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GLYPHOSATE FOR THE CONTROL OF SEEDLING ANNUAL WEEDS

by

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Glyphosate was applied to seedling annual weeds in the field, in the greenhouse and in the growth cabinet in order to determine the rates required and the best method of application, i.e, spray volume and surfactant concentration, for optimum weed control.

In the field under conditions of moderate crop competition .21 kg/ha, .14 kg/ha, .42 kg/ha, and .28 to .42 kg/ha was required to control *Avena fatua* (wild oat), *Setaria viridis* (green foxtail), *Polygonum convolvulus* (wild buckwheat), and *Brassica kaber* (wild mustard) respectively.

In the field with no crop competition .56 kg/ha glyphosate did not give sufficient control of wild buckwheat but controlled *Polygonum persicaria* (lady's thumb). Under the same conditions .14 kg/ha glyphosate controlled green foxtail. In the greenhouse the ED_{50} for wild oats, green foxtail, wild buckwheat, and wild mustard was .44 kg/ha, .04 kg/ha, .51 kg/ha, and .05 kg/ha, respectively.

The addition of surfactant[1] to the spray solutions (up to 0.50 per cent) generally increased the phytotoxicity of glyphosate to plants grown in the growth cabinet. In the field, using wild buckwheat as the

[1]MON-0011 - Surfactant supplied by Monsanto Company Limited.

major indicator, optimum control was achieved with glyphosate when the surfactant comprised at least 0.50 per cent of the spray solution. The addition of surfactant to the spray solution increased the retention on grassy species but did not increase the spray retention on broad leaved species.

The method used to measure spray retention on plants involved the recovery of the water-soluble dye, Niagra Sky Blue. A differential dye recovery was obtained from plants, washed 36 or more hours after spray application. Less dye was recovered from plants sprayed with solutions of high surfactant concentrations.

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INTRODUCTION

Tillage of the soil for growth of agricultural crops is becoming increasingly expensive due to rising costs of fuel, machinery and labour. It has been shown that tillage is not necessary for crop growth provided weed control is adequate. The compound paraquat has given excellent control of seedling annual weeds prior to emergence of the crop. However, paraquat does not control perennial weed species. In attempting to control perennial weeds, researchers have turned to N-(phyosphonomethyl) glycine, (glyphosate). Glyphosate is a suitable herbicide for zero tillage seed bed preparation because of its wide spectrum control, its nonresidual action, and its effective control of perennial weeds through single applications.

Donaghy (1973) found glyphosate at .56 kg/ha resulted in annual weed control equivalent to the control obtained from the use of paraquat plus diquat at .84 + .28 kg/ha. Since the rates of glyphosate required and the methods of its application for control of seedling annual weeds had not been fully investigated, a study was initiated using glyphosate in the field and in the greenhouse to determine the potential of this compound for zero tillage seed bed preparation.

Four seedling annual weeds including *Avena fatua* (wild oat), *Setaria viridis* (green foxtail), *Polygonium convolvulus* (wild buckwheat), and *Brassica kaber* (wild mustard) were chosen for this study.

LITERATURE REVIEW

A. Glyphosate

Glyphosate is formulated as an isopropylamine salt and sold under the trade name Roundup.[2] Roundup contains 4 pounds of the salt or the equivalent of 3 pounds of the glyphosate acid per U.S. gallon (Monsanto 1973).

Glyphosate is essentially a nonselective herbicide, killing most green vegetation at normal use rates of 1.12 to 3.36 kg/ha active. The use of glyphosate as a broad-spectrum herbicide was first reported by Baird *et al.* in 1971. At that time it was also reported that glyphosate was a nonresidual type chemical.

Work by Sprankle *et al.* (1974) demonstrated that the nonresidual effects of glyphosate are partly due to adsorption of the glyphosate to the soil constituents and possibly due to rapid breakdown. Addition of 1 per cent montmorillonite clay to the herbicide spray solution reduced the herbicidal effects by 80 to 90 per cent, thus supporting the soil adsorption theory. Rieck *et al.* (1974) stated that soil adsorption cannot account for all the reduction in herbicidal effect.

