# *Effects of Herbicide Mixtures, Surfactants and Spray Volumes on the Control of* Imperata cylindrica (L.) Raeuschel

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The effects of selected herbicide mixtures, surfactants and spray volumes on Imperata cylindrica under immature rubber were compared Mixtures of glyphosate at 108 kg ae/ha with either 2,4–D dimethylamine at 003, 005 or 008 kg ae/ha or fluroxypyr at 001, 002 or 003 kg ae/ha resulted in reduced control Mixtures of glyphosate at 108 kg ae ha with glufosinate ammonium at 015 or 03 kg ai/ha produced comparable control while reduced control was obtained when mixed with paraquat at 02 or 04 kg ai/ha Glyphosate at 054 kg ae/ha improved control when mixed with imazapyr at 03 kg ae/ha while comparable control was obtained when glyphosate at 108 kg ae/ha was mixed with imazapyr at 015 or 03 kg ae/ha was mixed with imazapyr at 015 or 03 kg ae/ha was mixed with imazapyr at 015 or 03 kg ae/ha Glyphosate at 108 kg ae/ha was mixed with imazapyr at 015 or 03 kg ae/ha Glyphosate at 108 kg ae/ha exhibited slight enhancement in control when mixed with the cationic surfactants Hyspray 52<sup>®</sup>, Ethokem<sup>®</sup> or Arsenal 62<sup>®</sup> Addition of the organosilicone surfactant Pulse 250<sup>®</sup> at 10 or 20 l/ha to glyphosate at 108 kg ae/ha or imazapyr at 05 kg ae/ha improved control Spray volumes of 85 l/ha with the controlled droplet applicator or 480, 560 and 640 l/ha with the knapsack sprayer using glyphosate at 1 44 kg ae/ha or imazapyr at 05 kg ae/ha showed almost comparable control

Imperata cylindrica (L) Raeuschel is an aggressive weed which does not tolerate heavy shade and as such is more prevalent in young than in mature rubber plantations. It spreads rapidly via rhizomes and seeds and if neglected forms a dense undergrowth which hinders accessibility in the rubber planting strips and also competes with the rubber trees for nutrients and water I cylindrica retarded the growth of young rubber trees<sup>1</sup> This delays the maturity period of the rubber trees and subsequently reduces their productivity During land preparation for planting of rubber, effective control of I cylindrica is achieved if the

rhizome fragments are removed from the soil Slashing or application of contact herbicide only provides good initial control of aerial shoots but does not affect the rhizomes in the soil New shoots regenerate and hence it results in short term control With the current high cost and scarcity of labour. planters resort to herbicides for *I cylindrica* control Systemic herbicides provide more effective control than slashing or contact herbicides since systemic herbicides also kill the rhizomes The degree of control varies with the types and rates of herbicides applied and also the densities of the weed Currently, the number of herbicides that

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could control *I cyhndrica* effectively is limited Dalapon<sup>®</sup> was effective on this weed<sup>2</sup> and was popular for more than three decades Glyphosate which was introduced around the mid-seventies was also effective against this weed in rubber plantations<sup>3 4</sup> and its cheaper price made dalapon obsolete Recently, imazapyr was introduced and is effective against *I cyhndrica*<sup>5 9</sup>, however, it is expensive

Information on interaction of other herbicides or surfactants with glyphosate on *I cylindrica* is limited This study therefore investigates the effects of mixtures of glyphosate with selected herbicides or surfactants on *I cylindrica* in order to improve weed control

Water needed for weed control is a serious problem in some rubber areas The possibility of using very low spray volume of glyphosate and imazapyr was investigated in view of reports that very low spray volume was effective on I cylindrica<sup>10-12</sup>

### MATERIALS AND METHODS

### **General Procedure**

Trials were conducted on moderately dense stands of *I cylindrica* with heights ranging from 70 cm to 90 cm under immature rubber conditions of up to 40% shade The experimental design was a completely randomised design with 3. 4 or 5 replicated plots of  $10 \text{ m}^2$  or  $20 \text{ m}^2$ 

