THE USE OF AIR-INDUCTION NOZZLES
FOR HERBICIDE APPLICATION TO SUGAR BEET

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Teagasc acknowledges the support of Irish Sugar plc
and Sugar Beet Levy Farmer Funds in the financing
of this project

ISBN 1 84170 306 0

August 2002

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Summary

Trials were carried out over a three-year period in Oak Park to compare air-induction with conventional nozzles for weed control in sugar beet. Two makes of low-drift nozzle (Bubble Jet and DriftBETA) were compared with conventional fans. All nozzles were used at a pressure of 3 bar. Two sizes (015 and 03) of each type of nozzle were used, to allow volumes of 110 and 220 litres per hectare to be applied. These nozzles were used to apply two-spray programmes to sugar-beet crops. In four of the weed control trials, tank mixes of products with some residual action (Progress, Goltix, Venzar and Debut) were used. In the other two trials, a contact-only spray (Betanal E) was used. The aim was to see how the nozzles behaved with contact-only sprays as well as those with more complex modes of action. Spray drift was also measured with the size 03 nozzles.

Spray drift reductions from 37% to 64% were measured when the air-induction nozzles were compared with conventional fans. In general, the tank mix programme gave better weed control than the contact-only treatments. Within programmes, differences between the application methods were significant in two trials. In both of these, the conventional nozzles gave the best results. Looking at the mean results of the tank-mix trials, two trends were suggested: higher water volumes gave slightly better weed control, and the effect of the coarser sprays was slight. With the contact-only sprays, the decline in performance with the coarser sprays was more emphatic, and the lower volumes appeared to give slightly better control.

It is concluded that in calm conditions conventional fan or cone nozzles should continue to be used, but that air-induction nozzles are a valuable fall-back when it is necessary to spray in a moderate breeze. In these situations, and with the normal tank-mix programmes, small nozzle sizes applying very low volumes should be avoided. Makes of air-induction nozzle which give very coarse spray should also be avoided.

Nomenclature

Fat hen *(Chenopodium album)*, shepherd's purse *(Capsella bursa pastoris),* field pansy *(Veronica arvensis),* bindweed *(Polygonum convolvulus),* fumitory *(Fumaria officinalis),* speedwell *Veronica arvense),* chickweed *(Stellaria media),* cleaver *(Gallium aparine)* knotgrass *(Polygonum aviculare)*, poppy *(Papaver rhoeas),* red deadnettle *(Lamium purpureum)*.

Actipron (BP): *Adjuvant oil.* Betanal E (AgrEvo): *Phenmedipham+isophorone*. Betanal Progress (AgrEvo): *Phenmedipham+Desmedipham+ethofumesate.* Debut (Du Pont): *Triflusulfuron methyl*. Goltix (Bayer): *Metamitron*. Venzar (Du Pont): *Lenacil*

Bubble Jet (Billericay Farm Services Ltd, Billericay, Essex CM11 1QU, UK).

DriftBETA, LO-DRIFT and F-110 (Lurmark Ltd., Longstanton, Cambridge CB4 5DS, UK).

INTRODUCTION

Air-induction nozzles have come into widespread use for crop spraying throughout Europe. There are several reasons for their rapid adoption. Firstly, their potential to reduce water pollution and other environmental damage by spray drift is now seen as a high priority. Secondly, they also provide an opportunity to reduce drift contamination of operators and equipment. For most Irish growers, especially those farming in exposed areas, the ability to spray in wind speeds that would be too high for conventional fans or cones is seen as the main advantage of these nozzles.

Wind is a bigger problem in Ireland than in most neighbouring countries. The mean annual wind speed over most of the country varies between 4 and 6 m/s at a height of 10 metres (Rohan, 1975). This would correspond to about 2 to 3 m/s at sprayer boom height. Since the lowest wind speeds occur in the hours of darkness, the average wind speeds during daylight hours are somewhat greater than this.

