Billion Drop Technology:
Spray Deposit and Field Studies, 1986

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Introduction

Cost input saving for the producer is a necessary priority to help him get through this severe down cycle. **A dollar saved in input costs is a dollar less debt whether the crop is harvested or not, or even remains unsold.** This paper discusses research that indicates that large savings can be made by taking advantage of the following 5 synergetic application factors that increase chemical efficacy.

1. Spray with mist-sized drops to increase coverage.
2. Decrease carrier [water] which increases chemical concentration which increases uptake of many chemicals by the plant.
3. Spray when plants are at the earliest recommended stage.
4. Spray when plants are vigorously growing.
5. Use the proper adjuvant in relation to the weed and chemical.

The Co-operative Extension Service of the state of **Arkansas recommends methods of achieving control with less than label rates.** Rogers Engineering is proposing the same thing be done in Canada and is petitioning the governments to support research that will lead to such recommendations being made in Canada. The potential is to save western Canadian producers 50% of their post emergence herbicide chemical bill [**\$150,000,000.$^{\underline{00}}$ + annually**]. Application costs would be reduced, resulting in less soil contamination and chemical exposure by the operator, plus a reduction in soil degradation by making chem-fallow cheaper than tillage which would help to accelerate its acceptance. Note the present research is only for 1 -> 2 years, which is not enough to prove a technology. However, the research indicates that we can reduce both water and chemical rates. More research is required to make this technology reliable. The down side is that if chemical is applied at less than label rates, there will be no warranty for function. Is that a problem? How much function warranty is given out and does not the producer have the right to make that decision?

BDT: Objective

To develop an agricultural chemical application technology, utilizing the increased coverage advantages of ultra small drops and other factors to achieve acceptable control with 10% of the presently recommended carrier rate and double the chemicals' ability to control weeds.

Deposit Studies

Objective

To compare the deposit efficiency of mist-sized drops ($\approx$ 130 µm) created by an 800017TC tip at 900 kPa with 22.2 L/ha carrier with conventional drops (410 µm) created by 80015LP, at 100 kPa with 100 L/ha carrier.

Equipment

A laboratory spray track 2m wide and 10m long with hydraulic speed control was used in conjunction with a 2m plot sprayer to apply sodium flourescein and Hoegrass to targets and greenhouse-grown plants. The samples were extracted, analysed using flourescein spectrometry, and spray catch efficiencies calculated. The targets were paper rectangles 4 mm x 4.75 mm, mounted on both sides of aluminium holders, and mounted at various orientations to the spray direction. Various speeds, pressures and tips were used.

An indoor spray test track was built that controlled and monitored sprayer speed and maintained constant nozzle-to-target distances. A hydraulic motor through cables pulled the sprayer. Sprayer speed was controlled from 2 to 13 km/h by changing the hydraulic fluid flow rate to the drive motor. Adams (1986) describes the design of the spray track.

Spray deposit was measured using three deposit indicators: individual targets, horizontal strips, and live plants. Different target orientations were used to estimate deposit on similarly oriented leaves found on a live plant. Ten target planes were examined, vertical facing travel direction, front and back, 45^0 toward travel direction top and bottom, 45^0 away from travel direction right and left sides, and perpendicular to the direction of travel. Four sets of each target orientation were placed on the spray track test area. Each plane was repeated four times in each run, each positioned at a different location with respect to the spray nozzles. Targets consisted of an aluminum frame elevated 15 cm above ground level with paper on each side to absorb the chemical. The area variance study used metal washers as targets placed on a flat paper surface on 15 cm centers.

Two horizontal paper strips, 5 cm wide and 150 cm long, were placed in front of and behind the test area. Strips were positioned 15 cm above ground level to avoid shading from targets and artificial plants. They monitored spray application variance and checked for nozzle plugging. Sprayer speed was monitored at 27 cm increments to record actual sprayer speed as the sprayer travelled along the track.

Live flax, canola, and wheat plants were grown in a greenhouse and sprayed for deposit analysis after a three week growing period. Flats 61 cm wide by 82 cm long by 6 cm deep were filled with soil and planted. The size of flat allows four 15 cm space rows to be grown in each flat. An artificial crop canopy of plastic wheat plants covered the non-test area of the spray track to simulate field conditions.

