# Paraquat Behavior as Influenced by 2, 4-DB in Peanut (*Arachis hypogaea*) and Selected Weeds[1]

Glenn Wehtje*, John W. Wilcut and John A. McGuire[2]

**ABSTRACT**

The interaction of 2,4-DB and paraquat on weed control and crop safety in peanuts was examined in greenhouse, field, and laboratory experiments. Tank mixtures of paraquat and 2,4-DB were no more injurious to peanuts than paraquat applied alone in greenhouse and field experiments. These tank mixtures were neither interactive nor synergistic with respect to weed control. Under field conditions, tank mixtures provided more comprehensive weed control and improved yield relative to either herbicide applied alone. Studies with $^{14}C$-labeled herbicides revealed that the absorption and translocation of paraquat and 2,4-DB was not influenced by the presence of other herbicide.

Key Words: 2,4-DB, paraquat, Florida beggarweed, *Desmodium tortuosum* (SW.) DC; peanut, *Arachis hypogaea* L.; Sicklepod, *Cassia obtusifolia* L. antagonism, synergism, translocation.

The Environmental Protection Agency suspended all registered uses of the herbicide dinoseb [2-sec-butyl-4, 6-dinitrophenol (2-(1-methylpropyl)-4, 6-dinitrophenol] in October of 1986 (1). Dinoseb had been used extensively in peanuts as an early postemergence treatment for the control of a variety of dicotyledonous weed species including sicklepod and Florida beggarweed (3, 7).

Paraquat (1,1'-dimethyl-4, 4'-bipyridinium ion) was registered for use in peanuts in 1987. Paraquat controls many grass and broadleaf weeds encountered in peanuts and is currently a standard treatment in southeastern peanut production (15, 18, 19). Applications must be restricted to early postemergence; i.e. no later than 28 days after emergence to minimize crop damage (15). Paraquat is rapidly absorbed into foliage where it inhibits photosynthesis; it is not extensively translocated (2, 6, 13).

A number of legume crops, including peanuts are tolerant of 2,4-DB [2,(2,4-dichlorophenoxy) butanoic acid] applied postemergence for broadleaf weed control (3). Ketchersid (9) reported that a single applications of 2,4-DB at 0.9 kg/ha to peanuts during the reproductive stage (the most herbicide sensitive period) reduced both yield and market grade. However, repeat applications of 0.45 kg/ha had no effect. In peanuts, 2,4-DB is used for the control of various broadleaf weeds including sicklepod (*Cassia obtusifolia* L.), morningglories (*Ipomoea* species) and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb] (9). These species, alone with Florida beggarweed, are among the weeds most commonly encountered in southeastern peanut production (5).

The 2,4-DB molecule is not phytotoxic. However, beta oxidation within plant tissue produces 2,4-D which is phytotoxic (9, 14). 2,4-DB is not readily absorbed nor translocated (8, 14). Peanut seedlings held at 100% relative humidity retained 80% of the amount of 2,4-DB applied on the leaf surface (9). The 2,4-D, formed from beta-oxidation within the treated leaf, appeared to be the more mobile product (9). The tolerance of peanuts and several other legumes to 2,4-DB relative to that of the target weeds is attributed to the combined effects of less spray retention, less absorption and translocation, and the more rapid metabolism of any 2,4-D produced into benign forms (8).

Since application times of paraquat and 2,4-DB overlap, interest has developed in combining these herbicides into a tank mixture. In previous research, both naptalam {2-[(1-naphthalenyl-amino)carbonyl]benzoic acid}(16) and bentazon {3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide} (17) were demonstrated to antagonize paraquat phytotoxicity. In both cases the antagonism was attributed to reduced paraquat absorption.

The objective of this study were to evaluate the effectiveness of 2,4-DB and paraquat tank mixtures on weeds pertinent to peanut production and peanut under greenhouse

[1]Alabama Agric. Exp. Stn. J. Ser. No. 3-913137.

[2]Assoc. Prof., Dep. Agronomy and Soils, and Alabama Agric. Exp. Stn., Auburn Univ., AL 36849, Asst. Prof., Dep. Agronomy, Box 748, Coastal Plain Exp. Stn., Univ. of Georgia, Tifton, GA 31794-0748, and Prof., Res. Data Analysis and Alabama Agric. Exp. Stn., Auburn Univ., AL 36849.