Selection of an upper limit on wind speed for spraying involves a compromise between reduced spraying capacity and untimely applications on the one hand and excessive drift levels and uneven spray distribution on the other. In the Code of Practice of the UK Ministry of Agriculture, Fisheries and Food (1999), spraying with conventional equipment is considered to be inadvisable if the wind speed at boom height is greater than 2.7 m/s. In exposed locations and in windy periods compliance with this guideline would leave few spraying opportunities.

Air induction nozzles have the potential to produce less spray drift, and cope better with windy weather. However, they produce a coarser spray, with bigger droplets than conventional fan or cone nozzles, and the effect of this on the efficacy of weed control has not yet been fully determined. There is little doubt that the performance of many systemic and soil-acting products would not be affected by the larger droplet sizes. In the past when contact-action herbicides were widely used on sugar-beet, it was widely felt that a fine spray was required for best results. Now that tank mixes of products with several modes of action are in general use, the suitability of air-induction nozzles for this purpose is worthy of investigation.

Research on the performance of air-induction nozzles is still at an early stage. Robinson *et al.* (2001) reported substantial differences in droplet diameter between two makes of air-induction nozzle. They also reported little consistent difference in deposit or efficacy between these and conventional fans when spraying cereal herbicides at 100 and 200 l/ha. Jensen (1999) reported a reduction of efficacy when spraying difficult targets such as grass weeds at an early growth stage. Wolf (2000), after trials covering 19 herbicides with 6 modes of action applied to 27 weed species, concluded that the coarsest air-induction sprays should be avoided when spraying contact products and grassy weeds. Work with sugar beet at Morley Research Station has shown indications of reduced coverage of very small weeds with foliar-acting herbicides (Powell, 2001). In summary, research to date is suggesting big differences within makes of air-induction nozzles, no effect on efficacy in many situations, but occasional reductions with small weeds that present difficult targets.

The objectives of the current trials were:

1. To examine the effectiveness of the weed control achieved with the most widely-used air-induction nozzles for the application of typical sugar beet spray programmes.
2. To measure the reduction of spray drift achieved by the use of these nozzles in comparison with conventional fan nozzles.

EXPERIMENTAL PROCEDURE

Weed control assessment

Quarter sections of a 12-metre tractor-mounted Hardi NK sprayer boom were fitted with two alternative makes of low-drift nozzle (Bubble Jet and DriftBETA) as well as conventional (Lurmark F110) fans. Two sizes (015 and 03) of each type of nozzle were fitted, to allow volumes of 110 and 220 l/ha to be applied. All plots were sprayed at a pressure of 3 bar (300 kPa) and a forward speed of 6.5 km/h.

These nozzles were used to apply two-spray programmes to a sugar-beet crop. The degree of weed control achieved was assessed about two weeks after application of the second spray. A score between 0 and 10 was assigned to each plot; the extreme values represented no effect and complete control. Treatments were replicated six times in a split-plot design. Plots were 3 m wide and 20 m long.

The treatments were as follows:

A.1. Flat fan 015-F110, 110 l/ha
B.1. Bubble Jet 015, 110 l/ha
C.1. DriftBETA, DB 015, 110 l/ha
A.2. Flat fan 03-F110, 220 l/ha
B.2. Bubble Jet 03, 220 l/ha
C.2. DriftBETA, DB03F120, 220 l/ha

Drift measurement

To measure spray drift, three masts were placed ten metres apart in a straight line perpendicular to the direction of the wind. The sprayer was driven past the masts while spraying a fluorescent tracer solution, with the end of the spray boom five metres from the masts. The masts used were five metres high. Pairs of drift collectors (pipe cleaners) were attached to each mast at 0.5-metre height intervals, giving a total of twenty collectors per mast. All trials were carried out in a grassland area where the grass had been recently mown or grazed.

For each treatment, the sprayer was put into operation and driven past the masts six times (three times in each direction). After this, the collectors were removed from the masts and placed in individual vials. The vials were then stored in darkness pending analysis.

In each trial, a randomised block design was used, with each test setting replicated four times. Emphasis was placed on keeping the field test period as short as possible. With a team of three, a trial involving four replications of four treatments could be carried out in about four hours.

