

Herbigation* in a Vineyard through a Microjet Irrigation System

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The control of a variety of weeds by one post-emergence and five pre-emergence herbicides applied through a microjet irrigation system was determined. Oxadiazon and simazine gave good control of the weed species present in the trial. Napropamide controlled the different grass species effectively, but did not control the broadleaf weeds. A combination of chlorsulfuron and metsulfuron methyl, in the ratio 3:1, controlled two grasses and one broadleaf weed effectively. Oryzalin controlled three of the predominant grass species effectively, but did not control the broadleaf weeds. It was found that herbigation with any of the five pre-emergence herbicides mentioned, can be utilized commercially to control susceptible weeds on medium textured soils in South African vineyards. A comparative study with simazine showed that herbigation through microjet irrigation systems can replace tractor boom sprayers as an application technique on medium textured soils. In the case of a microjet irrigation system with the emitters mounted at 3 m intervals, the microjets should be situated on top of the irrigation line and the pressure in the system maintained at 200 kPa to ensure an efficient application. The post-emergence weed control by paraquat dichloride was unacceptable.

Conventional applications of herbicides in South African vineyards are done mainly by tractor boom sprayers. However, applications of herbicides through irrigation systems (herbigation), hold great promise. According to Threadgill (1981), herbigation increases crop production efficiency by reducing costs for equipment, labour and fuel, especially for farmers who already have the equipment to inject fertilizer into the irrigation system.

The feasibility of herbigation was well proven by previous research. Various researchers achieved effective weed control with different combinations of irrigation systems and herbicides (Uda & Morimoto, 1977; Ogg, 1980; Banks & Dowler 1984). Fisher *et al.* (1985) found that oryzalin (3,5-dinitro-N⁴-diethylpropionamide), a mixture of simazine [2-chloro-4,6-di(ethylamino)-1,3,5-triazine] and oryzalin as well as a mixture of simazine and napropamide [2-(α -naphthoxy)-N',N'-diethylpropionamide] gave good weed control when applied through a low-volume sprinkler system. Lange *et al.* (1974) also achieved good weed control with a combination of simazine and oryzalin. Another effective combination was simazine plus oxadiazon [5-tert-butyl-3-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazol-2-one]. The weed control efficiency of napropamide was more constant than that of the other herbicides over the 9-month evaluation period which was probably due to its resistance to leaching.

Researchers reported dissimilar results when they compared the weed control efficiency of herbicides applied through an irrigation system and with a conventional sprayer. The performance of alachlor (α -chloro-2',6'-diethyl-N-methoxymethylacetanilide and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-S-triazine] was identical for the two methods of application (Robison & Mulliner, 1972; Fischbach & Martin, 1976). Weed control obtained with butylate (S-ethyl di-

isobutylthiocarbamate), EPTC (S-ethyl dipropylthiocarbamate) and vernolate [S-propyl dipropyl (thiocarbamate)] however, was slightly better with the conventional applications than with the sprinkler applications (Fischbach & Martin, 1976). Oren and Israeli (1977) found that a mixture of bromacil (5-bromo-3-sec-butyl-6-methyluracil) and diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] gave better and longer control of the predominant weeds when applied through the irrigation system. King, Miller and Smith (1980) found that chlorthal dimethyl (dimethyl-2,3,5,6-tetrachloroterephthalate) applied through a sprinkler irrigation system was slightly more effective than when applied by a conventional sprayer. Trifluralin (2,6-dinitro-N,N-dipropyl-4-trifluoromethylaniline) was much less effective when applied through a sprinkler system than when applied conventionally (Smith, Berner & Walter, 1973; Ogg, 1976; Ogg, 1980).