[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.

[4]Biological Sample Oxidizer OX-400. R. J. Harvey Instrument Corp., Hillsdale, NJ 07642.

*Corresponding author.

and field conditions. In addition, laboratory studies using radiolabeled herbicides were conducted to evaluate the absorption and translocation of both herbicides as influenced by the presence of each other.

# Materials and Methods

**Greenhouse study.** A greenhouse study was conducted to evaluate the interaction of 2,4-DB with paraquat on phytotoxicity in peanut, sicklepod, smallflower morningglory and Florida beggarweed.

Seeds of all species were allowed to germinate and subsequently transplanted into 1-L pots. The soil had been taken from the site of the field study as described below. Plants were grown for 3 weeks in a greenhouse with approximate day/night temperatures of 32/24 C and a photoperiod of 16 h. Plants were surface watered on an as-needed basis.

Herbicide treatments consisted of a factorial arrangement of 0, 0.07, and 0.14 kg ai/ha of paraquat, and 0, 0.05, 0.10 and 0.20 kg ai/ha of 2,4-DB. Treatments were assigned to three pots, with each pot containing three plants of a common species. All species were in the 3- to 4-leaf stage at the time of application. Treatments were applied with a moving-belt sprayer calibrated to deliver a spray volume of 168 L/ha. A nonionic surfactant[3] was added (0.25% v/v) to the spray solutions.

Ten days after treatment, paraquat phytotoxicity on peanuts was visually rated and foliar fresh weights of the three weeds were determined and expressed as percent of the untreated control. The expected response for each herbicide combination was calculated by the method described by Colby (4). An expected value was calculated by first multiplying the weed control provided by the two herbicides applied individually and then dividing by 100. Weed control provided by the tank mixture was termed the observed value. The expected and observed values were compared using Fisher's Protected LSD test at the p=0.05 level. If the observed response for a particular combination was not significantly different from the expected value, the combination was considered to be additive. However, if the observed response was significantly less than or greater than the expected value, the combination was deemed to be antagonistic or synergistic, respectively.

**Absorption and translocation.** The absorption and translocation of paraquat and 2,4-DB, whether applied alone or as a tank mixture was evaluated on seedlings of each species which had been grown as indicated above. Commercially formulated and $^{14}C$-labeled herbicides were used to prepare solutions of each herbicide so that the concentration of radioactivity was approximately 5,000 dpm/uL. The total herbicide concentration was equivalent to application rates of 0.14 kg/ha for paraquat and 0.20 kg/ha for 2,4-DB as described in the aforementioned greenhouse study. The specific activity of the radioactive paraquat and 2,4-DB was 22.1 and 13.7 mCi/mmol, respectively. Additional solutions were prepared in which paraquat and 2,4-DB were combined and the $^{14}C$ atom(s) was a part of either the paraquat or the 2,4-DB molecule, resulting in a total of four treatments.

Each treatment was applied to four single-plant replicates of each species. Solutions were applied as a single 5-uL drop to the youngest fully-expanded leaf of each plant. Small 'O' rings (3 mm diameter) which had been sealed to the leaf surface with lanolin were used to keep constant the amount of leaf surface area exposed to the solutions. All applications were made at 0900 h and analysis of treated plants began 48 h later.

The 'O' ring was carefully removed and a 1-cm-diameter cork borer was used to remove the disk of leaf tissue that encompassed the treated site. The disk was rinsed for 30 s with 20 mL $H_2O$: methanol (90:10 v/v) to remove unabsorbed herbicide. A 5-mL aliquot of this rinse was added to scintillation fluid and radioactivity was quantified by liquid scintillation spectrometry. The remainder of the treated leaf was also removed from the plant. In the case of sicklepod and peanut, the adjacent leaflet was taken. Separating the leaf tissue into progressively more distal areas from the site of applications was considered an appropriate method to detect subtle differences in herbicide behavior. All plant parts were oven dried for 48 h at 40 C, weighed, and combusted in a biological sample oxidizer[4]. Radioactivity was quantified by liquid scintillation spectrophotometry.