The spray solution consisted of 10 g of sodium fluorescein dye per 100 litres of water with Agral (a non-ionic surfactant) at approx. 0.1% v.v. To avoid cross-contamination of new and used collectors during handling, disposable gloves worn by each operative were replaced after taking down a used set of collectors and before putting up the next set.

The average wind-speed for each of the tests was measured using an anemometer mounted two metres above the ground and directly upwind of the spray track. A nearby portable weather station was used to record the temperature and humidity for the duration of the tests.

When all the tests for the day had been completed, each pipe cleaner was placed in a 20-ml vial. Wash-off solution was added to each vial; this consisted of 2 ml of 1 molar NaOH and 1 ml of Agral per litre of water. The pipe cleaners were left to soak overnight in the wash-off solution. On the following day the fluorescein content of the solution in each vial was measured using a Perkin Elmer LS32 luminescence spectrometer set in fluorometric mode. The spectrometer was initially calibrated with a solution of 20 microlitres of spray solution in 20 ml of wash-off solution, to give a reading of 20.0. This allowed the results to be related to the amount of spray solution applied per unit area.

Some variation in wind speed during the trials was inevitable, which would clearly have an effect on drift deposits. A method was devised to remove the influence of wind speed on the trial results. The correction was based on the work of Miller (1993). His work indicated that drift varied linearly with wind speed over a wide range of wind speeds, and that this relationship was roughly of the form:

Spray drift = K x (wind speed (m/s) –1) where K is a constant

To allow comparisons to be made between the results obtained in different wind speeds, all results were corrected to a wind speed of 5 m/s using the above formula.

In these tests, the two air induction nozzles (Bubble Jet and DriftBETA) included in the weed control trials were compared with standard fan nozzles and also with an alternative drift-reducing nozzle (Lurmark LO-DRIFT) with a pressure-reducing orifice in the entry to the nozzle. All nozzles were size 03. All tests were carried out at a forward speed of 8 km/h, a boom height of 0.5 m and a spray pressure of 300 kPa (3 bar).

Results and discussion

Weed control

1999 trials

The beet was sown on March 23 in Oak Park. Weed density was high with up to 200 weeds per square metre, of which fat hen and shepherd's purse were most prominent. Other species present were field pansy, poppy, bindweed, fumitory, speedwell, chickweed, cleavers and knotgrass.

The crop established quickly, and weeds were at the early cotyledon stage on April 8, at the time of the first spray application. Growing conditions remained good during this period; all sprays were applied in favourable conditions, with no excesses of soil moisture or temperature.

In the first spray programme, the first (T1) spray was applied on April 8, and the second (T2) on April 30. The products used were as follows:

T1: 0.5 l/ha Progress, 0.5 l/ha Venzar, 30 g/ha Debut

T2: 0.5 l/ha Progress, 0.5 kg/ha Goltix, 30 g/ha Debut

The first spray (T1) of the second programme was not applied until April 23, when most of the weeds were at the two-leaf stage. The T2 spray was applied on April 30. The products used were as follows:

T1: 0.5 l/ha Progress, 0.5 l/ha Venzar, 30 g/ha Debut

T2: 0.5 l/ha Progress, 0.5 kg/ha Goltix, 30 g/ha Debut

Weed control assessments were made of the treatments in Programme 1 on May 10, and Programme 2 on May 12. This was about two weeks after the second spray. Results were as in Table 1. Weed control was good in all treatments, and no differences were apparent between the two programmes or between treatments.

Table 1: **Weed control scores, May 10-12, 1999**

Programme	**A1**	**A2**	**B1**	**B2**	**C1**	**C2**	**sed**	**Significance**
	Weed control score							
1	8.9	9.4	8.5	8.8	9.1	9.3	0.55	ns
2	8.8	9.0	9.1	8.8	9.5	8.9	0.53	ns

[1] *1 = no control, 10 = 100% control*

2000 trials

The beet was sown on March 28 in Oak Park. Weed density in the trial area was high, with up to 400 weeds per square metre. The main species were speedwell, knotgrass and pansy, but poppy, red dead nettle, bindweed and fumitory were also present.