Reports by Freeman, by Dhindsa and by Molberg in the 1973 Resarch Report of the Canada Weed Committee, Western Section, demonstrated that many weed and crop species are controlled by foliar applications of glyphosate. However because glyphosate is nonresidual, weeds emerging after treatment are not affected. Weeds germinating prior to emergence

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[2]Roundup is manufactured and sold by Monsanto Company Limited.

of the crop compete much more severely with the crop than those germinating 5 days after emergence of the crop Dew (1973).

Perennial weeds such as *Agropyron repens* (quack grass) and *Cirsium arvense* (Canada thistle), which presented problems under zero tillage (Donaghy, 1973), have been controlled by the use of glyphosate according to reports by: Gottrup (1974), Valgardson (1974), Hughes (1974), and Friesen (1974). Gottrup (1974), reported effective control of Canada thistle from glyphosate applications at all growth stages. Best control was obtained from applications made at mature growth stages but application to young regrowth after cutting or harvest was also effective.

Hughes (1974) reported good quack grass control from spring applications of glyphosate at 1.68 to 3.68 kg/ha. Friesen (1974) reported good control of quack grass from September applications of glyphosate at 1.12 to 3.36 kg/ha.

Valgardson (1974) reported effective control of quack grass when glyphosate was applied in spring at a rate of 2.24 to 3.36 kg/ha. No residual effects of the herbicide were seen on rapeseed or buckwheat from using 2.8 kg/ha of glyphosate in the field. Some toxic effects were seen on rapeseed and buckwheat sown in soil sprayed with high dosages of glyphosate (4.48 to 8.96 kg/ha).

Jaworski (1972), based on studies with *Lemma gibba* and *Rhizobium japonicum*, suggested that glyphosate interfered with the synthesis of aromatic amino acids. Plants treated with glyphosate did not suffer herbicidal effects if the aromatic amino acids, L-phenylalanine and/or L-tyrosine, were added to the nutrient media.

B. Zero Tillage

The first successful work on zero tillage crop production was reported by Russel in 1945, cited by Donaghy (1973). Since that time much work has been done on the zero tillage production of cereal and oil seed crops as well as corn, soybeans, and several fruit and vegetable crops.

In Manitoba Donaghy (1973) concluded wheat, barley, flax, and rape crops could be produced under zero tillage conditions provided that proper management practices were carried out. Weed growth at the time of seeding was controlled with paraquat plus diquat at 0.84 + 0.28 kg/ha, with paraquat plus 2,4-D ester at 0.84 + 1.12 kg/ha, and with paraquat plus bromoxynil at 0.28 + 0.56 kg/ha. The perennial weeds, quack grass and Canada thistle, became a problem under zero tillage conditions in these test areas. Glyphosate at .56 kg/ha resulted in weed control equivalent to control from paraquat plus diquat at 0.84 + 0.28 kg/ha.

C. Phytotoxicity of Foliar Applied Herbicides

Blackman (1952) stated that the phytotoxicity of a systemic type herbicide depends upon the amount of herbicide reaching the site of action and the tolerance of the species at that point. The amount of material reaching the site of action in the case of a foliar applied herbicide is determined by retention, penetration, translocation, and the degree of localized accumulation in the different tissues. For materials easily translocated, methods of growth analysis are of value for assessing toxic effects (especially of nonlethal dosages). If per cent mortality is plotted against the amount of toxicant a sigmoid relationship exists. This curve forms a straight line when per cent mortality is converted to the probit scale and then plotted against the log of the dosage. Dosages should be chosen so that the lower dose kills some of the plants and the higher dose does not kill all the plants. Concentrations should increase on a geometric scale.