Procedure

To measure deposit, a fluorescent tracer dye, sodium fluorescein (Uranin), was mixed with a spray solution of water and Hoegrass (diclofop-methyl) 2.5% by volume. The concentration of Uranin in the spray solution was dependent on the carrier application rate for each treatment. Dye concentration was selected to give a dye application rate of 6 mg/m^2, ensuring proper deposit solution concentrations for the spectral fluorometer to operate in a linear range.

Each treatment required 4 flats of plants, 40 target positions (10 orientations x 4 positions), and 2 test strips. After spraying, catch paper from targets and strips were collected and placed in plastic bags. Catch paper from both 150 cm long strips were cut into ten 15 cm samples. Each row of plants were cut at ground level and placed in a plastic bag.

To extract the deposit of Uranin on catch paper and plants, a known amount of wash solution, consisting of .5N solution of sodium hydroxide, was placed in each plastic bag. Each bag was then shaken for 30 seconds to wash Uranin off the catch paper and plants. Wash solution was analysed for Uranin concentration, using the spectral fluorometer. After washing, plant material from the rows were oven-dried and weighed.

Spray Treatments

The deposit study investigated how drop size and speed affected deposit of a spray solution. Two drop sizes were used: fine (≈130 µm MVD) with 22.2 L/ha of carrier and large (410 µm MVD)with 100 L/ha carrier. Fine droplets were applied by using an airless paint spray tip (800017TC) with a 500 mesh strainer, at an operating pressure of 900 kPa. Large droplets were applied by using a conventional agricultural spray tip (80015LP) with a 200 mesh strainer at an operating pressure of 100 kPa. Both nozzles are made by Spraying Systems Co. The spray sheet , angled 30^0 forward from vertical, was standard in all treatments.

Trials were conducted with: 3.2, 6.4, and 12.8 km/h, two drop sizes and two plant types, canola and wheat.

In the variance test, the same solution was applied with 800017 TC tips, at 6.4 km/h, at 900 kPa with 22.2 L/ha carrier. The plants were removed from the deck and paper put down to support metal disc targets on 15 cm centres.

Results & Discussion

Target data shows a 35% increase in deposit with fine droplet application over conventional large droplet application.

The fine droplet application tips, having a patternator CV of 28% at 900 kPa, gave uneven spray application due to poor tip design (airless paint spray tips were used). The 80015LPs had a patternator CV of 12.1% at 100 kPa. As previously indicated, fine application gave increased weed control over large drop application, even with uneven spray deposition.

The effective size of the target used was 4 cm wide by 4.75 cm high. Tu et al (1986) showed that fine droplet application is enhanced by using a long narrow target. A large square target surface will disturb air currents around the target. The target size used in this deposit study produced results that were biased toward large droplets.

Target results indicated deposit efficiencies, ranging from 5% to 95% with large droplet application and 12% to 140% with fine droplet application. Deposit efficiencies over 100% resulted on target orientations of vertical, facing the travel direction and 45^0 away from travel direction . Because spray application is calculated on a plan spraying area (19 cm^2) and the spray sheet angle is at 30^0 forward off vertical, the effective spray area of the target is decreased when the target is oriented at less than 90^0 to the spray sheet. Despite this, Targets #1 and #5 have greater than 100% efficiency. This may be the result of the forward horizontal velocity of the drops, which becomes the dominant factor as the vertical velocity is decreased by friction with the air. The larger drops with greater mass will lose less vertical velocity than the fine drops. Therefore, they will have less horizontal velocity and hit the ground with less horizontal traverse. It is also suspected that the fine droplet deposit on all surfaces is composed of direct spray deposit and a deposit of fine droplets that is carried in the air by turbulence.