Various factors influence the efficiency of herbigation. Crutchfield, Clark and Wiese (1977) showed that about 85% of the trifluralin applied in irrigation water was lost by evaporation before it reached the soil surface. Under the same conditions, loss of atrazine was only 10%. These results explain why atrazine can be applied through sprinkler systems and efforts to do the same with trifluralin have failed. According to Ogg (1986), herbicides with relatively low vapour pressure such as alachlor, atrazine and metribuzin (4-amino-6-tert-butyl-4,5-dihydro-3-methylthio-1,2,3-triazin-5-one) controlled weeds equally well when applied through sprinklers or sprayed conventionally, whereas herbicides with relatively high vapour pressures such as EPTC, vernolate and trifluralin are less effective when applied through sprinklers. Some pre-emergence herbicides are less effective when applied conventionally, because the spray droplets dry rapidly and the herbicides are partly adsorbed on the soil particles of the sur-

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face soil. During the subsequent irrigation the herbicide must first be desorbed before it can move into the top soil layer. Where herbigation is used, the herbicide is moved into the soil without intermediate drying, thus making it more available for pre-emergence weed control (Horowitz & Bucsbaum, 1978).

Effective distribution of the herbicides depends on an even water distribution which was defined as the Coefficient of Uniformity (CU) (Christiansen, according to Vories & Von Bernuth, 1986). According to Woodward (1959), the following factors primarily influence the water distribution pattern of a system namely 1) the spacing of the emitters and laterals; 2) the emitter size and 3) the water pressure in the system. Whenever the spacing of the emitters is changed, the extent of the overlap from adjacent emitters changes. Therefore, a decrease in the spacing of the emitters usually increases the CU if all the other variables are held constant (Vories & Von Bernuth, 1986). Increasing the pressure, increases the wetting diameter of emitters. This tends to give more uniform distribution patterns. Low CU values indicate an incorrect combination of emitter size, operating pressure and spacing (Woodward, 1959). Wind is the environmental factor that most reduces the uniformity of application. Woodward (1959) stated that the CU decreased as wind speed increased. According to Ogg *et al.* (1983), herbicides should not be applied through a solid set irrigation system when wind velocities exceed 12 km/h.

In most cases, crop tolerance to a herbicide is the same whether it is applied conventionally or through an irrigation system (Robison & Mulliner, 1972; Fishbach & Martin, 1976; Horowitz & Bucsbaum, 1978). Oryzalin, oxadiazon, oxyfluorfen (2-chloro- $\alpha\alpha\alpha$ -trifluoro-p-tolyl-3-ethoxy-4-nitrophenyl ether) and metolachlor [2-chloro-6'-ethyl-N-(2-methoxy-1-methylethyl) acet-O-toluidide] with or without simazine applied by means of herbigation resulted in 9-19% less injury to three container-grown ornamental species and 6-13% better control of *Digitaria sanguinalis* than the conventional spray applications (Caviness, Talbert & Klingaman, 1983). A factor affecting phytotoxicity in herbigation is the rinse factor. According to Ogg (1981) very little herbicide remains on the leaves of crop plants due to rinsing, which explains why seedling lucerne (*Medicago sativa*) is more tolerant to bromoxynil (3,5 dibromo-4-hydroxybenzonitrile) applied through sprinklers than bromoxynil applied with a conventional sprayer. Oren and Israeli (1977) found that a rinse period of ten minutes after application of a bromacil and diuron mixture through a solid set irrigation system is needed to prevent damage to the leaves of 4-year-old grapefruit trees.

In the case of the post-emergence herbicides, Dowler (1982) found that acifluorfen [5-(2-chloro- $\alpha\alpha\alpha$ -trifluoro-p-toloxo)-2-nitrobenzoic acid] and sethoxydim [($\pm$)-2-[1-(ethoxyiminobutyl)]-5-(2-ethylthio) propyl]-3-hydroxy-cyclohex-2-enone] showed moderate to good activity when applied by means of a centre pivot irrigation system. Ogg (1981) found that bromoxynil and a mixture of bromoxynil and MCPA (4-chloro-2-methylphenoxyacetic acid) applied to both wheat (*Triticum aestivum*) and lucerne through herbigation did not control the weeds as effectively as when applied

conventionally. Robison and Mulliner (1972) concluded that herbigation was not appropriate for foliage-active herbicides because these are washed off the leaves.