Herbicides were sprayed using a Solo knapsack sprayer fitted with a fan nozzle of 0 198 cm orifice At specified intervals, weed control was scored based on a 0 to 100 rating system where 0 = no kill and 100 = completekill of weed foliage Data on percentage control were transformed to arcsin  $\sqrt{percentage}$  for statistical analysis

The commercial herbicides used in the trials were Roundup<sup>®</sup> (glyphosate, isopropylamine salt --- 41 0% w/w), Assault 100A<sup>®</sup> (imazapyr, isopropylamine salt --- 11 4% w/w), Basta 15<sup>®</sup> (glufosinate ammonium --- 13 5% w/w), Gramoxone PP910<sup>®</sup> (paraquat dichloride ---25 3% w/w), 2,4-D Amine E<sup>®</sup> (dimethylamine salt of 2,4-D --- 60 2% w/w) and Starane 200<sup>®</sup> (fluroxypyr, 1-methylheptyl ester --- 29 64% w/w)

### **Effects of Glyphosate Mixtures**

Three trials were conducted to evaluate glyphosate mixtures on control of I cylindrica on sandy loam soil. In the first trial, glyphosate at 1 08 kg ae/ha was mixed with low rates of either 2,4–D dimethylamine at 0 03, 0 05 and 0 08 kg ae/ha or fluroxypyr at 0 01, 0 02 and 0 03 kg ae/ha

In the second trial, glyphosate at 1 08 kg ae/ha was mixed with either paraquat at 0 2 kg ai/ha or 0 4 kg ai/ha or glufosinate ammonium at 0 15 kg ai/ha or 0 3 kg ai/ha

In the third trial, glyphosate at either 0 54 kg ae/ha or 1 08 kg ae/ha was mixed with imazapyr at 0 15 kg ae/ha or 0 3 kg ae/ha

## Effects of Glyphosate Plus Surfactants

Four trials were conducted to evaluate the effectiveness of glyphosate plus surfactants In the first trial glyphosate at 2 16 kg ae/ha was mixed with either the cationic surfactants Hyspray  $52^{\text{(B)}}$ , Ethokem<sup>(B)</sup> or Arsenal  $62^{\text{(B)}}$ , or non-ionic surfactant Polypol Ace<sup>(B)</sup> in the ratio of 1 1 v/v of product of glyphosate to surfactant on sandy loam soils In the second trial glyphosate at 1.08 kg ae/ ha was mixed with Hyspray  $52^{\text{(b)}}$  at 3.0 l/ha and dry weights of foliage were taken at nine weeks after treatment using two 1 m<sup>2</sup> quadrats per plot of 10 m<sup>2</sup>.

In the third trial, glyphosate at 1.08 kg ae/ ha and 2.16 kg ae/ha were mixed with Hyspray  $52^{\text{(s)}}$  in the ratio of 1:1 v/v of product respectively, on sandy clay loam soil. Dry weights of *I. cylindrica* samples were taken at 27 weeks after treatment using four 0.25 m<sup>2</sup> quadrats per plot and mean dry weights of foliage per square meter were determined from three replicates.

In the fourth trial, glyphosate at 1.08 kg ae/ ha or imazapyr at 0.5 kg ae/ha was mixed with an organosilicone surfactant, Pulse  $250^{\text{(s)}}$  at 1.0% or 2.0% product. The trial was on sandy loam soil.

## **Different Spray Volumes**

Two trials were conducted on sandy clay loam soils with about 40% shade to evaluate glyphosate at 1.44 kg ae/ha or imazapyr at 0.5 kg ae/ha applied using either a Solo knapsack sprayer or a Microfit Herbi which is a controlled droplet applicator. The knapsack sprayer was fitted with fan nozzles with orifice sizes of 0.159 cm, 0.198 cm and 0.278 cm. The volume of water delivered by the fan jet nozzles were 480, 560 and 640 l/ha for the 0.159 cm, 0.198 cm and 0.278 cm nozzles, respectively. The output of the Microfit Herbi was about 85 l/ha.