The combined [fine and large] drop data showed significant deposit increases with speed [P=5%]. The average target deposit for 3.2 km/h is 34.5%, 6.4 km/h is 43.7% and for 12.8 km/h is 51.8%. The increase in deposit occurred 15 cm above ground level, as targets and strips were positioned at this height. An increase in deposit may occur at this position of the plant but may

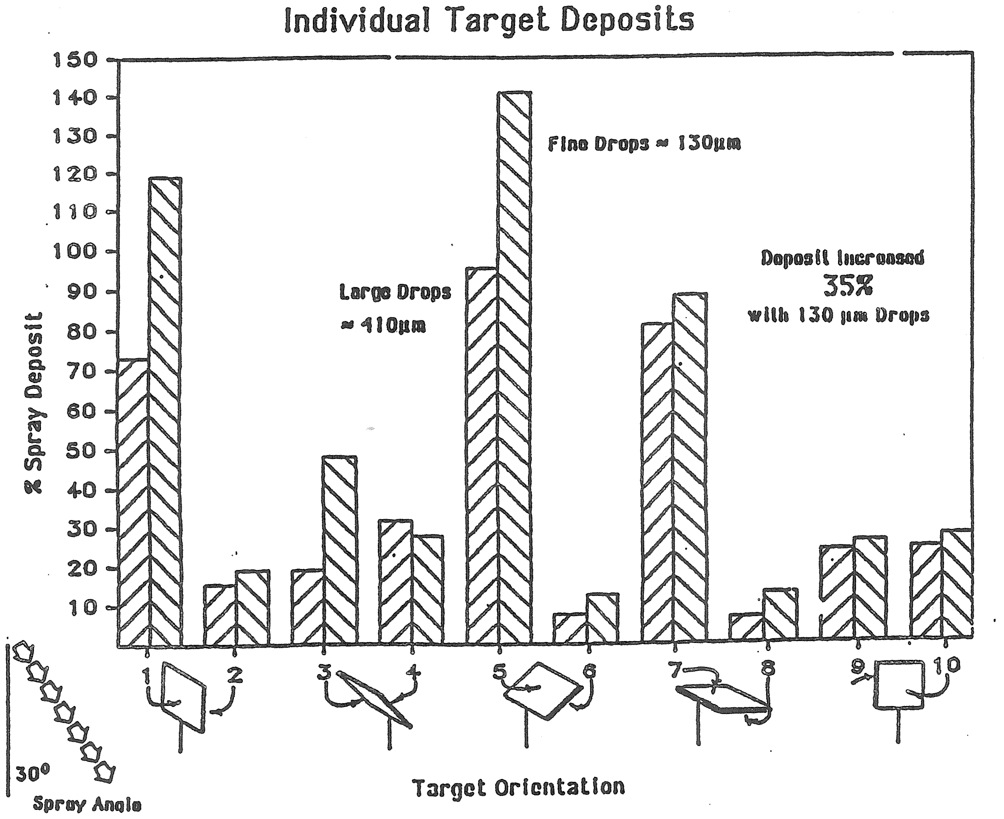

Figure #1: Individual target deposits

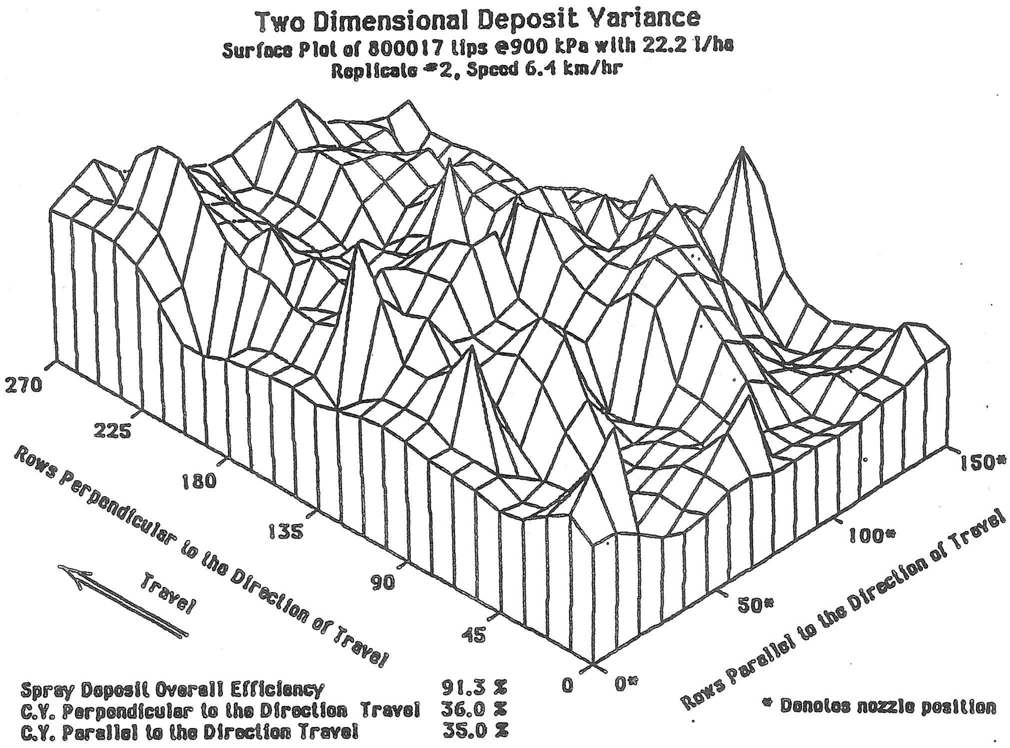

Figure #2: Two dimensional deposit variance not occur on target weeds that are shaded by larger plants at ground level. There was no interaction between drop size and speed for any target orientation. Targets 1, 4 and 5 had significant deposit increases [P=5%] as speed increased, with the major increase being between 3.2 and 6.4 km/h.

The two dimensional deposit variance studies illustrate the variation that is being dealt with when using the 800017TC tip while travelling over an ideal track. Yet the tips have resulted in uniform control in the field situation with 10 L/ha and 25% of the recommended chemical rate. There must be a redistribution of the spray or a considerably different deposit pattern on vertical standing targets. Deposit C.V.s ranged from 32.7 to 36.0% on flat, metal targets while patternator C.Vs were 28%. Note that the C.V.s were not statistically different in the direction of travel or across it.
Canola, flax and wheat plants were sprayed after a three week growing period. Deposit assessment on plants was statistically insignifcant because of plant variation, even when divided by dry weight. As the plant grows, it tends to shade itself, therefore the catch area increases at a lesser rate than its dry weight.

Field Studies