Blackman also stated that if the probit regression lines were parallel, the modes of action were similar, because the relationship between toxicity and the amount of herbicide reaching the site of action (i.e., per cent retained, penetrated, and translocated, etc., to the site of action) was the same in each case. By changing the formulations it would be possible then to change the slope of the regression line. Sampford (1952) stated that parallel regression lines suggest similar physiological action.

McKinlay *et al.* (1972) studied the herbicidal effect of the droplet number and the droplet concentration of 2,4-D on sunflower seedlings. He found that for any given droplet size the dosage could be effectively increased either by increasing the droplet number or by increasing the droplet concentration. Microscopic examinations of sprayed leaves confirmed work done by Ennis (1963) that the smaller droplets were more effective in controlling plants than larger droplets, because the larger droplets became physiologically isolated. The cells under the 400 μ droplet died whereas the cells under a 100 μ or 200 μ droplet didn't die. It appeared that less herbicide was translocated from under the larger droplet as compared to the smaller droplet because dead cells did not translocate. Another factor would be that the total area of leaf contacted from many small droplets was greater as compared to the same amount of herbicide sprayed in large droplets.

In McKinlay's tests 3 times and 6 times as much 2,4-D was required to produce the same herbicidal effect on sunflower seedlings when applied as 200 μ and 400 μ droplets respectively, as compared to applications of 100 μ droplets.

D. Retention of Foliar Applied Herbicides

Aslander (1927) concluded that the effectiveness of sulphuric acid as a selective herbicide for broadleaved weed control in cereal crops was dependent on the differential retention of spray droplets. Differential retention was mainly due to the different angles of incidence and the difference in wax development of the cuticle on broadleaved weeds compared to cereal plants. Blackman (1936, cited by Blackman *et al.*, 1957) demonstrated that the addition of a surface active agent to the spray solution could bring about greater toxicity of the acid to species with a waxy cuticle owing to the enhanced retention. Smith (1956, cited by Blackman *et al.*, 1957) found that depressions in the growth of kidney beans induced by 2,4-D varied with the droplet size and the spray volume, and that both of these factors influenced retention. Fogg (1947) demonstrated that with the large contact angle between the spray droplet and the leaf surface in cereals, the area of contact was small and the droplet tended to roll off. The contact angle is different for cotyledons than for true leaves so differential retention could be expected for these different plant parts.

Loomis (1949, cited by Blackman *et al.*, 1957) noted that for translocated herbicides, coarse sprays of high surface tension were more effective than a combination of a fine spray and a low surface tension.

Ennis *et al.* (1952) concluded that the greater growth depression induced in a pubescent as opposed to a glabrous variety of soybeans when using 2,4-D could be attributed to the greater retention. These workers also demonstrated that the addition of a wetting agent reduced the incidence of droplets bouncing off the leaf surface (regardless of leaf type).

Hellquist (1955, cited by Blackman *et al.*, 1957) found that particularly the larger droplets had greater tendency to roll off leaves where the angle of incidence was greater, eg., with *Hordeum vulgare* (barley) than where the angle of incidence is smaller (eg., with *Pisum sativum*, field peas).

Woofter (1953) and Hellquist (1955, cited by Blackman *et al.*, 1957) demonstrated that with *Triticum vulgare* (wheat), *Hordeum vulgare* (barley), *Linum usitatissium* (flax), *Pisum sativum* (field peas), *Chenopodium album* (lamb's quarters), and *Brassica kaber* (wild mustard) as output increased the proportion of spray droplets retained diminished. Hellquist also demonstrated that as surface tension was reduced from 50 to 35 dynes per centimeter the amounts retained by field peas and barley increased.

It was shown by Fraser *et al.* (1956, cited by Blackman *et al.*, 1957) that for fan spray nozzles the mean droplet size was linked with the surface tension of the spray solution and with the orifice area but for any orifice there was a wide distribution of droplet size formed.