When stationary sprinkler systems are used, most herbicides should be applied during the first part of the irrigation period (Callihan *et al.*, 1978). According to Oren and Israeli (1977) a minimum of 15 minutes of application time is required to ensure an even distribution of the herbicide used. Successful weed control through herbigation as well as crop tolerance towards a herbicide depends greatly upon the amount of water applied after the herbicide has passed through the irrigation system (Ogg *et al.*, 1983; Ogg, 1986). Phatak (1982) found that metham sodium (sodium N-methyldithiocarbamate) was the most effective when applied with 6,4 mm and 12,7 mm irrigation water on a Lakeland sand by means of solid set overhead sprinklers. In the case of atrazine as well as a mixture of butylate and r-25788 (S-ethyl diisobutylthiocarbamate), Todd and Klocke (1984) obtained the most effective weed control with applications of a 19 mm and 25 mm irrigation on a fine sandy soil. Callihan and Leino (1979) found that EPTC and vernolate applied through solid set sprinklers on a silt loam controlled wheat (used as a bioassay plant) better when followed by 13 mm or 25 mm of water.

Although herbigation was researched well in the case of sprinkler irrigation systems, very little research was done with low volume systems. It was, therefore, necessary to evaluate the feasibility of herbigation through a microjet irrigation system as an application technique in South African vineyards. Five pre-emergence herbicides and one post-emergence herbicide were included in the study to determine their weed control efficiency when applied through a microjet irrigation system.

MATERIALS AND METHODS

Experiment 1: Water distribution pattern

Irrigation lines were mounted 3 m apart on a wire 450 mm above the soil surface with the microjets installed 3 m apart. In this study microjets with a 280° and 360° wetting pattern delivering 32 l/h were evaluated. The microjets on adjacent irrigation lines were installed in alternating positions. To determine the water distribution pattern, catch cans were placed 300 mm apart over the whole area wetted by a microjet (9 m²). The microjets were operated at water pressures of 100 kPa, 150 kPa and 200 kPa. The first series of water distribution patterns were determined with the microjets situated on top of the irrigation line, whereupon the whole process was repeated with the irrigation line in the inverted position. Each treatment was replicated five times. The treatments were evaluated for surface wetting (% coverage) and the variation in the water distribution pattern which was expressed as the Coefficient of Uniformity.

Experiment 2: Evaluation of different pre-emergence herbicides

This investigation was carried out in a seven-year-old *Vitis vinifera* cv Pinotage vineyard grafted on 99 Richter rootstock. The vines were growing on a medium tex-

tured Clovelly soil, with a clay content of 18%, and were trained onto a slanted trellis system. The irrigation system used for this experiment consisted of irrigation lines with a diameter of 20 mm, mounted 3 mm apart on a wire 450 mm above the soil surface. Microjets (360°) delivering 32 l/h were mounted 3 m apart on top of the irrigation line with the microjets on adjacent lines in alternating positions. Each plot consisted of an area of 108 m² and was replicated four times in a randomized block design. The treatments were a control (no herbicide application) and five pre-emergence herbicides, namely simazine (3 kg/ha), oxadiazon (1,2 kg/ha), napropamide (2,7 kg/ha), oryzalin (2,3 kg/ha) and a mixture of chlorsulfuron [2-chloro-N(4-methoxy-6-methyl-1,3,5-triazin-2-yl) aminocarbonyl benzene sulfonamide] and metsulfuron methyl [methyl 2-[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino] carbonyl] amino] -sulfonyl] benzoate] at a dosage of 25 g and 8 g/ha respectively. These herbicides were injected into the microjet irrigation line by means of a diaphragm pump during the first 20 minutes of an irrigation with the pressure in the system at 200 kPa. The herbicides were applied with 20 mm of irrigation water at the flowering stage of the vines. Ten weed species (or bioassay plants) were sown one day before herbigation to ensure a good weed stand in the experimental plots. For the duration of the experiment, 25 mm of irrigation water was applied weekly. The rainfall over the 90 days in which the weed control efficiency was monitored amounted to 73 mm. The dry mass per m² was determined and the number of weeds per m² counted 30, 60 and 90 days after herbigation to determine the weed stand and the efficiency of the different treatments. Simultaneously the vines were monitored visually for any phytotoxicity symptoms on the leaves. Additionally, all species representing more than 5% of the spectrum were identified and their control by the different herbicides expressed as a percentage of the control treatment.