Chemicals were applied at 0, 25, 50, 75 and 100% of the recommended rate with 10, 30, 50 and 100 L/ha of carrier (water) with 130 and 410 µm dia drops MVD. All tests were replicated 4 times on 3 x 5 meter plots. Only 2 meters in the plots were sprayed to allow for operational room and to give a check on each side of the sprayer. To get low application rates with large drops the sprayer was pulled up to 22 km/h with a Yamaha Quadrunner equipped with a speedometer that read to .1 km/h (speed could be controlled +/-1 km/h). The rear brake control was unhooked and used to control the on/off spray valve. To apply chemical with ultra small drops (130 µm), an enclosed boom is a necessity to prevent the drops from drifting away. Two 2 meter plot sprayers, plus a conventional sprayer, were used in this project.

Liquid pressure was provided by a 2 kg CO^2 bottle c/w regulator and a plastic chemical bottle mounted on either the Yamaha or the shroud, depending on whether it was pushed or pulled. The boom was equipped with 80015LP or 800025TC tips. The second shrouded sprayer was equipped with Air Jet tips AJ.016TK3, plus AJ.020TK5. Both the air and liquid pressure were derived from one CO^2 with two regulators. Both sets of tips were used to apply the 10 gal rate; valves were used to select the proper tip for lower rates. Tips were placed in a patternator to check C.Vs. Air Jets' C.V. was 8.8 with ≈ 130 µm drops, 80015LP was16.2 with 410 µm drops, and 800025TC with ≈ 130 µm drops was 86 at 207 kPa, 50 at 410 kpa, and 34 at 690 kPa. The 800025TC is an airless paint spraying nozzle. Drop size was estimated from 800040 tip information.

Application Table for 10 L/ha

Tip	Estimated Drop Size MVD µm	Pressure kPa	Speed km/h	Screen Mesh
800067SS	275	400	36.5	200
800040SS	205	400	19	500
800025TC	150	690	18	500
800017TC	130	900	14	500

The C.V. of the 800017TC at 900 kPa is 28% and 38% at 690 kPa. **A new tip needs to be developed that will give a reasonable C.V. at low pressures and, thus, lower flow rates.** This tip would reduce the plugging tendency as the orifice would be larger, yet the flow lower. 500 mesh stainless steel material is readily available and can be easily soldered to an 80 mesh outer shell. A plastic filter body is more corrosive-resistant than brass. Ammonium sulfate corrodes brass and the particles plug the tips.

