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Effects of Certain Additives on Activity of Some Postemergence Herbicides in Relation with Carrier Volume

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ABSTRACT

Field experiments were conducted to determine the effect of OPPEE (octyl phenoxy polyethoxyethanol), AAPE + SASA (alkyl aryl polyethoxylate + sodium salt of alkylsulfonated alkylate), thalestol, and TAE (tallow amine ethoxylate) at various concentrations to increase activity of glyphosate, glufosinate, and imazapyr on *Imperata cylindrica* L. and the effect of the same additive to increase activity of glyphosate on *Cyperus rotundus* L. and *Cynodon plectostachyous* (L.) Pers. Herbicides in combination with additives were applied at low carrier volume (14.4-48.7 l/ha) and at high carrier volume (138.2-265.0 l/ha). It was found that various additives alone did not increase activity of glyphosate, glufosinate, and imazapyr on *I. cylindrica and C. plectostachyous.* But OPPEE at 0.12, 0.25, and 0.5% (v/v), thalestol at 0.25 and 0.5% (v/v), and TAE at 0.25, 0.5, and 1.0% (v/v) increased activity of glyphosate at 0.63 kg ai./ha when it was applied at 14.4 l/ha on *C. rotundus.* OPPEE, AAPE + SASA, and thalestol at 0.25% (v/v), and TAE at 0.5% (v/v) also increased activity of glyphosate at 1.8 or 1.4 kg ai./ha on *C. rotundus* at the carrier volume of 38.1 and 128.2 l/ha. Phytotoxicity of glyphosate on *I. cylindrica, C. rotundus,* and *C. plectostachyous* increased when carrier volume was reduced. However, phytotoxicity of glufosinate and imazapyr on *I. cylindrica* decreased when carrier volume was reduced.

INTRODUCTION

Alternation (enhancement or decrease) of the activity of a given herbicide on a target plant brought about by the prior or simultaneous application of another agrochemical may be the result of changes in the amount of herbicide reaching the site of its action in an active form. There are many known cases of agrochemical mixture influences the toxicity of a herbicide by interfering with the patterns of its penetration, translocation or biotransformation in plants. However, a given agrochemical may also influence the toxicity of a herbicide by interacting with it at the site of its biochemical or physiological action within plant cells (Hatzios and Penner, 1985). Several classes of agrochemicals including additives, fertilizers, herbicides, insecticides, and growth regulators have been reported to synergize the activity of selected herbicides on certain plant species.

The importance of additives for optimizing activity of many post-emergence compounds is well recognized. The most obvious and generally accepted action of additives is the reduction of surface and interfacial tensions which can greatly enhance coverage and retention of the target species (Hull *et al.*, 1982). However, many other types of mechanism on additive action have been suggested but exact roles of additive are still unclear (McWhorter, 1985).

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Absorption and translocation of glyphosate in field bindweed (*Convolvulus arvensis* L.) was enhanced two to three folds when herbicide was applied together with a polyethoxylated tallow amine under low light and high humidity or high light and low humidity condition (Sherrick *et al.*, 1986 a). However, polyoxyethelene sorbitan monolaurate enhanced glyphosate absorption into field bindweed when plant was grown under low light and high humidity (Sherrick *et al.*, 1986 a). Polyethoxylated tallow amine did not disrupt the cuticle of the field bindweed, however, the compound might act as a counter ion at the cuticle, cell wall or plasmalemma. This may provide a more favorable electrochemical gradient for cellular absorption of glyphosate (Sherrick *et al.*, 1986 b).

The activity of glyphosate for gorse (*Utex europaeus* L.) control also increased when octyl phenoxy polyethoxyethanol at 0.5 percent or polyalkyleneoxide modified by dimethyl polysiloxane at 0.25 percent was added to glyphosate at 0.36 kg ai./100 liters. Both of these additives conferred significant rain-fastness to glyphosate when applied to gorse (Lane and Park, 1984). Moreover, addition of octyl phenoxy polyethoxyethanol nullify the negative impact of rainfall on the foliar activity of glyphosate on corn plants (Rahman, 1985). Certain additives increase activity of specific herbicide on specific weed species under optimum environmental condition (Hull *et al.*, 1982).