Preliminarily trials by the authors (data not shown) indicated that recovery of $^{14}C$-paraquat was ≥97% of the amount applied. Since bipyridylium herbicides are not degraded in plant tissue (6), it was assumed that all recovered radioactivity represented unaltered paraquat. Recovery of $^{14}C$-2, 4-DB was ≥94%. 2,4-DB has been reported to remain immobile until converted to 2,4-D through beta oxidation (9, 14). Ketchersid (9) applied $^{14}C$-2, 4-DB to peanut seedlings which were maintained at 100% relative humidity. After 24 h, 96% of the applied radioactivity was recovered as unaltered 2,4-DB in either the leaf wash or the treated leaf and 3% was recovered within the treated leaf as 2,4-D. Consequently, in our study we assumed that all recovered radioactivity represented unaltered 2,4-DB. The amounts of radioactivity recovered from the rinsate and each tissue segment were expressed as percent of the total applied. Data for each species were analyzed by multivariate techniques so that the absorption and translocation of paraquat applied alone could be to when applied in combination with 2,4-DB. Similarly, the absorption and distribution of 2,4-DB with and without the addition of paraquat were compared.

**Field study.** Field experiments were conducted in 1987 and 1989 at Headland Ala. on a Dothan sandy loam soil (fine-loamy, siliceous thermic Kandiudults). Soil organic matter was 1.3% and the pH was 6.5. For the control of annual grasses, the experimental area was treated with a broadcast, preplant incorporated application of benefin[*N*-butyl-*N*-ethyl-2, 6-dinitro-4-(trifluoromethyl) benzenamine] at 1.7 kg ai/ha. The experimental areas were uniformly and heavily infested with Florida beggarweed and sicklepod. Experimental area was moldboard plowed in the spring following a winter cover crop of rye (*Secale cereale* L.). Peanuts were planted with conventional equipment at a seeding rate of 112 kg/ha. The experiment consisted of a factorial arrangement of paraquat at 0, 0.14 and 0.28 kg/ha and 2,4-DB at 0, 0.20, 0.30 and 0.50 kg/ha. Two nontreated treatments were also included with one hand weeded on a weekly basis, and weeds allowed to grow in the other. Each treatment was assigned to four plots utilizing a randomized block design. Individual plots consisted of four rows spaced 91 cm apart and 6.1 m long. Herbicide applications were made with a tractor-mounted, compressed-air sprayer delivering 140 L/ha at 220 kPa. A nonionic surfactant at 0.25% (v/v) was included in all herbicide-containing treatments. Treatments were applied in the third week after peanut emergence. At this time peanuts had 5-to 7-true leaves and had not started to flower; Florida beggarweed and sicklepod ranged from the cotyledonary stage to 2-true leaves.

Visual estimates of weed control and crop injury were taken 3 weeks after herbicide application. Weed control was evaluated on a scale of 0% (no control) to 100% (complete control) on the basis of weed density and vigor. A similar scale was used for crop injury. The crop was harvested with conventional harvesting equipment and plot yield was expressed on a kg/ha basis.

Data from both years were subjected to analysis of variance and since treatment performance did not vary significantly between years, data were pooled for presentation. All visual data were analyzed in their original form and with arcsin transformation. The results of the analysis were the same, therefore the visual evaluation data were analyzed in the original form.

# Results and Discussion

**Greenhouse study**. Paraquat applied alone to peanuts at 0.07 and 0.14 kg/ha resulted in 3 and 7% injury, respectively (Table 1). 2,4-DB applied alone produced no visual injury. All tank mix combinations of the two herbicides were noninteractive on peanuts.