Field Results

1985 Roundup Study: % Weed Control

Herbicide Rate	10L/ha			30L/ha			50L/ha		100L/ha		100 L/ha Bike
% RR*	AA*	Hy*	Lg*	AA	Hy	Lg	AA	Lg	AA	Lg	Lg
25	84	97	-	-	97	68	87	97	84	67	93
50	90	99	-	97	99	96	97	100	100	95	97
75	98	100	-	100	100	96	99	-	100	99	100
100	100	100	-	100	98	99	100	100	100	-	100
SE	1.8	1.1	-	0.4	2.0	5.0	2.6	0.5	1.8	3.8	2.2

*(AA) Small drops 130 µm MVD, Air Assist Nozzles AJ.016TK3 C.V. 9
140 µm MVD, Air Assist Nozzles AJ.020TK5 C.V.12
*(Hy) Hydraulic ≈150 µm MVD, Spraying Systems 800025TC C.V. 50
*(Lg) Large Drops 410 µm MVD, Spraying Systems 80015LP C.V. 16
*(%RR) Recommended Rate .267 kg ai/ha, & .05% Agrol 90 by vol

Glyphosate, formulated as Roundup, was used as an indicator to illustrate the effect of small drops and higher concentrations. **Decreasing dilution of the chemical with carrier from 100 L/ha to 10 L/ha increased control on tame oats. Increasing drop numbers or decreasing drop size increased control.** Adequate control was achieved at 25% of the recommended rate of 1/3 L/ha for chem fallow with 800025TC tips , and achieved with 30 L/ha and 50% of the recommended rate through 80015LP. Dust tracks were more prevalent in the lower chemical and carrier rate plots. The low application rates were applied with 800025TC tips (Spraying Systems), the large drops with 80015LP tips. Spraying Systems' Air Jet (AJ.016TK3) tips (drops 130 µm MVD) were also tested, but did not give comparable control to the 800025TC tips. Operational problems may have been responsible for the lack of control.

1986 Roundup Study on Stressed Wild Oats

Visual control of wild oats with Roundup 28 days after spraying * (0-9)

Chemical	Drop/Volume (L/ha)			
% RR	≈ 130 µm	≈ 130 µm	≈ 280 µm	≈ 410 µm
	10	20	50	100
100	8.4	9.0	8.9	9.0
50	8.3	7.3	7.5	5.6
25	3.3	4.5	1.5	3.3

LSD (p = 0.05) 1.8
* = 1 year's results

The reduction control can be attributed to the extreme stress the wild oats in flag leaf were under. The tips of the leaves were brown from drought and temperatures were low. These results of the three studies agree with Ambach and Ashford (1982) who found that increasing the concentration of glyphosate increased its phytotoxicity. Buhler and Burnside (1983) found that glyphosate phytotoxicity was increased as the carrier volume was decreased from 190 L/ha to 24 L/ha. The effects of carrier volume and drop size in the experiment, as well as others, were confounded. However, the total number of drops being applied per unit area was similar. These authors reported maximum weed control when applied to actively growing seedlings because of adequate soil moisture and favourable temperatures.

Control of Wild Oats with Hoegrass (diclofop-methyl) in 1985

Visual control of wild oats with Hoegrass (mean of 4 tests)

Chemical % RR	Carrier Volume (L/ha)							
	100			50		30		10
	L	S	C	L	S	L	S	S
100	8.8	8.7	8.9	8.2	8.8	7.8	8.6	6.3
75	8.7	8.2	8.8	8.1	8.3	6.3	7.8	5.8
50	7.7	6.6	6.3	7.3	5.9	4.0	6.3	4.1
25	4.2	3.9	3.0	2.8	3.9	1.3	5.3	1.9
SE	0.38	0.36	0.42	0.46	0.34	0.47	0.28	0.37

(L) = Large drops, 410 µm MVD; (S) = Small drops ≈ 130 µm MVD; (C) = Conventional

Under the environmental conditions encountered at these sites in 1985, control of wild oats did not differ when herbicide rates were reduced to 75% of the recommended rate of 0.71 kg/ha. The only effect of drop size and carrier volume at these rates was reduced control at 30 L/ha with large drops and at 10 L/ha with small drops. Fair control was also obtained with 50% of the recommended rate, except for the previously mentioned 30 L/ha in large drops and 10 L/ha in small drops. On the basis of this data, we conclude that 100 L/ha volumes are not required in most cases. At the 50% herbicide rate, slightly better control was obtained with large drops at the 50 and 100 L/ha rates. Control was poor and extremely variable at the 25% herbicide rate, regardless of the application method. It seems unlikely that the activity of Hoegrass can be improved by applying the herbicide in small drops. Also, the application of 10 L/ha of carrier with air-assist nozzles did not give as much control as other methods of application.