Glyphosate is a nonselective, translocated, foliage absorbed herbicide that control many annual and perennial weeds (Thomson, 1983). Glufosinate is a herbicide in the same group as glyphosate being nonselective, contacted and foliage absorbed herbicide. It was reported to control annual and perennial weeds (Thomson, 1983). Imazapyr is an imidazole compound used as a nonselective pre- and post-emergence herbicide. Imazapyr can control many annual and perennial weeds in noncrop areas. The persistence of the compound in soil is three months to one year depending upon dosage and moisture (Thomson, 1983). Glyphosate has been reported to control *Imperata cylindrica* and *Cyperus rotundus*. The activity of glufosinate and imazapyr on both weeds should be investigated.

Greenhouse and field observations indicated that glyphosate phytotoxicity is influenced by several application factors (Ambach and Ashford, 1982). Carrier volume has a significant influence on glyphosate phytotoxicity. Carrier volume above 100 l/ha has resulted in less than maximum glyphosate phytotoxicity (Buhler and Burnside, 1983).

I. cylindrica and *C. rotundus* are problem weeds in crops in Thailand and many parts of the world (Holm *et al.*, 1977). Both weeds are perennials. *I. cylindrica* is the most serious weed in rubber, oil palm, coffee and many other orchards. *C. rotundus* is an important weed in corn, sorghum, soybean, peanut, cotton, upland rice and vegetables. *Cynodon plectostachyous* is also a perennial weed found in some areas of Thailand. It was brought into Thailand as a forage crop almost 20 years ago.

Objectives of this research are (a) to compare the effect of additives at different concentration to increase activity of glyphosate, glufosinate, and imazapyr on *I. cylindrica, C. rotundus,* and *C. plectostachyous,* (b) to compare the effect of low carrier volume (applied by mist blower sprayer) and high carrier volume (applied by knapsack sprayer with flat fan) of glyphosate, glufosinate, and imazapyr activity on *I. cylindrica, C. rotundus,* and *C. plectostachyous.*

MATERIALS AND METHODS

Field experiments were conducted at National Corn and Sorghum Center, Pak Chong district, Nakhon Ratchasima province, Research Station of College of Agricultural Technology, Makham district, Chanthaburi province and Royal Angkhang Highland Research Station, Fang district, Chiang Mai province.

At National Corn and Sorghum Center, soil is clay loam. The soil was cultivated to allowed *C. rotundus* to grow for one month before herbicide application. During the time of application *C. rotundus* was 15-20 cm tall with 6 to

8 leaves per plant. Plants were uniformly dense with population of 750 to 1,100 plants/0.25 m^2 Plot size was 2×2 m^2 The plants were counted and recorded before herbicide application, and at 170 days after herbicide application. Herbicides were applied on October 15 and 16, 1986 with high relative humidity and 40 percent sunshine. Weed control rating was recorded at 8, 20 and 35 days after application.

At Research Station of College of Agricultural Technology, soil is loam. *I. cylindrica* was cut and allowed to grow for two months before the herbicide application. Plants were 45 to 65 plants/0.64 m^2, 1.0–1.5 m^2 tall and uniformly dense. Plot size was 3.0×3.0 m^2. Plants were counted and recorded before herbicide application and at 165 days after herbicide application. Herbicides were applied on October 31 and November 1 and 2, 1986 with low relative humidity and 100 percent sunshine. Weed control rating was recorded at 7, 15 and 45 days after application.

At Royal Angkhang Highland Research Station, soil is clay. *I. cylindrica* and *C. plectostachyous* were cut and allowed to grow for two months before herbicide application. Plants were 90 to 100 plants/m^2, 0.8-1.2 m tall and uniform dense. *C. plectostachyous* could not be counted because of prostrate habitat. Plot size was 4×5 m^2, *I. cylindrica* was counted before herbicide application and at 145 days after herbicide application. Herbicides were applied on December 3 and 4, 1986 with medium relative humidity and 100 percent sunshine. Weed control rating was recorded at 38 days after herbicide application.

