, and 16 cm, respectively, at the time of herbicide application. Thus, the cumulative growth of peanut seedlings from small, medium and large seed was 383, 358 and 380%, respectively.

Inspection of data reveals that generally, across all seed sizes, treatments in descending order of injury (i.e. temporary reduction in growth) were paraquat at 0.14 kg/ha, paraquat at 0.28 kg/ha, and the sequential application. Within the small seed, starting at the second week after application and continuing through the remainder of the observational period, the canopy diameter following paraquat at 0.14 kg/ha consistently remained numerically less (though never statistically different) than the nontreated check (Fig. 1.).

By the end of the observation period, canopy diameters for this treatment and the nontreated check were 46 and 50 cm, giving a cumulative increase of 356 and 383%, respectively. Paraquat at 0.28 kg/ha and the 0.14 plus 0.14 kg/ha sequential treatment resulted in progressively greater suppression in canopy size. However, canopy size following paraquat at 0.28 kg/ha was significantly less than that of nontreated check at only the 3rd observational period; cumulative increase in canopy size was 315%. The canopy width of the sequential treatment was less than that of the nontreated check from the third through the fifth observational period, resulting in a cumulative increase of 290%.

Results from medium seed were very similar to those obtained with small seed. Starting from 14 cm at the time of herbicide application, peanut treated with paraquat at 0.14 kg/ha and the nontreated check increased to 47 and 50 cm, for a cumulative increase of 335 and 358%, respectively. While the treatment with 0.14 kg/ha of paraquat consistently was numerically inferior to the nontreated check, the difference was never significant. Peanut treated with paraquat at 0.28 kg/ha increased to 44 cm (311% cumulative), but at only one observation was the canopy width significantly less than that of the nontreated check. Peanut receiving the sequential treatment had the smallest increase in canopy width (283%); canopy width was significantly less than the nontreated check at the third through the fifth observation.

Seedlings from the nontreated large seed increased from 16 cm to 61 cm, resulting in a cumulative increase of 380% (Fig. 1). From the third to the fifth observation canopy widths of all herbicide-treated peanut were significantly less than the nontreated check, though statistically equivalent to

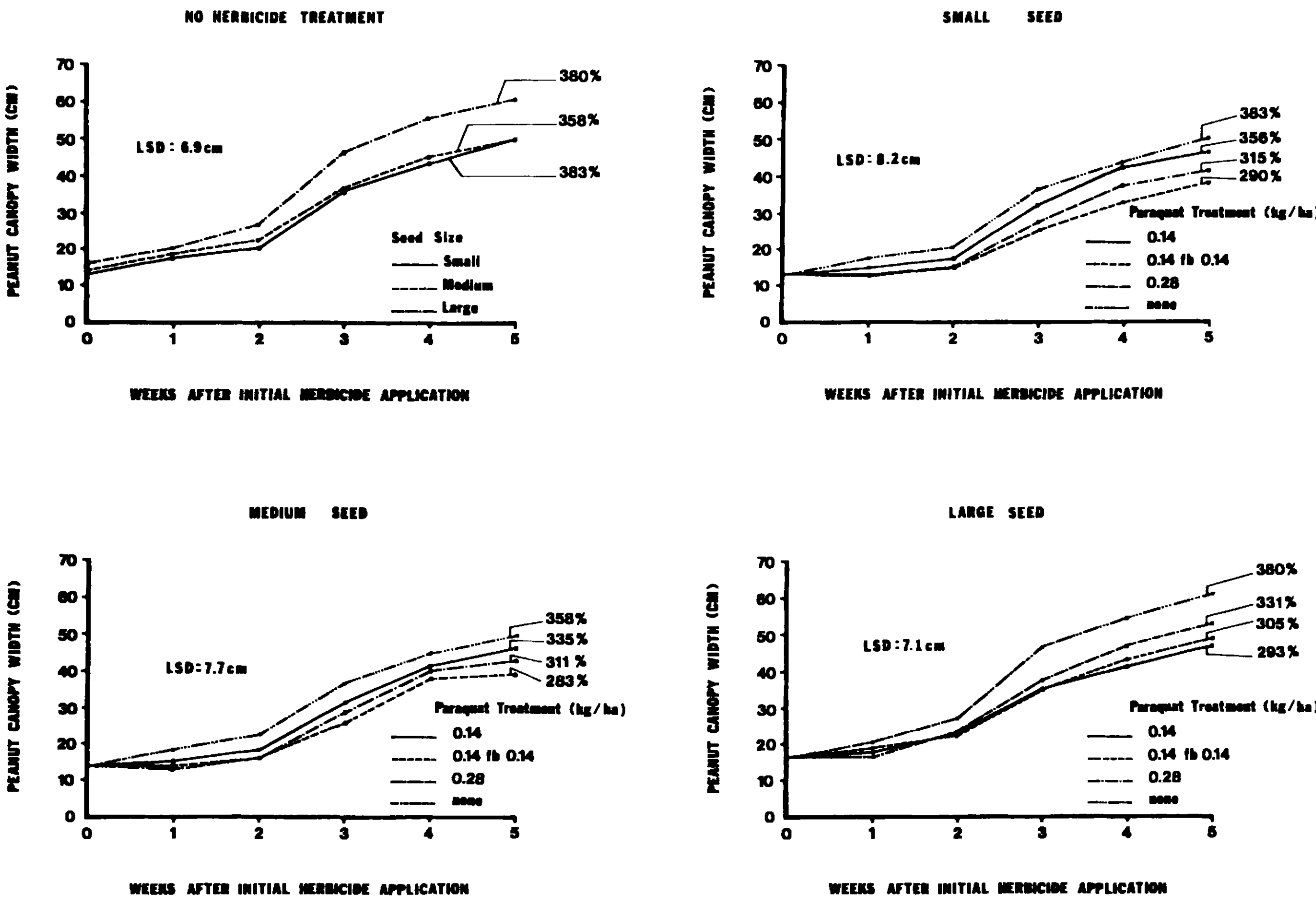

Fig. 1. Increase in peanut canopy diameter subsequent to the application of paraquat (weeds removed) as influenced by seed size.