Paraquat was most active on Florida beggarweed. The lowest rate of paraquat applied alone (0.06 kg/ha) provided 89% control. The most tolerant species to paraquat applied

**Table 1. Interaction of paraquat and 2,4-DB on peanuts and selected species under greenhouse conditions.**

| Herbicide | | Visual injury | Fresh weight reduction[a] | | |
|---|---|---|---|---|---|
| Paraquat | 2,4-DB | Peanut | Smallflower morningglory | Florida beggarweed | Sicklepod |
| kg/ha | | % | | | |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0.07 | 0 | 3 | 33 | 89 | 46 |
| 0.14 | 0 | 7 | 62 | 99 | 94 |
| 0 | 0.05 | 0 | 16 | 12 | 11 |
| 0 | 0.10 | 0 | 44 | 21 | 49 |
| 0 | 0.20 | 0 | 45 | 29 | 52 |
| 0.07 | 0.05 | 3 | 48 | 99 + | 72 + |
| 0.07 | 0.10 | 4 | 66 | 99 + | 86 + |
| 0.07 | 0.20 | 4 | 67 | 99 + | 94 + |
| 0.14 | 0.05 | 6 | 67 | 99 | 93 |
| 0.14 | 0.10 | 7 | 70 + | 99 | 95 |
| 0.14 | 0.20 | 8 | 72 + | 99 | 92 |
| LSD(0.05) | | | 3 | 2 | 4 |

[a] Interactions were evaluated by the method described by Colby(4), '+' denotes synergism and no marking indicates an additive effect. Interactions were considered significant if the difference between the observed and expected values exceeded the appropriate LSD value.

alone was smallflower morningglory with 0.07 and 0.14 kg/ha resulting only 33 and 62% control, respectively. Sicklepod was intermediate with these two rates resulting in 46 and 94% control, respectively.

Smallflower morningglory and sicklepod were more sensitive to 2,4-DB than was Florida beggarweed. 2,4-DB applied at 0.20 kg/ha resulted in 45 and 52% control for these two species, respectively. Florida beggarweed control was only 29% with the highest application rate of 2,4-DB (0.9 kg/ha).

All tank mixtures of 2,4-DB and paraquat were either noninteractive or were synergistic. With sicklepod and Florida beggarweed, tank mixtures of paraquat at 0.07 kg/ha combined with any rate of 2,4-DB were deemed synergistic. The high rate of paraquat resulted in at least 92% control of both species, thereby masking any potential interactions. With smallflower morningglory, only combinations of the two higher rates of 2.4-DB and the higher rate of paraquat were synergistic and all remaining combinations were non-interactive. With the registered rate of paraquat and 2,4-DB (i.e. 0.14 and 0.20 kg/ha, respectively) the tank mixture resulted in no interactions on sicklepod and Florida beggarweed, but was synergistic with respect to smallflower morningglory control.

**Absorption and translocation.** Across all species, with $^{14}C$-paraquat applied alone approximately 30% of the amount applied was recovered in the leaf wash (Table 2). Paraquat absorption and translocation was not affected by the addition of 2,4-DB in any species. With $^{14}C$-2,4-DB applied alone, approximately 10% of the amount applied was recovered in the leaf wash. In only one species (smallflower morningglory) was the distribution of 2,4-DB affected by the addition of paraquat. In this case, the difference was not due to a difference in the amount absorbed, but to a greater amount

**Table 2. Absorption and distribution of $^{14}C$-paraquat and $^{14}C$-2, 4-DB alone and in reciprocal mixtures in peanuts and selected weeds[1].**

| | $^{14}C$-paraquat | $^{14}C$-paraquat + 2,4-DB | Univariate contrast | $^{14}C$-2,4-DB | $^{14}C$-2,4-DB + paraquat | Univariate contrast |
|---|---|---|---|---|---|---|
| | (% of amount applied) | | | (% of amount applied) | | |
| Peanut | | | | | | |
| Leaf wash | 34 | 30 | 0.29 | 9 | 16 | 0.04 |
| 1-cm radius around target | 54 | 54 | 1.00 | 87 | 80 | 0.16 |
| Remainder of treated leaf | 10 | 11 | 0.85 | 3 | 3 | 1.00 |
| Adjacent leaf | 2 | 4 | 0.21 | 1 | 1 | 1.00 |
| Multivariate Comparison | 0.59 | | | 0.25 | | |
| Sicklepod | | | | | | |
| Leaf wash | 30 | 36 | 0.46 | 8 | 10 | 0.73 |
| 1-cm radius around target | 39 | 35 | 0.71 | 84 | 77 | 0.39 |
| Remainder of treated leaf | 14 | 14 | 1.00 | 3 | 8 | 0.33 |
| Adjacent leaflet | 17 | 14 | 0.81 | 4 | 4 | 1.00 |
| Multivariate Comparison | 0.77 | | | 0.82 | | |
| Smallflowered morningglory | | | | | | |
| Leaf wash | 26 | 30 | 0.62 | 8 | 7 | 0.90 |
| 1-cm radius around target | 38 | 36 | 0.84 | 80 | 47 | 0.01 |
| Remainder of treated leaf | 36 | 34 | 0.87 | 11 | 46 | 0.02 |
| Multivariate Comparison | 0.89 | | | 0.01 | | |
| Florida beggarweed | | | | | | |
| Leaf wash | 31 | 33 | 0.62 | 13 | 15 | 0.67 |
| 1-cm radius around target | 67 | 66 | 0.56 | 74 | 76 | 0.67 |
| Remainder of treated leaf | 2 | 1 | 0.71 | 13 | 9 | 0.21 |
| Multivariate comparison | 0.73 | | | 0.91 | | |