Herbicides were applied by MD 300 Maruyama motor driven mist blower for the low carrier volume and Flix knapsack sprayer with 80015 flat fan nozzle for high carrier volume. The pressure of knapsack sprayer is controlled by manual pump with pressure gauge.

Herbicides, glyphosate, glufosinate and imazapyr used in these experiments are Round Up, Basta and Assault, respectively. Additives OPPEE (octyl phenoxy polyethoxyethanol), AAPE+SASA (alkyl aryl polyethoxylate + sodium salt of alkylsulfonated alkylate), thalestol and TAE (tallow amine ethoxylate) are Triton X-45, Triton CS-7, Triton B-1956, and Agrisorb respectively.

Experiments were designed as split plot or split-split plot in randomized complete block with three or four replications.

RESULTS AND DISCUSSION

Different rates of glyphosate provided different control of *I. cylindrica* at both Chanthaburi and Chiang Mai (Table 1, 2 and 3). At higher rate glyphosate gave better control in both locations (Tables 1, 2 and 3). Glyphosate applied at low carrier volume (17.5 l/ha) caused reduction of plants in 0.64 m^2, approximately 5 percent higher than at higher carrier volum (223.7 l/ha) (Table 1). The additive OPPEE, AAPE + SASA, thalestol and TAE did not increase glyphosate activity when the rate of glyphosate was in the range of 0.7 to 1.2 kg/ha in both locations (Tables 1, 2 and 3). Since glyphosate was applied at the end of the rainy season and the weather was dried. The weather condition might has influenced on additives to increase herbicidal activity. Additives increased glyphosate activity under low light intensity and high humidity (Sherrick *et al.*, 1986). Studied should be conducted to determine the effect of soil moisture on additive to increase glyphosate activity. Certain additive was suggested to be a binder on plant cuticle. They might improve glyphosate activity when the rain occurred at short period after application.

The efficacy of glyphosate was increased when it was applied on *C. rotundus* at the rate of 0.63 kg/ha at low carrier volume (14.4 l/ha) (Table 4). Additive OPPEE at 0.12, 0.25, and 0.5% (v/v), thalestol at 0.25 and 0.5% (v/v) and TAE at 0.25, 0.5, and 1.0% (v/v) increased glyphosate activity on *C. rotundus* at 20 days after application (Table 4). However, when different rates of glyphosate were applied in the carrier volumes of 38.1, 48.7, and 128.2 l/ha, additives did not increase herbicidal activity (Tables 5, 6 and 7). The activity of glyphosate was increased when the rate was increased (Tables 5, 6 and 7).

Table 1 Various additives in combination with different rates of glyphosate applied at two carrier volumes on *Imperata cylindrica* at Chanthaburi.

Glyphosate rate kg ai/ha	Carrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3] 7	15	45	% Reduction of[2] plants (DAA) 165
0.8				39.6	54.3	89.0	88.4
1.2				44.1	59.0	94.2	93.6
							NS
LSD (0.05)				4.15	3.38	1.53	
	17.5			40.7	57.6	91.0	93.3
	223.7			42.1	57.2	91.3	87.9
	LSD (0.05)			NS	NS	NS	3.92
			0	40.8	57.2	89.2	90.5
		OPPEE	0.12	39.3	53.7	90.1	87.6
		OPPEE	0.25	45.6	57.8	92.4	92.1
		OPPEE	0.5	40.0	57.2	92.5	90.4
		AAPE+SASA	0.12	39.2	58.3	91.5	93.2
		AAPE+SASA	0.25	43.3	58.3	91.5	84.2
		AAPE+SASA	0.5	38.1	55.8	88.7	94.4
		Thalestol	0.12	41.1	58.9	92.1	91.0
		Thalestol	0.25	43.9	57.8	90.0	89.9
		Thalestol	0.5	44.4	61.1	91.7	90.6
		TAE	0.25	37.2	52.5	91.0	92.9
		TAE	0.5	43.3	61.4	93.5	95.2
		TAE	1.0	42.2	56.1	89.8	89.4
	17.5	LSD (0.05)		NS	NS	NS	NS
0.8	223.7						
0.8	17.5			28.3	56.1	89.4	92.8
1.2	223.7			37.8	52.4	88.6	84.0
1.2				43.3	56.8	93.4	96.1
				40.0	61.1	95.1	91.2
LSD (0.05)							
				NS	4.78[4]	NS	NS

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 0.64 m^2/plot after herbicide application.