The nozzles were compared in two trials with two-spray programmes. The first programme was based on sprays with contact and residual action, the second was confined to contact-action sprays. In each programme, the T1 sprays were applied on May 1-2, the T2 on May 18. The first programme was as follows:

T1: 1.75 l/ha Progress, 0.5 l/ha Venzar

T2: 2.0 l/ha Progress, 0.7 l/ha Venzar, 1.0 l/ha Actipron

The second programme was as follows:

T1: 3.5 l/ha Betanal E

T2: 5.0 l/ha Betanal E, 1.0 l/ha Actipron

All sprays were applied in favourable conditions. Weed assessments were made on May 15 and May 23. There was little difference between assessments, so an average of the two is presented in Table 2.

Table 2: **Weed control scores for two spray treatments with conventional and air induction nozzles**

Spray treatment	Programme 1 (Progress-Venzar)	Programme 2 (Betanal E)
	Weed control score[1]	
A1	6.0	6.0
A2	7.8	6.2
B1	5.1	5.0
B2	5.6	4.8
C1	3.9	4.6
C2	5.6	4.7
sed (significance)	0.37(***)	0.57 (ns)

[1]1 = no control, 10 = 100% control

In the Progress-Venzar treatments, the best control was obtained with the conventional nozzles at 220 l/ha, which were significantly better than all other treatments. The worst control was obtained with the DriftBETA nozzles at 110 l/ha, which were significantly inferior to all other treatments. Differences between other treatments did not reach significance. These results differ from the previous year, when there were no differences between nozzles. In the Betanal E programme, while the results showed similar trends, there were no significant differences between treatments (Table 2).

2001 trials

The beet was sown on April 17-18 in Oak Park. Weed density in the trial area was high with up to 250 weeds per square metre. The main species were knotgrass, fat hen, shepherd's purse and speedwell, with red dead nettle, poppy and pansy also present.

The nozzles were compared in two trials with two-spray programmes. The first programme was based on sprays with contact and residual action, the second was confined to contact-action sprays. T1 sprays were applied on May 14, T2 on May 25. In the first programme, the products used were as follows:

T1: 0.5 l/ha Progress, 0.5 l/ha Venzar, 30 g/ha Debut

T2: 0.75 l/ha Progress, 0.6 l/ha Venzar, 30 g/ha Debut, 1.0 l/ha Actipron

In the second programme, the products used were as follows:

T1: 5.0 l/ha Betanal E

T2: May 25 (7.0 l/ha Betanal E, 1.0 l/ha Actipron)

All sprays were applied in favourable condition. Weed assessments were made on May 25 (i.e just before the second spray treatments) and on June 7. The results are given in Tables 3 and 4.

In the Progress-Venzar-Debut trial, the DriftBETA low-volume application (C1) was significantly inferior to all other treatments at the first assessment. By the time of the second assessment, a very high level of control had been achieved (Table 3). Although the C1 treatment still achieved the lowest score, the difference was no longer significant.

Table 3: **Weed control scores at two assessment dates with conventional and air induction nozzles in Progress-Venzar-Debut two-spray programme, May-June 2001**

Spray treatment	First assessment (May 24)	Second assessment (June 7)
	Weed control score[1]	
A1	8.3	9.8
A2	8.6	9.3
B1	7.0	9.2
B2	7.8	10.0
C1	5.9	8.8
C2	8.3	9.2
sed (significance)	0.77(*)	0.72 (ns)

[1]1 = no control, 10 = 100% control

With the Betanal E programme, weed control was poorer, especially after the second spray. There were no significant differences at the first assessment. The DriftBETA treatments gave the poorest results at both dates, and this difference reached significance at the second assessment.

