PEANUT SCIENCE

VOLUME 26 | JANUARY - JUNE 1999 | NUMBER 1

Influence of Adjuvants on Efficacy of Imazapic and 2,4-DB

D. L. Jordan[1]

ABSTRACT

Adjuvants can have a major influence on efficacy of postemergence herbicides. Imazapic and 2,4-DB are applied postemergence in peanut (*Arachis hypogaea* L.) to control a variety of weeds. Determining how adjuvants influence efficacy of these herbicides could lead to more efficient weed management. Field experiments were conducted during 1997 and 1998 to determine the influence of nonionic surfactant, crop oil concentrate, organosilicone surfactant, and a blend of organosilicone surfactant and methylated seed oil on efficacy of imazapic and 2,4-DB. No-adjuvant and nontreated controls were also included. Adjuvants did not increase redroot pigweed (*Amaranthus retroflexus* L.) or common cocklebur (*Xanthium strumarium* L.) control by imazapic. Only minor differences in control of eclipta (*Eclipta prostrata* L.), entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), and pitted morningglory (*Ipomoea lacunosa* L.) by imazapic were noted among adjuvants. Sicklepod [*Senna obtusifolia* (L.) Erwin and Barneby] and pitted morningglory control increased when 2,4-DB was applied with adjuvants. Common cocklebur control was improved in one of three experiments when adjuvants were applied with 2,4-DB. Redroot pigweed and entireleaf morningglory control by 2,4-DB was not affected by adjuvants.

Key Words: Additives, adjuvant blend, crop oil concentrate, herbicide, methylated seed oil, nonionic surfactant, organosilicone surfactant, weed control.

Efficacy of postemergence herbicides can be influenced by weed species, growth stage (King and Oliver 1992; Klingaman *et al.*, 1992), environmental conditions (Wanamarta and Penner, 1989; Kent *et al.*, 1991), and adjuvants (Nalewaja *et al.*, 1986; Reddy and Singh, 1992; Hatzios and Penner, 1995). Adjuvants enhance herbicide efficacy primarily through increased herbicide absorption (Wanamarta and Penner, 1989). Crop oil concentrates, methylated seed oils, organosilicone surfactant, nonionic surfactants, and various blends of these adjuvants are commercially available (Mack *et al.*, 1995).

Imazapic {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyridinecarboxylic acid} and 2,4-DB [4-(2,4-dichlorophenoxy)butanoic acid] are registered for postemergence application in peanut. Imazapic is used to control sedges (*Cyperus* spp.) and certain annual grasses and broadleaf weeds (Wilcut *et al.*, 1995). Peanut growers routinely apply 2,4-DB to control common cocklebur and morningglory (*Ipomoea* spp.) (Wilcut *et al.*, 1995). They also apply 2,4-DB with other herbicides to improve efficacy on certain broadleaf weeds or to increase the spectrum of control. The manufacturer of imazapic recommends use of crop oil concentrate or nonionic surfactant to maximize efficacy (Anonymous, 1999). Nonionic surfactant is often applied with 2,4-DB (Anonymous, 1996).

Organosilicone surfactants are a relatively new group of adjuvants. Efficacy of several postemergence herbicides has been increased when applied with organosilicone surfactants compared with conventional nonionic surfactant (Reddy and Singh, 1992). Other research (Jordan *et al.*, 1996) reported greater efficacy of clethodim {(*E*,*E*)-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} applied with a blend of methylated seed oil and organosilicone surfactant or crop oil concentrate rather than nonionic surfactant or organosilicone surfactant. In contrast, hemp sesbania [*Sesbania exaltata* (Raf.) Rybd. ex. A. W. Hill] was controlled more effectively when chlorimuron {2-[[[[(4-chloro-6-methoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid} was applied with organosilicone surfactant or nonionic surfactant than when applied with crop oil concentrate (Jordan and Burns, 1996).

Determining if adjuvants improve efficacy of imazapic

[1]Asst. Prof., Dept. of Crop Science, North Carolina State Univ., Raleigh, NC 27695-7620.

and 2,4-DB may lead to more efficient weed control. Therefore, research was conducted to compare efficacy of imazapic and 2,4-DB when applied with nonionic surfactant, crop oil concentrate, organosilicone surfactant, a blend of methylated seed oil and organosilicone surfactant, or without adjuvant.

Materials and Methods

The experiments were conducted at the Peanut Belt Research Station located near Lewiston, NC, the Upper Coastal Plain Research Station located near Rocky Mount, NC, and at on-farm sites in Chowan County located near Edenton, NC in 1997 and 1998. Soils at these locations ranged from sandy loam to sandy clay loam. Organic matter content ranged from 1.3 to 2.1% and pH ranged from 5.6 to 6.2. Experiments were conducted in fallow areas or in fields with peanut (cv. NC 7). Plot size was 2 m by 6 m. Peanuts were not harvested.