#### RESULTS AND DISCUSSION

## **Efficacy of Glyphosate Mixtures**

Mixtures of glyphosate at 1.08 kg ae/ha with 2,4–D dimethylamine at 0.03, 0.05 or 0.08 kg

ae/ha or fluroxypyr at 0.01, 0.02 or 0.03 kg ae/ha produced lower percentage weed control as compared to glyphosate only (Table 1). Increasing the rates of 2,4-D dimethylamine in the mixtures caused further reduction in weed control. In the case of glyphosate plus fluroxypyr, the reduction in weed control was higher with lower rates of fluroxypyr than with higher rates of fluroxypyr. Reduced activity of glyphosate when mixed with 2,4-D dimethylamine had also been reported on wheat, barley and wild  $oats^{13}$ , on johnsongrass<sup>14</sup> and on wheat<sup>15</sup>. It was suggested that the antagonism was probably due to chemical or physical incompatibility rather than biological interaction within the plant<sup>13</sup>. This was based on their findings that sequential application of the individual herbicide on the same plant did not result in antagonism compared with tank mixed application of the herbicides. They also noted that antagonism increased with increased rates of 2.4-D amine in the mixture which agrees with results of the present trial. The interaction of the herbicides probably reduced uptake and translocation of glyphosate and hence reduction in control.

Mixtures of glyphosate with the contact herbicide paraquat produced significantly lower control than glyphosate alone while almost comparable control was obtained with glyphosate mixed with glufosinate ammonium (Table 2). The reduction in weed control increased with the increased concentration of paraquat. Higher initial weed kill was obtained when glyphosate was mixed with paraquat than with glufosinate ammonium. Glufosinate ammonium or paraquat alone was ineffective on the weed compared to glyphosate alone. Reduction in control of mixtures with paraquat could probably be due to the rapid injury of plant tissue caused by paraquat which

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T	Rate		Mean % Control		
	(kg ae/ha)	7 wks.	12 wks	24 wks.	31 wks.
Glyphosate	1.08	99	99	97	95
Glyphosate + 2,4-D amine	1.08 + 0.03	98	99	96	72
Glyphosate + 2,4D amine	1 08 + 0.05	99	98	85	75
Glyphosate + 2,4-D amine	1.08 + 0 08	55	80	80	30
Glyphosate + fluroxypyr	1.08 + 0.01	70	67	45	25
Glyphosate + fluroxypyr	1.08 + 0.02	77	80	65	40
Glyphosate + fluroxypyr	$1.08 \pm 0.03$	90	96	87	80
	LSD (p=0.05)	12.6	6.9	72	77

# TABLE 1. EFFECTIVENESS OF GLYPHOSATE MIXTURES WITH 2.4–D AMINE OR FLUROXYPYR ON I. CYLINDRICA

# TABLE 2 EFFECTIVENESS OF GLYPHOSATE MIXTURES WITH GLUFOSINATE AMMONIUM OR PARAQUAT ON *I. CYLINDRICA*

Treatment	Rate/ha	l wk	Mean % 3 wks	6 Control 14 wks.	17 wks.
Glyphosate	1.08 kg ae	22	83	95	92
Glyphosate + glufosinate ammonium	1.08 kg ae + 0.15 kg ai	33	78	92	92
Glyphosate + glufosinate ammonium	1 08 kg ae + 0.30 kg ai	42	87	93	84
Glyphosate + paraquat	1.08 kg ae + 0 20 kg ai	83	85	85	80
Glyphosate + paraquat	1 08 kg ae + 0.40 kg ai	82	83	65	50
Glufosinate ammonium	0 30 kg ai	30	63	25	10
Paraquat	0 40 kg ai	68	53	10	0
	LSD (p=0.05)	12.8	13.1	5.8	6.4

subsequently reduced uptake of glyphosate Higher rate of paraquat probably enhanced injury further reducing the uptake of glyphosate In the case of glufosinate ammonium, this herbicide provided slower contact injury compared to paraquat and this probably caused higher uptake of glyphosate and hence reduced antagonism The mode of action of glufosinate ammonium has been suggested to involve inhibition of glutammesynthase activity which results in ammonia toxicity in affected plants<sup>16</sup>