[3] DAA = days after application.

[4] Comparision between the same or different rates of glyposate.

Table 2 Various additives in combination with three rates of glyphosate applied at the carrier volume of 45.6 l/ha on *Imperata cylindrica* at Chiang Mai

Glyphosate rate kg ai/ha	Additives % (v/v)		Control rating[1] (DAA)[3]	% Reduction of[2] plants (DAA)
			38	145
0.7			57.8	29.9
0.9			68.2	32.5
1.1			77.6	52.2
LSD (0.05)			4.48	NS
		0		
	OPPEE	0.12	67.2	50.6
	OPPEE	0.25	65.6	39.1
	OPPEE	0.5	67.8	50.8
	AAPE+SASA	0.12	67.2	42.8
	AAPE+SASA	0.25	67.8	22.2
	AAPE+SASA	0.5	67.8	34.2
	Thalestol	0.12	67.2	25.0
	Thalestol	0.25	67.8	41.0
	Thalestol	0.5	69.4	38.8
	TAE	0.25	67.2	48.1
	TAE	0.5	68.3	55.2
	TAE	1.0	70.0	30.9
			69.4	17.2
	LSD (0.05)		NS	NS

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 1.0 m^2/plot after herbicide application.

[3] DAA = days after application.

Table 3 Various additives in combination with three rates of glyphosate applied at the carrier volume of 226.9 l/ha on *Imperata cylindrica* at Chiang Mai.

Glyphosate rate kg ai/ha	Additives % (v/v)		Control rating[1] (DAA)[3]	% Reduction of[2] plants (DAA)
			38	145
0.7			54.6	60.2
0.9			61.1	65.9
1.1			67.0	70.9
LSD (0.05)			5.91	NS
		0	56.7	60.9
	OPPEE	0.12	61.1	72.2
	OPPEE	0.25	62.2	71.1
	OPPEE	0.5	58.3	76.0
	AAPE+SASA	0.12	61.1	59.7
	AAPE+SASA	0.25	62.2	65.9
	AAPE+SASA	0.5	61.7	56.4
	Thalestol	0.12	62.8	70.5
	Thalestol	0.25	65.0	71.6
	Thalestol	0.5	56.7	65.8
	TAE	0.25	57.8	53.1
	TAE	0.5	62.8	74.5
	TAE	1.0	63.9	63.7
	LSD (0.05)		NS	NS

1 Control rating; 0 = no control, 100 = complete control.

2 % Reduction of plants calculated from number of plants decreased in 1.0 m^2/plot after herbicide application.

3 DAA = days after application.

Table 4 Various additives in combination with glyphosate at the rate of 0.63 kg/ha applied at three carrier volumes on *Cyperus rotundus* at Nakhon Ratchasima.

Glyphosate volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
			8	20	35	170
14.4			25.3	38.9	63.2	54.4
24.2			14.9	30.4	53.3	30.7
113.6			17.3	31.3	55.6	16.0
LSD (0.05)			3.54	3.80	4.34	17.18
		0	12.1	24.2	51.7	18.9
	OPPEE	0.12	22.7	39.2*[4]	58.7	37.2
	OPPEE	0.25	17.1	32.9*	57.3	35.6
	OPPEE	0.5	16.7	34.6*	60.0	38.7
	AAPE+SASA	0.12	18.7	30.8	55.0	26.3
	AAPE+SASA	0.25	18.3	31.7	53.7	34.8
	AAPE+SASA	0.5	19.6	30.0	49.2	15.9
	Thalestol	0.12	15.8	31.2	52.9	24.7
	Thalestol	0.25	20.0	34.6*	61.7*	44.5
	Thalestol	0.5	20.8	36.2*	61.2*	44.5
	TAE	0.25	18.7	35.0*	59.6	37.9
	TAE	0.5	22.5	33.3*	57.1	25.1
	TAE	1.0	26.2	42.5*	67.5*	53.9
	LSD (0.05)		NS	7.60	9.05	NS

1 Control rating; 0 = no control, 100 = complete control.

2 % Reduction of plants calculated from number of plants decreased in 0.25 m^2/plot after herbicide application.