Control of Wild Oats in Flax with Fusilade (fluazifop-butyl) 1985

Chemical % RR	Carrier Volume (L/ha)							
	100			50		30		10
	L	S	C*	L	S	L	S	S
100	9.0	9.0	9.0	5.0	9.0	5.0	9.0	9.0
75	8.2	9.0	8.8	3.7	8.8	4.0	9.0	8.5
50	3.0	7.0	6.7	1.0	7.8	0.0	8.0	4.0
25	1.0	5.3	1.8	1.0	4.3	0.0	8.2	1.3
LSD	3.2	3.3	2.5	3.0	3.7	0.8	0.8	2.5

* Conventional sprayer

The recommended rate of Fusdilade used was 0.25 kg/ha ai

Effect of drop size, carrier volume and rate of Fusilade on wild oat weights as percent of untreated plot (1985)

Chemical	Carrier Volume (L/ha)							
% RR	100			50		30		10
	L	S	C*	L	S	L	S	S
100	40	19	10	20	10	74	13	30
75	35	14	23	84	7	90	11	22
50	47	22	34	78	33	97	14	31
25	85	47	90	79	88	83	15	71
LSD	46	26	21	31	24	35	15	41

* Conventional sprayer

At the 25% herbicide rate, there was a dramatic improvement in the control of wild oats when Fusilade was applied in 30 L/ha and small drops versus any other application method. Reducing carrier volume to 10 L/ha was detrimental. At the 50% herbicide rate, fair control was obtained with the 100 L/ha application in large drops while control with large drops at 50 and 30 L/ha of carrier was poor.

Control of Wild Oats and Barley in Flax with Fusilade in 1986

	Visual control 28 days after spraying (0-9) Carrier Volume (L/ha)							Fresh weight as % of untreated control Carrier Volume (L/ha)						
Chemical	100		50		30		10	100		50		30		10
% RR	L	S	L	S	L	S	S	L	S	L	S	L	S	S
100	5.8	7.3	7.3	7.0	6.3	7.5	5.3	17	12	17	13	15	9	38
75	3.2	5.0	2.8	6.5	4.3	5.3	4.5	46	26	46	14	36	23	29
50	1.8	2.3	1.0	1.5	1.5	5.0	1.0	79	74	65	66	63	35	61
25	0.3	0.0	0.0	0.0	0.0	2.3	0.0	100	116	102	109	121	74	86

LSD (p = 0.05) 2.2 LSD 25

The results obtained with Fusilade in 1986 agree with those obtained in 1985 in that small drops improved control when herbicide rates were marginal. However, the amount of active ingredient required for control was higher in 1986 than in 1985, probably due to larger plants and less favourable growing conditions.

Drop Size Applications of Glyphosate (Roundup) and Clopyralid/MCPA on Canada Thistle and Quackgrass:

Trials were conducted east and south of Saskatoon, as part of the Billion Drop Technology Project funded by Farming For The Future. The experimental design was a randomized complete block, with 4 replicates on 2 x 5 meter plots which were permanently marked for future counts. Treatments were applied with a Windproof sprayer, equipped with 800017 tips, at 900 kpa for 10 L/ha; 800025 tips,at 640 kpa for 20 & 30 L/ha; and 80015 LP at 150 kpa. Drop sizes were estimated at 130-150 µm for 10 to 30 L/ha; 410 µm for 100 L/ha; 4 chemical rates:

100, 50, 30, 20% of the recommended rate, plus an additional 20% treatment mixed with 2 kg/ha of technical grade ammonium sulfate, were used. There were 4 carrier rates 10, 20, 30 & 100 L/ha.