These measurements were taken during both the 1985/86 and 1986/87 season.

Experiment 3: Comparison of herbigation vs conventional method

In this experiment simazine (3 kg/ha) was applied during November by means of a tractor boom sprayer (an application volume of 500 l/ha) and a microjet irrigation system as described in Experiment 2, respectively. Each treatment covered an area of 420 m². From each treatment 10 randomly selected sites (1 m²) were chosen on which the dry mass and the number of weeds per m² were determined 90 days after the application date.

Experiment 4: Evaluation of a foliage-active-herbicide

The efficiency of paraquat dichloride applied early September (before budburst) by means of a microjet irrigation system as a post-emergence treatment on *Secale cereale*, established as a cover crop in the working rows of the vineyard used in Experiment 2, was determined. The paraquat dichloride (1 kg/ha) was injected into the microjet irrigation system by means of a diaphragm pump while the pressure in the system was 200 kPa. Injection times of 9, 10 and 11 minutes were used and evaluated as three different treatments. The effi-

ciency of the applications were evaluated visually, 14 days after the application and expressed as a percentage of the control.

RESULTS AND DISCUSSION

Experiment 1: With the irrigation line in the inverted position, neither the 280° nor the 360° microjet could give a 100% coverage of the measured area at the three water pressures applied (Table 1), which is unacceptable for total weed control by means of herbigation. With the microjet situated on top of the irrigation line, a 100% coverage of the area was achieved at all the given pressures. The Coefficient of Uniformity (CU) of the 280° microjet was constantly higher than that of the 360° microjet (Table 1). This could be attributed to the fact that the 360° microjet consisted of twelve orifices distributing the water as twelve separate jets, whereas the 280° microjet delivered the water through two orifices that fanned the water over the wetting area. For both types of microjets used in the study, the CU improved with an increase in the water pressure. The highest CU's were achieved with the 280° microjet at a pressure of 200 kPa followed by the 280° microjet at 150 kPa and the 360° microjet at a pressure of 200 kPa. A CU of 80% and higher is acceptable for field applications (Griffin, 1978). Therefore herbigation through a microjet system should be done with the microjets mounted on top of the irrigation line and the water pressure at 200 kPa. This study showed that the water pressure in a solid set irrigation system affected the water distribution of the emitters, which is contrary to what was found for a centre pivot irrigation system (Banks & Dowler, 1984).

TABLE 1

Water distribution and Coefficient of Uniformity of microjet emitters, mounted on the irrigation line at 3 m intervals determined at three different pressures.

Nozzle	Pressure (kPa)	Emitters inverted	Emitters in vertical positions	
		%coverage	%coverage	CU*
280°	200	43	100	90
	150	32	100	88
	100	24	100	68
360°	200	70	100	80
	150	70	100	74
	100	57	100	53

*Not determined for emitters underneath the line because of inadequate coverage

Experiment 2: The efficiency of the five pre-emergence herbicides is illustrated in Tables 2 to 4. The results obtained, showed the same tendencies for both seasons and therefore only the results of the 1986/87 season are presented in this paper. Thirty days after the herbicides were applied, the stand of the weeds (compared on a dry mass basis) in all the treatments was no higher than 11% of that of the control (Table 2). Sixty days after application the weed stand in the simazine, oxadiazon and napropamide treatments still did not exceed 4,5%

TABLE 2

Effect of herbicides on weed stand per m² at different periods after application through microjets.