3 DAA = days after application.

4 Comparision between the same or different rates of glyphosate,

* Surfactants increased phytotoxicity of glyphosate.

Table 5 Various additives in combination with three rates of glyphosate applied at the carrier volume of 38.1 l/ha on *Cyperus rotundus* at Nakhon Ratchasima.

Glyphosate rate kg ai/ha	Additives % (v/v)		Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
			8	20	35	170
1.8			39.2	69.0	86.0	65.6
3.6			40.7	81.2	91.7	63.6
LSD (0.05)			NS	6.92	NS	NS
		0	34.6	66.2	87.9	53.4
	OPPEE	0.25	43.3	77.9	90.0	64.6
	AAPE+SASA	0.25	45.0	77.5	88.3	61.4
	Thalestol	0.25	37.1	74.2	88.3	58.7
	TAE	0.5	43.3	77.9	92.1	67.3
	LSD (0.05)		NS	NS	NS	NS
1.8		0	20.0	45.0	80.0	72.3
1.8	OPPEE	0.25	48.7	73.7*[4]	87.5	69.3
1.8	AAPE+SASA	0.25	50.0	81.2*	90.0	59.6
1.8	Thalestol	0.25	31.2	68.7*	82.5	51.2
1.8	TAE	0.5	46.2	76.2*	90.0	75.6
3.6		0	45.0	82.5	93.7	60.0
3.6	OPPEE	0.25	36.2	81.2	93.7	63.1
3.6	AAPE+SASA	0.25	26.2	76.2	85.0	67.9
3.6	Thalestol	0.25	45.0	85.0	95.0	54.3
3.6	TAE	0.5	41.2	81.2	91.2	72.7
	LSD (0.05)		NS	14.67	NS	NS

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 0.25 m^2/plot after herbicide application.

[3] DAA = days after application.

[4] Comparision between the same or different rates of glyphosate,

* Surfactants increased phytotoxicity of glyphosate.

Table 6 Various additives in combination with three rates of glyphosate applied at the carrier volume of 48.7 l/ha on *Cyperus rotundus* at Nakhon Ratchasima.

Glyphosate rate kg ai/ha	Additives % (v/v)		Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
			8	20	35	170
0.8			67.2	87.7	97.7	54.3
1.3			78.5	90.0	100.0	62.0
1.8			75.0	89.7	100.0	60.7
LSD (0.05)			8.29	NS	1.56	NS
		0	68.3	88.3	98.3	51.6
	OPPEE	0.25	80.4	90.0	100.0	64.8
	AAPE+SASA	0.25	76.2	89.6	99.2	63.1
	Thalestol	0.25	72.5	89.6	99.6	60.8
	TAE	0.5	70.4	88.3	99.2	54.7
	LSD (0.05)		NS	NS	NS	NS

1 Control rating; 0 = no control, 100 = complete control.

2 % Reduction of plants calculated from number of plants decreased in 0.25 m^2/plot after herbicide application.

3 DAA = days after application.

Table 7 Various additives in combination with three rates of glyphosate applied at the carrier volume of 128.2 l/ha on *Cyperus rotundus* at Nakhon Ratchasima.