Brunskill (1957), using field peas as a horizontal surface, demonstrated that when surface tension was high a very high proportion of the droplets with diameter 250 μ to 350 μ bounce off the leaves but below a critical value of surface tension (45 to 50 dynes/cm) there was a sharp rise in the number of droplets retained. For small droplets (80 μ to 95 μ) of a high surface tension, retention was almost complete but as size increased up to 250 μ to 325 μ the percentage retained falls progressively. That is, reducing the surface tension to 45 dynes/cm has little influence on the retention of the smaller droplets but causes more of the larger droplets to remain on the leaf.

Brunskill demonstrated that if the velocity of a large droplet (380 μ and surface tension 55 dynes/cm) was accelerated five-fold then the percentage of droplets retained rose from 57 to 95. Also, as the surface tension increased the percentage of large droplets retained decreased and it decreased to a greater degree as the angle of incidence increased from 0^{o} to 60^{o}C.

Contrary to Brunskill's findings (1957) (that the critical range for surface tension as it affects retention was from 47 to 42 dynes/cm), Blackman *et al.* (1957) found that retention was not greatly augmented until surface tension was reduced from 40 to 30 dynes/cm. Davies *et al.* (1967) suggested that the discrepancy mentioned above could have been due to the differences in surfactants used, in the nature of the surfaces examined, and/or in the droplet sizes used.

Blackman *et al.* (1957) demonstrated that spray retention on a leaf surface was influenced by the spray output, the mean droplet size, and the droplet surface tension. The magnitude of the induced changes were dependent on the species involved. Plant characteristics affecting spray retention were morphology of the shoot, particularly the ease or difficulty of wetting the surfaces, the types and position of the leaves, and the stage of plant development. They found that repeated applications with smaller nozzles gave higher total retention than single applications using larger nozzles. They concluded that maximum differences in retention would be with large spray droplets of a high surface tension where the leaf surfaces of one species repelled the droplets and those of the other species did not. Blackman *et al.* also concluded that optimum spray volumes were just below where run-off takes place.

Furmidge (1962) found that run-off caused little reduction in retention on leaves with rough surfaces, however, on smooth surfaced leaves the reduction in retention was considerable. He stated that retention was reduced by wind moving the leaves and this reduction in retention was taking place because the impact velocity of droplets striking the leaf surface was increasing. Furmidge found that for surfaces that show little contact angle hysteresis with water, the addition of wetters in low concentrations increased both the retention of spray solution and the degree of cover on the surface.

Davies *et al.* (1967) found retention of ioxynil by mustard leaves, which are easy to wet, was proportional to the concentration sprayed and was not affected by the surface tension of the spray solution. Addition of the surface active agent (Tween 20) up to 1.0 per cent to ioxynil spray solution increased the retention on field peas and barley. Phytotoxicity, however, was not increased on barley to the same extent as it was with field peas as a result of the addition of Tween 20 to the ioxynil spray solution. Leaf angle studies by Davies confirmed that the angle of incidence with barley was an important factor in determining the degree of retention.

Schafer (1973) using the Niagra Sky Blue water-soluble dye found that the addition of surfactant (Tween 20) only enhanced retention on those species which were difficult to wet.

MATERIALS AND METHODS

Field Experiments 1973

Field experiments in 1973 (Experiments 1, 2, and 3) were carried out on an Almasippi very fine sandy loam soil at Carman, Manitoba. Seven rates of glyphosate, .07, .14, .21, .28, .42, .56, and .84 kg/ha were applied at 3 different postemergence stages. *Vicia faba* (faba beans) were planted over the experimental area on May, 1973 so that the tolerance of this crop to glyphosate could be assessed.

The experimental design used was a randomized complete block design with 4 replications. Plots, 2.0 m x 6.4 m, were sprayed with a hand operated bicycle type push sprayer. Spray applications were made using Tee-jet 6502 nozzles delivering 138.2 l/ha at 2.46 kg/cm^2 pressure and 5.6 kph.

Visual ratings were based on a 0 to 9 scale which is outlined in Table 1.

Dry weight measurements were obtained from labeled plants. Plants in the appropriate stage were labeled with plastic colored rings at the time of spraying. Five wild oat plants, 5 green foxtail plants, 5 wild buckwheat plants, and 3 wild mustard plants were labeled from each plot in 2 replications.