Table 1. Peanut yield as influenced by seed size and herbicide treatment.

Experiment		Paraquat treatment	Seed size			
Location	Year		Small	Medium	Large	Mean
		—(kg/ha)—	(kg/ha)			
Headland, AL.	1989	0.14	3917	3631	3674	3771A[2]
		0.28	3994	3488	3703	3662AB
		0.14 +[1] 0.14	3131	3182	3383	3223B
		Nontreated	3499	3815	3611	3641AB
		Mean	3635a	3529a	3616a	
Jay, FL.	1989	0.14	5220	5089	5281	5200A
	0.28	4427	4123	5074	4541B	
		0.14 + 0.14	4208	5220	4940	4789AB
		Nontreated	4562	4940	5001	4834AB
		Mean	4604b	4843ab	5074a	
Headland, AL.	1990	0.14	3080	3142	3764	3329A
	0.28	3203	3933	3143	3359A	
		0.14 + 0.14	2448	3121	2530	2700B
		Nontreated	3182	3835	4121	3713A
		Mean	2978b	3508a	3390a	
Jay, FL.	1990	0.14	3832	4205	4250	4095A
	0.28	3974	4161	4116	4083A	
		0.14 + 0.14	4258	4178	4001	4146A
		Nontreated	4063	4276	3996	4110A
		Mean	4032a	4205a	4091a	

1 '+' indicates 'plus', i.e. two applications of paraquat which were separated by approximately 10 days.

2 Means within a column (upper case) or row (lower case) followed by the same letter are equivalent according to Duncan's multiple range test at the 0.05 level.

Table 2. Peanut net return[1] as influenced by seed size and herbicide treatment (weeds removed by hand).

Experiment		Paraquat treatment	Seed size			
Location	Year		Small	Medium	Large	Mean
		—(kg/ha)—	($/ha)			
Headland, AL.	1989	0.14	1307	1072	1039	1139A[3]
		0.28	1362	970	1059	1130AB
		0.14 +0.14	749	753	832	778B
		Nontreated	1010	1203	994	1069AB
		Mean	1107a	1000a	997a	
Jay, FL.	1989	0.14	2232	2107	2180	2173A
		0.28	1669	1421	2033	1708B
		0.14 + 0.14	1514	2200	1937	1884AB
		Nontreated	1765	2001	1981	1916AB
		Mean	1795b	1933ab	2033a	
Headland, AL.	1990	0.14	713	725	1102	847A
		0.28	800	1286	662	916A
		0.14 + 0.14	264	710	226	400B
		Nontreated	785	1217	1356	1119A
		Mean	640b	985a	837a	
Jay, FL.	1990	0.14	1247	1480	1448	1392A
		0.28	1348	1448	1352	1383A
		0.14 + 0.14	1549	1460	1271	1427A
		Nontreated	1411	1530	1267	1403A
		Mean	1389a	1480a	1335a	

1 Net returns calculated by multiplying yield (Table 1) by 0.71 $/ha, and subtracting 114, 146, 210 $/ha for the seed cost for the small, medum and large seed, respectively, and by subtracting and additional 1,360 $/ha for all remaining productions costs.
2 '+' indicates 'plus', i.e. two applications of paraquat which were separated by approximately 10 days.
3 Means within a column (upper case) or row (lower case) followed by the same letter are equivalent according to Duncan's multiple range test at the p = 0.05 level.

each other. Final canopy diameters of peanut treated with paraquat at 0.14, 0.28 and 0.14 plus 0.14 kg/ha were 47, 53 and 49 cm, respectively; resulting in cumulative increases of 293, 331, 305%, respectively.

Peanut yield. Yield was influenced by seed size in two of the four experiments, i.e. Jay in 1989 and Headland in 1990 (Table 1). At Jay in 1989, increasing seed size resulted in a step wise increase in yield. In Headland in 1990, medium and large seed resulted in yields that were equivalent to each other though superior to that of small seed. Within these two experiments, average yield from medium and large seed was equivalent. Furthermore, the average yield increase from large and medium seed relative to that obtained with small seed was 12% and 10%, respectively. Any benefit from large seed is probably due to large seed producing larger seedlings, which require less vegetative growth before entering into the reproductive stage. Thus, these plants have more opportunity to flower and fruit within the time limits of the season.

Yield was significantly influenced by herbicide treatment in all but one experiment (Jay in 1990). In two of the three experiments where herbicide treatment had an effect (i.e. Headland in 1989 and Jay in 1989), none of the herbicide treatments were significantly less than the nontreated check. In the remaining test (Headland in 1990) paraquat applied at 0.14 plus 0.14 kg/ha had lower yield than all other herbicide treatments and the nontreated check., all of which were equivalent.

Growth and yield data reported herein serve to disprove the contention that small seed produces a crop that is more prone to paraquat injury than a crop from large seed. Conversely, a seedling from a large seed does not possess a greater ability to tolerate paraquat injury.

Net returns. Medium seed provided the highest numerical net returns in 2 of the 4 experiments (i.e. both locations in 1990). However, within these two test, the ranking of the second and third highest net returns were reversed. In 1989, net returns at Headland in descending order were small, medium and large, respectively; this ranking was completely reversed at Jay. No consistent pattern relating seed size to net return could be detected. Thus, the added expense of large seed can not be justified.

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