Glyphosate rate kg ai/ha	Additives	% (v/v)	Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
			8	20	35	170
0.6			22.2	45.0	59.5	51.8
1.0			24.0	57.7	74.5	59.3
1.4			27.0	57.0	73.5	58.0
LSD (0.05)			NS	9.99	9.02	NS
		0	21.1	45.0	65.0	56.6
	OPPEE	0.25	25.8	55.4	70.4	53.1
	AAPE+SASA	0.25	26.2	52.5	66.2	59.0
	Thalestol	0.25	22.1	53.7	71.7	63.8
	TAE	0.5	25.8	59.6	72.5	49.4
	LSD (0.05)		NS	NS	NS	NS
		0	27.5	45.0	66.2	58.8
0.6	OPPEE	0.25	16.2	38.7	51.2	39.4
0.6	AAPE+SASA	0.25	25.0	48.7	61.2	52.3
0.6	Thalestol	0.25	22.5	45.0	63.7	65.1
0.6	TAE	0.5	20.0	47.5	55.0	43.4
0.6						
		0	23.7	52.5	72.5	60.0
1.0	OPPEE	0.25	25.0	61.2	77.5	52.6
1.0	AAPE+SASA	0.25	25.0	53.7	68.7	59.9
1.0	Thalestol	0.25	20.0	56.2	72.5	64.1
1.0	TAE	0.5	26.2	65.0	81.2	60.0
1.0						
		0	15.0	37.5	56.2	51.0
1.4	OPPEE	0.25	36.2	66.2	82.5*	67.2
1.4	AAPE+SASA	0.25	28.7	55.0	68.7	64.7
1.4	Thalestol	0.25	23.7	60.0	78.7*	62.3
1.4	TAE	0.5	31.2	66.2	81.2*	44.8
1.4						
			NS	NS	14.82	NS

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 0.25 m^2/plot after herbicide application.

[3] DAA = days after application.

[4] Comparision between the same or different rates of glyphosate,

* Surfactants increased phytotoxicity of glyphosate.

Table 8 Various additives in combination with two rates of glyphosate applied at two carrier volumes on *Cynodon plectostachyous* at Chiang Mai.

Glyphosate rate kg ai/ha	Caarrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[2] 38
0.7				65.9
0.9				68.7
LSD (0.05)				NS
	36.9			70.7
	231.9			63.9
	LSD (0.05)			3.86
			0	69.2
		OPPEE	0.12	69.2
		OPPEE	0.25	71.2
		OPPEE	0.5	72.5
		AAPE+SASA	0.12	62.5
		AAPE+SASA	0.25	71.2
		AAPE+SASA	0.5	66.7
		Thalestol	0.12	63.1
		Thalestol	0.25	65.4
		Thalestol	0.5	68.3
		TAE	0.25	65.0
		TAE	0.5	66.2
		TAE	1.0	64.2
		LSD (0.05)		NS
0.7	36.9			65.6
0.7	231.9			66.1
0.9	36.9			75.8
0.9	231.9			61.7
LSD (0.05)				4.73

[1] Control rating; 0 = no control, 100 = complete control.

[2] DAA = days after application.

Table 9 Various additives in combination with two rates of imazapyr applied at two carrier volumes on *Imperata cylindrica* at Chanthaburi.

Imazapyr rate kg ai/ha	Caarrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3]	% Reduction of[2] plants (DAA)
				45	165
0.2				61.3	76.5
0.4				70.6	82.7
LSD (0.05)				2.45	3.36
	15.0			64.5	77.6
	265.0			67.4	81.6
	LSD (0.05)			2.45	NS
			0	62.3	73.2
		OPPEE	0.12	69.0	81.7
		OPPEE	0.25	64.8	83.9
		AAPE+SASA	0.12	64.0	82.2
		AAPE+SASA	0.25	68.5	82.6
		Thalestol	0.12	65.8	80.1
		Thalestol	0.25	65.4	85.7
		TAE	0.25	66.2	69.0
		TAE	0.5	67.5	78.0
		LSD (0.05)		NS	NS
0.2	15.0			61.1	79.3
0.2	265.0			61.6	73.6
0.4	15.0			68.0	75.9
0.4	265.0			73.5	89.5
LSD (0.05)				NS	6.92[4]

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 0.64 m^2/plot after herbicide application.

[3] DAA = day after application.

[4] Comparision between the same or different rates of imazapyr.

Table 10 Various additives in combination with two rates of imazapyr applied at two carrier volumes on *Imperata cylindrica* at Chiang Mai.