Mixture of glyphosate at 0 54 kg ae/ha with imazapyr at 0.3 kg ae/ha provided significantly better control than glyphosate alone, while glyphosate at 1 08 kg ae/ha produced almost comparable control with imazapyr at 015 kg ae/ha or 0 3 kg ae/ha (Table 3) Imazapyr 1s a slower acting herbicide compared with glyphosate and its mode of action has been suggested as inhibitor of acetohydroxyacid synthase which prevents plants from synthesising the amino acids value, leucine and isoleucine<sup>17</sup> The rapid action by glyphosate probably reduced the effect of imazapyr on the weed The absence of antagonism probably indicated absence of physical or chemical incompatibility prior to uptake of the mixture

# **Glyphosate Plus Surfactants**

The addition of the cationic surfactants Hyspray 52<sup>®</sup>, Ethokem<sup>®</sup> or Arsenal 62<sup>®</sup> at 601/ha to glyphosate at 2 16 kg ae/ha improved slightly the control of *I cylindrica* but was not significant, while addition of Polypol Ace<sup>®</sup> at 601/ha resulted in slight reduction in control (*Figure 1*) Reducing the rates of glyphosate and surfactants by half in similar mixtures produced significant improvement in control with the addition of Hyspray 52<sup>®</sup> or Ethokem<sup>®</sup>

based on dry weight of foliage taken at nine weeks after treatment (Figure 2) Amongst these surfactants, Hyspray 52<sup>®</sup> mixed with glyphosate provided the highest level of control Further evaluation of glyphosate at 2 16 kg ae/ha mixed with Hyspray 52<sup>®</sup> at 601/ha on I cylindrica also provided significant improvement in control as exhibited by the lower dry weights of shoots taken at 27 weeks after treatment as compared to glyphosate alone (Figure 3) This mixture also provided better control of the weed significantly than similar mixture at rates reduced by half. The latter mixture was also not significantly different compared to glyphosate alone Improved activity of glyphosate with the addition of cationic surfactants and not with non-ionic surfactants was similarly reported on common milkweed and hemp dogbane<sup>18</sup> In a study conducted, it was found that the increase in hydrophilic-lipophilic balance (HLB) of the surfactants resulted in the increase in effectiveness of the surfactants However. different surfactants with similar HLB could also provide variable effectiveness, thus indicating the importance of the chemical type of surfactants. It was also found that surfactants could interact with other surfactants Since the commercial glyphosate used in the present study was already formulated with a surfactant it was possible that the surfactants added to glyphosate might have interacted

Pulse  $250^{\text{(8)}}$ , which is an organosilicone surfactant, improved control of the weed when added to either glyphosate or imazapyr (*Table 4*) Organosilicone surfactants had been reported to improve efficacy of glyphosate on a number of weeds comprising grasses, broadleaves and sedges<sup>19</sup> The surfactants also improved activity of glyphosate on the grasses



Figure 1. Effectiveness of glyphosate plus surfactants on 1. cylindrica. Vertical lines represent LSD (p=0.05) bars.



Figure 2. Effectiveness of glyphosate plus surfactants on dry weight of foliage of I. cylindrica at 9 weeks after treatment.

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	Rate	]	Mean % Contro	d
Ireatment	(kg ae/ha)	11 wks	19 wks	26 wks
Glyphosate	0 54	43	40	28
Glyphosate + ımazapyr	0 54 + 0 15	63	50	33
Glyphosate + mazapyr	0 54 + 0 30	73	67	60
Glyphosate	1 08	85	82	73
Glyphosate + 1mazapyr	1 08 + 0 15	80	73	60
Glyphosate + ımazapyr	1 08 + 0 30	85	82	73
Imazapyr	0 15	53	40	10
Imazapyr	0 30	50	43	27
	LSD ( $p = 0.05$ )	10 2	<b>1</b> 5 1	13 9