On September 10, 1973 labeled plants were cut off at ground level, dried and weighed. The results are reported as the average weight in mg per plot for the two replications harvested. A statistical analysis was not carried out on this limited sampling as trends were obvious and in some cases where higher rates of glyphosate were used, death of the plant had occurred. The rates of glyphosate used ranged from 0.07 kg/ha to 0.84 kg/ha for all 3 experiments.

TABLE 1

Visual rating scale.

	Rating	Weed control	Crop tolerance
not commercially acceptable range	0	No weed control.	No crop tolerance (everything dead)
	1	Very slight evidence of weed control.	Very slight crop tolerance.
	2	Slight evidence of weed control.	Slight crop tolerance.
	3	Very poor weed control.	Very poor crop tolerance.
	4	Poor weed control.	Poor crop tolerance.
	5	Moderate weed control.	Moderate crop tolerance.
	6	Inadequate weed control.	Inadequate crop tolerance.
commercially acceptable range	7	Acceptable weed control.	Acceptable crop tolerance.
	8	Very good weed control.	Very good crop tolerance.
	9	Complete weed control (all weeds dead)	Complete crop tolerance.

Experiment 1. Inhibition of weed growth by glyphosate, plants cotyledon to 2 leaf stage.

Spray application was made on May 26, 1973 when faba beans had 2 bifoliate leaves fully expanded, 90 per cent of the wild oats were in the 1 leaf stage and 10 per cent were in the 2 leaf stage, green foxtail was in the 2 leaf stage, wild buckwheat was in the cotyledon stage, and wild mustard had 2 true leaves.

Experiment 2. Inhibition of weed growth by glyphosate, plants 2 to 4 leaf stage.

Spray application was made on June 6, 1973 when faba beans had 2 to 3 bifoliate leaves fully expanded, wild oats were in the 3 to 4 leaf stage, green foxtail was in the 4 leaf stage, and wild buckwheat and wild mustard were in the 2 leaf stage.

Experiment 3. Inhibition of weed growth by glyphosate, plants 3 to 6 leaf stage.

Spray application was made on June 14, 1973 when faba beans were 15 to 20 cm tall and had 3 to 4 bifoliate leaves. Wild oats, green foxtail, and wild mustard had 5 to 6 leaves, while wild buckwheat had 5 leaves.

Greenhouse Experiments 1973-1974

Greenhouse experiments (Experiments 4 through 7) were conducted on plants grown in metal pots (juice cans) 10.9 cm in diameter x 17.6 cm tall. Pots were arranged on the greenhouse bench in a randomized complete block design with 8 replications per treatment. Supplementary light ($2710\ \mu W/cm^2$) was provided by using very high output fluorescent tubes for a 16 hour light period. Growth media consisted of 3 parts clay loam soil, 1 part shredded peat moss, and 1 part sand. The media was fertilized as required with 11-48-0 plus 34-0-0 and RX 15 (6-12-6) fertilizers to maintain good plant growth.

Spraying was carried out in a cabinet type sprayer equipped with a Tee-jet nozzle. All treatments were sprayed at 135.4 l/ha and 2.46 kg/cm^2 pressure using a Tee-jet 6502 nozzle.

Control plants were harvested at spraying and with treated plants 10 days after spraying. Plants were dried and weighed, and the results are reported as relative growth. Relative growth (RG) was calculated according to the following formula.

$$R.G. = \frac{W_T - W_o}{W_c - W_o}$$

where: W_o = mean dry weight of plants at the time of spraying.

W_c = mean dry weight of the control plants 10 days after spraying.

W_T = mean dry weight of the treated plants 10 days after treatment.

Relative growth was converted to the probit growth analysis scale and plotted against the $\log_{10}$ of the dosage to give the ED_{50} value.[3]

[3] $E.D._{50}$ value = the dosage of herbicide required to reduce the relative growth by 50 per cent.