Roundup [Glyphosate] on Quackgrass

Sprayed June 23, 1986, 24^0 C., on to quackgrass in the early flag leaf to just prior to the heading stage. It had to be worked extensively by the farmer before the field was seeded to barley on May 20, 1986. A vigourous, consistant stand choked out most of the barley. Recommended rate used was 1.7 kg/ha ai.

Roundup [Glyphosate] on Canada Thistle

Sprayed June 25, 1986, 22^0 C., on Canada Thistle in the early bud stage. The soil had a pH of 8-8.5. Thistles were well rooted as the land had not been deeply tilled for several years. No crop was seeded; 1.7 kg/ha ai the recommeneded rate was used.

Curtail [Clopyralid/MCPA] on Canada Thistle

Sprayed June 24, 26^0 C., in the same field as above. Recommended rate used was .6 kg/ha ai.

Weed Control 0-9

	Glyphosate Quackgrass				Glyphosate Canada Thistle				Clopyralid/MCPA Canada Thistle			
Carrier	100	30	20	10	100	30	20	10	100	30	20	10
% RR												
100	8	7.75	8.25	7.5	6.5	7.5	5.5	7.5	7	7	7	6.75
50	8.5	7	7.75	7.75	3.75	5.25	6.25	6.5	7.25	6.5	6.25	6.5
30	6.25	7.5	7	7.5	2.25	3.75	5.75	5.5	6.25	5	5.5	4.25
20AS	6.5	6.75	7	7	3.75	5.25	3.25	4.25	5.75	5.25	4.25	2
20	6	6.5	6	6	.75	2.75	3.25	2.5	5	4.5	5.25	2

Results

Glyphosate on quackgrass showed little response to carrier, and only a slight response to a reduction in rate to 20%. On Canada thistle, it showed a slight increase in control with reduced carrier rates or higher concentration or coverage, especially at the lower rates, and a marked response to chemical rate which could be confounded by differences in growth vigour. Control of both quackgrass and Canada thistle responded to ammonium sulfate as an adjuvant.

Clopyralid on Canada thistle showed no response to carrier rate, but a significant response to chemical rate was documented. (Rogers Engineering Inc., Saskatoon, Sask.)

Conclusion

The Deposit Study has shown that 35% more chemical is deposited on paper targets with 130 µm drops as compared to 410 µm drops. The large targets and paper catch surface biased the data in favour of the large drops (see Tu et al). This research shows that more of the chemical applied will get on to the target and less will depart from the spray area.

More research is required to determine the increased spray catch that can be attributed to 130 µm drops. It must be done with leaf shaped targets that have a catch surface characteristic similar to a leaf surface, plus it must also be conductive. Studies also need to look at plant shading and the deposits on the shaded plants.

Many of the studies illustrate an improvement in efficacy as drop sized and carrier volume were reduced. It has not been proven if the increased concentration of the chemical or the increased coverage or the increased number of positions that the chemical contacts the leaf is/are responsible for the increased efficacy. Roundup is the most responsive chemical to BDT with successful control demonstrated at 25% of the recommended rate. The increased amount of chemical required for control under stress condition was illustrated with the summer and fall Roundup study. The studies have illustrated that reducing drop size and carrier rates can increase the efficacy of Roundup and that stress increases the amount of chemical required for control. Also that ammonium sulfate increased Roundup's efficacy. It is unclear if Roundup responds to increased coverage or concentration. Fusilade and Glean responded to BDT, showing control at 25% and 20% rates.

All chemical included in the test showed no reduction in control as the carrier volume was reduced to 30 L/ha. The reduction in control at 10 L/ha of some chemicals may be attributed to the plugging problems experienced with the small tips and the high speed required to apply 10 L/ha with larger tips. Development of better filtering systems and a nozzle flow monitor is in progress.

The studies indicate that there are 5 variables that the applicator can control that work synergetically to reduce the amount of carrier and herbicides required for control. Research needs to further investigate the interaction of the 5 with individual chemicals and weeds. If, as indicated in our research and the literature, the plant's susceptibility to herbicides vairies greatly with environment and other stress effects, a plant susceptibility meter or index needs to be developed to give a quantitative number with which the applicator can adjust his chemical rate to get both economical and reliable weed control. The fact that Arkansas has recommneded rates below label recommendation has destroyed the myth that it is illegal to apply less than label rates.

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