Imazapyr rate kg ai/ha	Caarrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3]	% Reduction of[2] plants (DAA)
				45	165
0.2				44.1	19.2
0.4				48.0	24.4
LSD (0.05)				2.35	NS
	15.0			43.8	29.9
	265.0			48.3	25.8
	LSD (0.05)			2.35	NS
			0	45.0	19.0
		OPPEE	0.12	46.7	12.2
		OPPEE	0.25	47.1	25.9
		OPPEE	0.5	45.4	38.1
		AAPE+SASA	0.12	42.1	24.0
		AAPE+SASA	0.25	47.1	23.6
		AAPE+SASA	0.5	44.6	29.0
		Thalestol	0.12	45.4	19.3
		Thalestol	0.25	49.2	28.3
		Thalestol	0.5	47.9	41.0
		TAE	0.25	44.6	36.3
		TAE	0.5	45.4	33.4
		TAE	1.0	48.3	16.9
		LSD (0.05)		NS	NS
0.2	30.9			40.6	20.1
0.2	218.7			47.6	23.4
0.4	30.9			46.9	24.6
0.4	218.7			49.1	28.2
LSD (0.05)				2.88[4]	NS

1 Control rating; 0 = no control, 100 = complete control.

2 % Reduction of plants calculated from number of plants decreased in 0.64 m^2/plot after herbicide application.

3 DAA = day after application.

4 Comparision between the same or different rates of imazapyr.

Table 11 Various additives in combination with two rates of glufosinate applied at two carrier volumes on *Imperata cylindrica* at Chanthaburi.

Glufosinate rate kg ai/ha	Carrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
				7	15	45	165
1.0				69.7	75.5	87.7	61.9
1.6				76.5	83.8	96.1	76.2
LSD (0.05)				3.60	2.55	2.12	7.41
	13.7			71.1	76.3	89.7	69.0
	221.9			75.1	83.0	94.0	69.1
	LSD (0.05)			3.60	2.55	2.12	NS
			0	71.7	79.2	95.0	69.3
		OPPEE	0.12	75.8	82.9	92.9	75.0
		OPPEE	0.25	75.8	81.7	92.5	75.5
		OPPEE	0.5	68.3	75.0	88.5	73.5
		AAPE+SASA	0.12	69.2	79.2	91.9	60.7
		AAPE+SASA	0.25	71.2	78.7	91.9	73.4
		AAPE+SASA	0.5	74.2	81.2	91.0	75.7
		Thalestol	0.12	74.2	78.3	86.2	55.9
		Thalestol	0.25	75.8	80.4	92.3	78.2
		Thalestol	0.5	71.7	77.9	90.8	64.7
		TAE	0.25	73.3	78.7	93.3	56.4
		TAE	0.5	72.9	80.0	93.3	74.5
		TAE	1.0	76.2	82.1	94.6	64.7
		LSD (0.05)		NS	NS	NS	NS
1.0			0	69.2	75.0	95.0	62.0
		OPPEE	0.12	72.5	78.3	92.5	68.4
		OPPEE	0.25	71.7	76.7	86.7*[4]	72.6
		OPPEE	0.5	60.6	68.3	85.0*	61.9
		AAPE+SASA	0.12	71.7	78.3	92.5	57.7
		AAPE+SASA	0.25	72.5	76.7	91.2	71.5
		AAPE+SASA	0.5	71.7	79.2	83.7*	67.5
		Thalestol	0.12	70.0	75.0	78.7*	47.2
		Thalestol	0.25	70.8	74.2	86.2*	67.2
		Thalestol	0.5	64.2	70.8	83.7*	49.9
		TAE	0.25	66.7	71.7	86.7*	46.4
		TAE	0.5	70.8	77.5	87.5	73.2
		TAE	1.0	75.0	80.0	90.0	58.7

Table 11 (Cont.)

Glufosinate rate kg ai/ha	Carrier volume l/ha	Additives % (v/v)		Control rating[1] (DAA)[3]			% Reduction of[2] plants (DAA)
				7	15	45	165
1.6			0	74.2	83.9	95.0	76.7
		0PPEE	0.12	79.2	87.5	93.3	81.6
		0PPEE	0.25	80.0	86.7	98.3	78.4
		0PPEE	0.5	76.7	81.7	92.1	85.1
		AAPE+SASA	0.12	66.7	80.0	91.2	63.7
		AAPE+SASA	0.25	70.0	80.8	92.5	75.3
		AAPE+SASA	0.5	76.7	83.3	98.3	83.7
		Thalestol	0.12	78.3	81.7	93.7	64.5
		Thalestol	0.25	80.8	86.7	98.3	89.2
		Thalestol	0.5	79.2	85.0	97.9	79.6
		TAE	0.25	80.0	85.8		66.4
		TAE	0.5	75.0	87.5	99.2	75.8
		TAE	1.0	77.5	84.2	99.2	70.7
LSD (0.05				NS	NS	7.51	NS

[1] Control rating; 0 = no control, 100 = complete control.