Treatments	Days after application					
	30		60		90	
	Dry mass (g)	% of the Control	Dry mass (g)	% of the Control	Dry mass (g)	% of the Control
Control	5,06	100	22,37	100	44,19	100
Oryzalin	0,54	10,7	5,06	22,6	8,21	18,6
Napropamide	0,02	0,4	1,01	4,5	1,77	4
Oxadiazon	0,12	2,4	0,33	1,5	2,16	4,9
Simazine	0,02	0,4	0,86	3,9	1,95	4,4
Chlorsulfuron/ Metsulfuron methyl	0,56	11	17,08	76,4	36,72	83,1
D value (P≤0,01)	2,49	—	14,04	—	16,75	—

of the control while the stand in the oryzalin and chlorsulfuron/metsulfuron methyl treatments was 22,6% and 76,4%, respectively. Ninety days after application, the tendency in all the treatments remained the same.

The number of weeds per m² was lower than 7% of the control for the simazine, oxadiazon and napropamide treatments up to 90 days after the application of the herbicides (Table 3). For the oryzalin treatment the number of weeds varied between 7,6% and 19,4% of the control. For the chlorsulfuron/metsulfuron methyl treatment it varied between 42% and 73%. In the control plots, the weed population did not increase from the second (60 days) to the third (90 days) evaluation. This might be due to the inhibitory effect of the established weeds on the germination of new weeds.

Seven weed species (two broadleaf weeds and five grasses) were found to be representative of the weed population in the control plots (Table 5). Simazine gave excellent control of all the weed species present except

for *Vicia sativa* which was controlled moderately at the 60 day period but good to excellent at the 30 day and 90 day periods. The reason for this is not clear. *Setaria italica*, *Eragrostis curvula* and *Digitaria smutsii* were controlled excellently by oxadiazon for a period of 90 days. This herbicide gave good control of the *Secale*, *Medicago* and *Rhyncheletum* species up to 90 days after application. *Vicia sativa* was controlled moderately at the 90 day evaluation. Both napropamide and oryzalin gave excellent control of the *Digitaria*, *Eragrostis* and *Rhyncheletum* species. The control of *Secale cereale* by the napropamide treatment was good up to 90 days after application, whereas the control of *Medicago sativa* was unacceptable after sixty days. The herbicide did not control *Vicia sativa* at all. Neither of the broadleaf weeds was controlled sufficiently by oryzalin. Initial control of the *Secale* and *Setaria* species by the oryzalin treatment was excellent, but the weeds broke through after a period of 30 days. The chlorsulfuron/metsulfuron methyl mixture gave excellent control of the *Seta-*

TABLE 3

The effect of different herbicides on weed number per m² at different periods after application through microjets.

Treatments	Days after application					
	30		60		90	
	Weeds per m ²	% of the Control	Weeds per m ²	% of the Control	Weeds per m ²	% of the Control
Control	134	100	499	100	444	100
Oryzalin	22	16,4	38	7,6	86	19,4
Napropamide	3	2,2	18	3,6	31	7
Oxadiazon	4	3,0	5	1	16	3,6
Simazine	1	0,7	6	1,2	11	2,5
Chlorsulfuron/ Metsulfuron methyl	94	70	211	42	324	73
D value (P≤0,01)	74	—	129	—	115	—

TABLE 4

The control of different weed species by five herbicides at different periods after application through microjets.