The experimental design was a randomized complete block with treatments replicated three or four times. In separate experiments, imazapic or 2,4-DB were applied alone or with nonionic surfactant (0.25% v/v), crop oil concentrate (1.0% v/v), organosilicone surfactant (0.125% v/v), or a blend of methylated seed oil and organosilicone surfactant (0.5% v/v). A nontreated control was included. Imazapic was applied at 0.07 and 0.09 kg ai/ha in 1997 and 1998, respectively. 2,4-DB was applied at 0.28 kg ai/ha. Trade names and a description of each adjuvant are listed in Table 1. Treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha at 220 kPa using flat fan nozzles. Although pressurization with CO_2 can alter spray solution pH (McCormick, 1990; Braverman and Griffin, 1995), changes in pH were not measured in these studies.

Common cocklebur, entireleaf morningglory, pitted morningglory, and redroot pigweed control by imazapic was evaluated in three, two, one, and three experiments, respectively. Control of these respective weeds by 2,4-DB was evaluated in two, two, one, and two experiments. Eclipta control by imazapic was evaluated in three experiments and sicklepod control by 2,4-DB was evaluated in two experiments. Herbicides were applied when common cocklebur, redroot pigweed, and sicklepod were 10 to 16 cm in height with six to 10 leaves. Morningglories had five to 12 leaves. Eclipta had three to six leaves and was 4 to 8 cm in height when herbicides were applied.

Visual estimates of percentage control were recorded approximately 3 wk after treatment using a scale of 0 to 100 where 0 = no control and 100 = complete control. Foliar chlorosis, necrosis, plant stunting, and plant death were used in determining the visual estimates. Data were jected to analysis of variance for individual species and were pooled over years or locations (referred to as experiments) when appropriate. Means were separated using Fisher's Protected LSD Test at P = 0.05.

Results and Discussion

Imazapic. The interaction of adjuvant by experiment was not significant for common cocklebur or redroot pigweed control by imazapic. When pooled over experiments, common cocklebur and redroot pigweed were controlled 94 to 98% and 92 to 93%, respectively (data not shown). There were no differences in control among adjuvants for these species, or when comparing control by imazapic applied with adjuvants to the no-adjuvant control. Other research (Wilcut *et al.*, 1995) had shown excellent control of common cocklebur and redroot pigweed by imazapic.

The interaction of adjuvant by experiment was significant for entireleaf morningglory and eclipta control. Therefore, data are presented by experiment for these species. Variation in control by the different adjuvants caused the interaction. At Lewiston in 1997, no difference in entireleaf morningglory control was noted when imazapic was applied with nonionic surfactant or crop oil concentrate (Table 2). Imazapic applied with the blend of methylated seed oil and organosilicone surfactant, crop oil concentrate, or organosilicone surfactant controlled entireleaf morningglory similarly. In this experiment, control by imazapic applied with nonionic surfactant exceeded that by imazapic applied without adjuvant or when applied with the blend of methylated seed oil and organosilicone surfactant or organosilicone surfactant. At Rocky Mount in 1998, applying imazapic with organosilicone surfactant was more effective than imazapic applied with other adjuvants or the no-adjuvant control. Control by imazapic applied with nonionic surfactant, the blend of methylated seed oil and organosilicone surfactant, crop oil concentrate, or application without adjuvant was similar.

Eclipta control did not exceed 55% regardless of the adjuvant treatment or the experiment (Table 2). Eclipta control by imazapic is generally unacceptable (Wilcut *et al.* 1995). In two of the experiments, control did not differ among adjuvant treatments. However, at Rocky Mount in 1998, imazapic plus organosilicone surfactant, crop oil concentrate, or the blend of methylated seed oil and organosilicone surfactant controlled eclipta more effectively than imazapic applied with nonionic surfactant or when applied without adjuvant.

Table 1. Adjuvants and adjuvant constituents used in experiments.

Adjuvant	Trade name	Adjuvant constituent
Nonionic surfactant	Induce	Alkylarylpolyoxyalkane ether, free fatty acids isopropyl (90%) and water and formulation aids (10%)
Crop oil concentrate	Agri-Dex	Paraffin-based petroleum oil (83%) and surfactant blend (17%)
Organosilicone surfactant	Kinetic	Proprietary blend of polyalkyleneoxide modified polydimethylsiloxane
Blend of methylated seed oil and organosilicone surfactant	Dyne-Amic	80% methlylated seed oil and 20% alkylene oxide, silicone

Table 2. Influence of adjuvants on efficacy with imazapic.

	Weed species					
			Eclipta			
	Entireleaf morningglory		Lewiston		Rocky Mount	Pitted morningglory
Adjuvant[a]	Lewiston, 1997	Rocky Mount, 1998	1997	1998	1998	Lewiston, 1997
	% control					
NIS	82	88	38	20	23	63
MSO/OSL	68	87	30	47	47	78
COC	73	83	18	50	55	73
OSL	67	98	27	48	52	45
No adjuvant	53	89	28	55	25	43
Nontreated	0	0	0	0	0	0
LSD (0.05)	12	8	25	32	20	18

[a]NIS, nonionic surfactant at 0.25% v/v; MSO/OSL, blend of methylated seed oil and organosilicone surfactant at 0.5% v/v; COC, crop oil concentrate at 1.0% v/v; OSL, organosilicone surfactant at 0.125% v/v.

subImazapic controlled pitted morningglory 43 or 45% when applied without an adjuvant or with organosilicone surfactant, respectively (Table 2). Applying this herbicide with crop oil concentrate or a blend of methylated seed oil and organosilicone surfactant increased control over that obtained with imazapic with no adjuvant or organosilicone surfactant. However, there was no difference in control by imazapic when applied with nonionic surfactant, crop oil concentrate, or the blend of methylated seed oil and organosilicone surfactant.