[1]Solutions were applied as a single 5 ul drop. These drops were confined by small "O" rings (3 mm diameter) which were sealed to the leaf surface with lanolin. All plants were 3 weeks old at the time of treatment. Treatment exposure time was 48 hrs.

being translocated out of the immediate target area and into the remainder of the treated leaf. The absorption and translocation of paraquat is not inhibited by the addition of 2,4-DB. And conversely, the absorption and translocation of 2,4-DB is not inhibited by the addition of paraquat.

**Field Study.** Paraquat applied alone at 0.14 kg/ha resulted in 83 and 91% control of the Florida beggarweed and sicklepod, respectively (Table 3). Increasing the paraquat rate to 0.28 kg/ha increased control by only 4%. Peanut yield was numerically higher with the higher rate of paraquat alone, yet both rates were statistically equivalent to the weed free control. All treatments with 2,4-DB applied alone provided at least 87% sicklepod control, and less than 45% Florida beggarweed control. Peanut yield was less than that obtained in the weed free control.

All tank mixtures of 2,4-DB and paraquat provided at least 83 and 93% control of Florida beggarweed and sicklepod, respectively. However this level of control was no better than that provided by either rate of paraquat alone. Peanut injury was equivalent to that obtained with paraquat applied alone. Peanut yields from all tank mixtures were equivalent to the weed free control.

These results indicates that paraquat and 2,4-DB are generally noninteractive with respect to crop response and to control of sicklepod and Florida beggarweed. Furthermore, absorption and translocation of these herbicides are not influenced by the presence of the other. It has been demonstrated that paraquat can provide good to excellent control of sicklepod (18). This data indicates that the addition of 2,4-DB generally offers no benefit over that from paraquat applied alone. However, it has been the authors' observation (unpublished) that this level of control is contingent on the sicklepod being no more mature than the 3 to 4-true leaf stage. Tank mixtures of paraquat and 2,4-DB are generally more effective in controlling more mature sicklepod plants than paraquat alone, in addition control is extended to smallflower morningglory.