Weed species	Control														
	Simazine			Oxadiazon			Napropamide			Oryzalin			Chlorsulfuron/ metsulfuron methyl		
	Days after application			Days after application			Days after application			Days after application			Days after application		
	30	60	90	30	60	90	30	60	90	30	60	90	30	60	90
<i>Medicago sativa</i>	A	A	A	A	A	B	A	B	E	D	B	E	A	A	A
<i>Vicia sativa</i>	B	C	A	A	B	C	E	E	E	D	E	E	E	E	E
<i>Rhyncheletum repens</i>	A	A	A	A	A	B	A	A	A	A	A	A	A	A	A
<i>Digitaria smutsii</i>	A	A	A	A	A	A	A	A	A	A	A	A	C	E	E
<i>Secale cereale</i>	A	B	A	A	A	B	A	B	B	A	D	E	C	E	E
<i>Eragrostis curvula</i>	A	A	A	A	A	A	A	A	A	A	A	A	E	E	E
<i>Setaria italica</i>	A	A	A	A	A	A	A	A	A	A	E	E	B	A	A

A = Excellent weed control = 90% – 100% control
 B = Good weed control = 80% – 90% control
 C = Moderate weed control = 70% – 80% control
 D = Poor weed control = 60% – 70% control
 E = Unacceptable weed control = 0% – 60% control

ria, *Rhyncheletum* and *Medicago* species for a period of 90 days after application. However, the control of the other weed species was unacceptable.

When evaluating the results as a whole, it is clear that simazine and oxadiazon gave acceptable control of all the weed species. Napropamide gave excellent control of the grass species, but failed to control the broadleaf weeds to the same extent. Oryzalin did not control the two broadleaf weeds and although all the grass species were controlled initially, only three were controlled eventually. The chlorsulfuron/metsulfuron methyl mixture controlled the same number of weed species as the oryzalin treatment. The much weaker performance of the mixture in comparison to oryzalin is due to the fact that the weed species controlled by oryzalin comprised 70% of the weed population. Unfortunately it is especially the *Digitaria* and *Eragrostis* species that give problems in vineyards under irrigation.

No phytotoxicity symptoms occurred on the vine leaves in any of the herbicide treatments even though the herbicides were applied in an actively growing vineyard.

Experiment 3: Simazine controlled weeds equally well when applied through microjet irrigation system or applied conventionally (Table 5). This result indicates

TABLE 5

Weed control by simazine applied with a tractor boom sprayer and a microjet irrigation system.

Application method	Weed dry mass in g (g/m ²)	Number of weeds/m ²
Tractor boom sprayer	7,94	78
Microjet irrigation system	6,36	43
Statistical significance	NS	NS

that the microjet irrigation systems can replace tractor boom sprayers as an application method for pre-emergence herbicides.

Experiment 4: None of the paraquat dichloride treatments had any effect on the cover crop (data not shown). It seems that the stand of the cover crop was too dense for sufficient penetration by the scorching agent. Furthermore the herbicide was diluted to such an extent by the irrigation water that it could not function properly. This finding supports the conclusion of Robison and Mulliner (1972) that herbigation is not suitable for foliage-active herbicides.

CONCLUSIONS

Simazine, oxadiazon, napropamide, oryzalin and a mixture of chlorsulfuron/metsulfuron methyl controlled susceptible weeds effectively when applied through the microjet irrigation system without damaging the vines, although applied during the active growth stage of trellised vines. The results indicate that herbigation can replace the tractor boom sprayers as an application technique on medium textured and possibly also on heavy soils as far as pre-emergence herbicides are concerned. Where solid set irrigation systems are concerned, the water pressure in the system during application greatly influences the water distribution. To make sure that the herbicide is applied efficiently, the irrigation system should have a CU of at least 80%. This can be achieved by mounting the emitters on top of the irrigation line at the correct spacings and by maintaining a suitable water pressure in the system during application.

Post-emergence weed control with paraquat dichloride applied by herbigation is unacceptable and the conventional method should still be used for post-emergence herbicides.

For the purpose of this study the herbicides were applied at the dosage normally used for the conventional application method. Research must be done to deter-

mine if a lower dosage can be used for herbigation without a loss of efficiency. The mobility of the pre-emergence herbicides in the different soil types should be investigated to determine the appropriate amount of irrigation water to obtain good weed control with the lowest dosage possible.

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