2,4-DB. The interaction of adjuvant treatment by experiment was not significant for entireleaf morningglory or redroot pigweed control. When data were pooled over experiments, entireleaf morningglory control ranged from 61 to 73% and redroot pigweed control ranged from 67 to 75% (data not shown). There was no difference in control of these species by 2,4-DB as a result of adjuvant treatment. In contrast, pitted morningglory control by 2,4-DB varied among adjuvant treatments (Table 3). Control by 2,4-DB applied with nonionic surfactant or organosilicone surfactant was 68 and 63%, respectively, while control with the blend of methylated seed oil and organosilicone surfactant and crop oil concentrate was 72 and 75%, respectively. Adjuvants improved pitted morningglory control by 2,4-DB at least 26% when compared with the no-adjuvant control.

Table 3. Influence of adjuvants on efficacy with 2,4-DB.

	Weed species			
	Pitted morningglory (1998)	Sicklepod (1998)		Common cocklebur
	Edenton,	Edenton		Edenton,
Adjuvant[a]	Loc. 1	Loc. 1	Loc. 2	1997
	% control			
NIS	68	60	50	87
MSO/OSL	72	58	73	83
COC	75	50	32	88
OSL	63	53	53	80
No adjuvant	37	37	25	70
Nontreated	0	0	0	0
LSD (0.05)	10	11	25	15

[a]NIS, nonionic surfactant at 0.25% v/v; MSO/OSL, blend of methylated seed oil and organosilicone surfactant at 0.5% v/v; COC, crop oil concentrate at 1.0% v/v; OSL, organosilicone surfactant at 0.125% v/v.

In most instances, sicklepod control by 2,4-DB increased when adjuvants were applied. At Location 1 in Edenton, sicklepod control increased from 13 to 23% with adjuvant treatments. No difference in control was noted among adjuvants. At the other location, sicklepod control by 2,4-DB applied with nonionic surfactant, the blend of methylated seed oil and organosilicone surfactant, or organosilicone surfactant was similar and ranged from 50 to 73%. Control by 2,4-DB applied with crop oil concentrate or no adjuvant was similar (32 and 25%, respectively).

The interaction of adjuvant treatment by experiment was significant for common cocklebur control by 2,4-DB (Table 3). In one experiment, 2,4-DB completely controlled common cocklebur regardless of the adjuvant treatment (data not shown). However, control by 2,4-DB applied with nonionic surfactant or crop oil concentrate exceeded that by the no-adjuvant control at Edenton in 1997. Common cocklebur control by 2,4-DB in combination with adjuvants ranged form 80 to 88%.

Results from these studies suggest that efficacy of imazapic and 2,4-DB can vary depending upon the species and the adjuvant. The manufacturer of imazapic recommends using nonionic surfactant or crop oil concentrate. Control by imazapic applied with these adjuvants was similar in all instances except for eclipta control in one experiment. With the exception of entireleaf morningglory control at Rocky Mount in 1998, the organosilicone surfactant and the blend of methylated seed oil and organosilicone surfactant did not improve control by imazapic over control with crop oil concentrate or nonionic surfactant. Thus, applying imazapic with adjuvants other that nonionic surfactant or crop oil concentrate appears to be of little benefit for controlling the weeds evaluated in these studies.

Adjuvants did not enhance control of entireleaf morningglory or redroot pigweed by 2,4-DB. Additionally, applying adjuvants with 2,4-DB had only minor effects on common cocklebur control. Therefore, these data suggest that adjuvants may not be needed when controlling entireleaf morningglory, common cocklebur, or redroot pigweed. However, pitted morningglory and sicklepod control by 2,4-DB increased when adjuvants were included. These weeds are difficult to control with 2,4-DB (Wilcut *et al.*, 1995), and applying adjuvants with 2,4-DB may increase the likelihood of obtaining acceptable control.

No differences in visual injury to peanut were noted among adjuvant treatments for either imazapic or 2,4-DB (data not presented). Results from these studies are consistent with other research showing that improvement in efficacy of postemergence herbicides by adjuvants can vary among weed species, adjuvants, and complex interactions among these factors. Therefore, growers must consider the entire weed spectrum when deciding whether or not specific adjuvants are more efficacious.

Acknowledgments

Imazapic was supplied by American Cyanamid and 2,4-DB was supplied by Rhone Poleunc. Adjuvants were supplied by Helena Chemical Co. Dewayne Johnson provided technical assistance.

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