TABLE 3 EFFECTIVENESS OF GLYPHOSATE MIXED WITH IMAZAPYR ON I CYLINDRICA

Cynodon dactylon, Panicum repens and Paspalum notatum in citrus<sup>20</sup> The improvement of glyphosate activity was believed to be due to reduced surface tension which increased leaf wetting, spread and cuticle penetration and subsequent increase in foliar uptake. In the present study, the difference in control at eight weeks was much better with glyphosate plus surfactants, than glyphosate alone, but assessment in subsequent weeks showed difference in control decreased indicating good initial uptake of glyphosate with surfactant No information is available on imazapyr plus organosilicone surfactants on grasses The improvement in control by imazapyr when with the surfactant indicated mixed compatibility of the two chemicals

#### **Effect of Spray Volumes**

Glyphosate at 1 44 kg ae/ha applied at 480 l/ha of spray volume resulted with better control of I cylindrica than at either 560 l/ha or 640 l/ha

using the knapsack sprayer or at 85 l/ha of spray volume using the controlled droplet applicator (CDA) as shown in *Figure 4* In fact, the lower volume of 480 l/ha provided better control significantly than application with the CDA The effectiveness of glyphosate at very low spray volume with the CDA on *I cylindrica* agrees with earlier reports<sup>10-12</sup>

Similarly, the three spray volumes of imazapyr at 0.5 kg ae/ha also produced slightly superior control with 480 l/ha of spray volume compared with other volumes (*Figure 5*)

*I cylindrica* generally have erect aerial shoots, and the tendency for herbicide spray droplets to drip is high and hence causes wastage Smaller droplets therefore is advantageous since they adhere much better on the foliage Application of herbicide using the CDA produced more uniform droplets and the low volume of spray solution required, therefore, can save usage of water However, the spray droplets from the CDA fall on to the



Figure 3 Effectiveness of glyphosate plus Hyspray 52® on dry weight of foliage of 1. cylindrica at 27 weeks after treatment.



Figure 4. Effectiveness of glyphosate at 1 44 kg ae/ha applied at different spray volumes on 1. cylindrica. Vertical lines represent LSD (p=0.05) bars

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Treatment	Rate	1		
	(kg ae/ha)	8 wks	13 wks	17 wks
Glyphosate	1 08	50	40	30
Glyphosate + Pulse 250®	108+101	77	45	35
Glyphosate + Pulse 250®	1 08 + 2 01	82	65	55
Imazapyr	05	75	47	40
Imazapyr + Pulse 250®	108+101	80	82	70
Imazapyr + Pulse 250®	1 08 + 2 01	80	82	75
	LSD(p = 0.05)	153	114	59

TABLE 4 EFFECTIVENESS OF ADDING PULSE 250® TO GLYPHOSATE OR IMAZAPYR ON I CYLINDRICA



Figure 5 Effectiveness of imazapyr at 0.5 kg ae/ha applied at different sprav volumes on 1 cylindrica Vertical lines represent LSD (p=0.05) bars

foliage by gravity and in situations of dense stand *I. cylindrica* could result in less effective control due to lack of thrust and coverage.

#### CONCLUSION

Addition of low rates of 2,4-D dimethylamine or fluroxypyr to standard rate of glyphosate reduced control of I. cylindrica. Glyphosate showed comparable control when mixed with glufosinate ammonium but reduced control was obtained when mixed with paraguat. Glyphosate at 0.54 kg ae/ha improved control when mixed with imazapyr at 0.3 kg ae/ha while glyphosate at 1.08 kg ae/ha mixed with imazapyr at 0.15 kg ae/ha or 0.3 kg ae/ha produced comparable control. Slight improvement in control was obtained when glyphosate was mixed with the cationic surfactants Hyspray 52<sup>®</sup>, Ethokem<sup>®</sup> or Arsenal 62<sup>®</sup>. The addition of the organosilicone surfactant Pulse 250<sup>®</sup> improved control of glyphosate and imazapyr. Different spray volumes at 480, 560 and 640 l/ha with the knapsack sprayer or 85 l/ha with the CDA showed almost comparable control of *I. cylindrica* with glyphosate at 1 44 kg ae/ha or imazapyr at 0.5 kg ae/ha.

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