## Literature Cited


1. Anonymous. 1986. Environmental Protection Agency: Pesticide Products Containing Dinoseb. Federal Register. Vol. 51. No. 198, Part II. pp. 36634-36661.
2. Brian, R. C. 1969. The influence of darkness of the uptake and movement of diquat and paraquat in tomatoes, sugar beet and potatoes. Ann. Appl. Biol. 63:117-126.
3. Buchanan, G. A., D. S. Murray, and E. W. Hauser. 1983. Weeds and their control in peanuts. pp. 206-249. *in* H. E. Pattee and C. T. Young (eds.), Peanut Science and Technology. Amer. Peanut. Res. and Educ. Soc., Yoakum, TX 77995.
4. Colby, S. R. 1967. Calculating synergistic and antagonistic responses of herbicide combinations. Weeds 15:20-22.
5. Elmore, C. D. 1989. Weed Survey - Southern States. Proc. South Weed Sci. Soc. 42:408-420.
6. Funderburk, H. B. and J. M. Lawrence. 1964. Mode of action and metabolism of diquat and paraquat. Weeds. 12:259-264.
7. Hauser, E. W. and G. A. Buchanan. 1974. Control of Florida beggarweed and sicklepod in peanuts with dinoseb. Peanut Sci. 1:40-44.
8. Hawf, L. R., and R. Behrens. 1974. Selectivity factors in response of plants to 2,4-DB. Weed Sci. 22:245-249.
9. Ketchersid, M. L., T. E. Boswell and M. G. Merkle. 1978. Effect of 2,4-DB on yield and pod development in peanuts. Peanut Sci. 5:35-39.
10. O'Donovan, J. T. and P. A. O'Sullivan. 1982. Amine salts of growth regulator herbicides antagonize paraquat. Weed Sci. 30:605-608.
11. O'Donovan, J. T., P. A. O'Sullivan, and C. D. Caldwell. 1983. Basis for antagonism of paraquat phytotoxicity to barley by MCPA dimethylamine. Weed Res. 23:165-172.
12. O'Sullivan, P. A. and J. T. O'Donovan. 1982. Influence of several herbicides for broad-leaved weed control and Tween 20 on the phytotoxicity of paraquat. Can. J. Plant Sci. 62:445-452.
13. Thrower, S. L., N. D. Ballam, and L. B. Thrower. 1965. Movement of


**Table 3. Weed control with paraquat, 2,4-DB and tank mixtures thereof in peanuts under field conditions; Headland Ala. 1987-1989.**

| Herbicide | Rate | Peanut injury | Weed Control: Florida beggarweed | Weed Control: Sicklepod | Yield |
|---|---|---|---|---|---|
| | kg/ha | % | % | % | kg/ha |
| Paraquat | 0.14 | 8 | 83 | 91 | 2250 |
| Paraquat | 0.28 | 14 | 87 | 95 | 2410 |
| 2,4-DB | 0.20 | 0 | 44 | 90 | 2100 |
| 2,4-DB | 0.30 | 0 | 38 | 87 | 2200 |
| 2,4-DB | 0.50 | 4 | 42 | 91 | 2200 |
| Paraquat + 2,4-DB | 0.14 + 0.20 | 7 | 83 | 95 | 2520 |
| Paraquat + 2,4-DB | 0.14 + 0.30 | 7 | 88 | 94 | 2470 |
| Paraquat + 2,4-DB | 0.14 + 0.50 | 9 | 92 | 94 | 2420 |
| Paraquat + 2,4-DB | 0.28 + 0.20 | 15 | 85 | 93 | 2460 |
| Untreated weedy | ---- | 0 | 0 | 0 | 2090 |
| Untreated weed free | ---- | 0 | 100 | 100 | 2560 |
| $LSD_{0.05}$ | | 3 | 9 | 7 | 290 |

diquat dibromide in leguminous plants. Ann. Appl. Biol. 55:253-260.
14. Wathana, S., F. T. Corbin, and T. W. Waldrep. 1972. Absorption and translocation of 2,4-DB in soybeans and cocklebur. Weed Sci. 20:120-123.
15. Wehtje, G., J. A. McGuire, R. B. Walker, and M. G. Patterson. 1986. Texas Panicum (*Panicum texanum*) control in peanuts (*Arachis hypogaea*) with paraquat. Weed Sci. 34:308-311.
16. Wehtje, G., J. W. Wilcut, D. L. Dylewski, J. A. McGuire and T. V. Hicks. 1991. Antagonism of paraquat phytotoxicity in peanuts and selected weed species by naptalam. Weed Sci. In press.
17. Wehtje, G., J. W. Wilcut, and J. A. McGuire. 1992. Influence of bentazon on the phytotoxicity of paraquat to peanuts and associated weeds. Weed Sci. In Press.
18. Wilcut, J. W., G. Wehtje, T. V. Hicks and J. A. McGuire. 1989. Postemergence weed control systems without dinoseb for peanuts (*Arachis hypogaea*). Weed Sci. 37:385-391.
19. Wilcut, J. W., and C. W. Swann. 1990. Timing of paraquat applications for weed control in Virginia-type peanuts (*Arachis hypogaea*). Weed Sci. 38:558-562.

Accepted March 7, 1992