[2] % Reduction of plants calculated from number of plants decreased in 0.64 m^2/plot after herbicide application.

[3] DAA = days after application.

[4*] Surfactants reduced glufosinate phytotoxicity.

There was the interaction between glyphosate at 1.8 and 1.4 kg/ha and OPPEE, AAPE + SASA, thalestol at 0.25 (v/v) and TAE at 0.5 (v/v) when carrier volumes were 38.1 and 128.2 l/ha at 20 and 35 days after application, respectively (Tables 5 and 7). The rate of 1.4 to 1.8 kg/ha might be the optimum rate of glyphosate for *C. rotundus* control affected by additives.

Additives did not increase phytotoxicity of glyphosate on *C. plectostachyous*. But application at low carrier volume (36.9 l/ha) provided greater control than high carrier volume (231.9 l/ha) (Table 8). The activity of glyphosate at high rate also increased when it was applied at low carrier volume (Table 8).

Imazapyr gave better control of *I. cylindrica* when it was applied at high rate and high carrier volume at Chanthaburi and Chiang Mai (Tables 9 and 10). Phytotoxicity symptom did not occur at 7 and 15 days after application (Table 9). However, additives did not increase imazapyr activity (Table 9 and 10). The adjuvants or surfactants already mixed in solution of commercial product may be high, therefore, it did not require any additives in spray solution. Moreover, additives used in both experiments may not appropriate for imazapyr (Hatzios and Penner, 1985).

Glufosinate provided better control of *I. cylindrica* when it was applied at high rate and high carrier volume (Table 11). High degree of phytotoxicity occurred at seven days after application. Additives did not increase glufosinate activity. However, OPPEE at 0.25 and 0.5% (v/v), thalestol at 0.12, 0.25, and 0.5% (v/v), AAPE + SASA and TAE at 0.5 and 0.25 (v/v) respectively, reduced low rate of glufosinate on *I. cylindrica* (Table 11). Certain additives might reduce herbicide phytotoxicity because of their specific chemical and physical properties (Hull *et al.*, 1982).

Glyphosate controlled *I. cylindrica.*, *C. rotundus*, and *C. plectostachyous* more effectively when applied at low carrier volume (Tables 1, 2, 3, 4 and 8). These results were supported by the report of Buhler and Burnside (1987). Imazapyr and glufosinate controlled *I. cylindrica* more effectively when applied at high carrier volume (Tables 9, 10 and 11). Glyphosate can translocate to all plant parts while glufosinate is contact herbicide (Thomson, 1983). The translocation of imazapyr in plant might be limited as that of glufosinate.

Glyphosate at 0.8 kg/ha applied in carrier volume of 17.5 and 223.7 l/ha was equal to 47,058 and 3,576 ppm respectively (Table 1). Imazapyr at 0.2 kg/ha applied in carrier volume of 15 and 265 l/ha was equal to 13,333 and 754 ppm respectiviely (Table 9). Glufosinate at 1.0 kg/ha in carrier volume of 13.7 and 221.9 l/ha was equal to 72,992 and 4,506 ppm respectively (Table 11). At low carrier volume the concentrations of glyphosate, imazapyr, and glufosinate were 13, 17, and 16 folds higher than at high carrier volume respectively. In contrast to glyphosate high concentration of imazapyr and glufosinate might cause reduction of their own absorption, translocation and phytotoxicity.

Insufficient foliar coverage of glyphosate in spray solution did not reduce glyphosate activity. However, application of glyphosate in low carrier volume and small droplets may subject to drift, but application of herbicide at low carrier volume reduces water requirement and increases the ability to spray more area per unit of time.

Increased weed control was observed when glufosinate and imazapyr were applied at high carrier volume and larger droplet size may result in greater canopy penetration and foliar coverage of herbicide solution.

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