Table 4: Weed control scores at two assessment dates with conventional and air induction nozzles in Betanal E-based two-spray programme, May-June 2001

Spray treatment	First assessment (May 24)	Second assessment (June 7)
	Weed control score[1]	
A1	7.0	7.3
A2	7.1	6.2
B1	6.8	6.5
B2	6.1	5.5

Spray treatment	First assessment (May 24)	Second assessment (June 7)
	Weed control score[1]	
C1	5.4	4.0
C2	5.7	3.5
F (significance)	2.14(ns)	3.66 (*)

[1]1 = no control, 10 = 100% control

Three-year trends

Of the six weed control trials, only two gave significant differences between treatments. The mean weed control scores with the tank mixes after the second application are given in Table 5. While the differences between treatments were small, two trends were suggested by the results:

- Higher water volumes appeared to give slightly better weed control.
- Weed control appeared to deteriorate slightly as the spray became coarser, with conventional fans best, Bubble Jets next and DriftBETA marginally inferior.

The Betanal-based programmes gave poorer weed control (Table 5). They also showed a more emphatic decline in control with the coarser sprays. While the difference between spray volumes was small, in this case it appeared to favour the lower values. This may lend some support to the traditionally-held view that this type of contact-action spray is best applied as a fine spray at low volume.

Table 5 : **Weed control scores after two-spray programmes based on tank mixes or Betanal E**

Nozzle	Volume (l/ha)	Tank mixes (4 trials)	Betanal E (2 trials)
		Weed control score[1]	
Fan	100	8.4	6.7
Fan	200	8.9	6.2
Bubble Jet	100	8.0	5.8
Bubble Jet	200	8.3	5.2
DriftBETA	100	7.8	4.3
DriftBETA	200	8.3	4.1

[1]1 = no control, 10 = 100% control

Spray drift

The average wind speed over the duration of the tests was 4.5 m/s. There was little variation in wind speed, so corrections to a constant speed were very small.

When compared with the standard fan nozzle, the respective reductions in spray drift were 15%, 37% and 64% with the LO-DRIFT, Bubble Jet and DriftBETA nozzles (Fig. 1, Table 6). While the difference between the standard and LO-

DRIFT nozzles was not significant, all other differences were highly significant (Table 6).

Table 6: **Spray drift deposits on 5-metre mast, as affected by nozzle type**

Nozzle	Spray drift (ul/collector)
Standard fan	2.67
LO-DRIFT	2.28
Bubble Jet	1.67
DriftBETA	0.97
sed (significance)	0.057 (***)

These measurements confirmed the potential of air-induction nozzles to spray with less drift than conventional nozzles. They were also much more effective at reducing drift than the alternative restrictor-plate type low-drift nozzle. The results also showed up the substantial differences in performance that can occur between air-induction nozzle types.

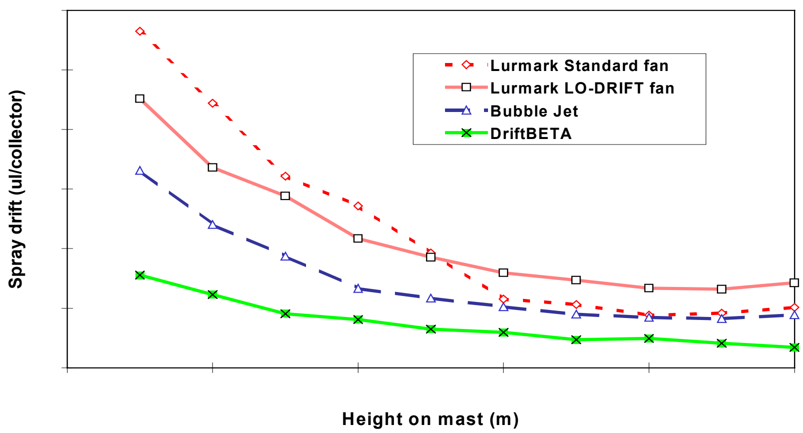

Figure 1: ***Spray drift deposits on 5-metre mast downwind of sprayer with standard and air induction nozzles***

Conclusions

The results of these trials agree well with the limited amount of work that has been carried out elsewhere with air-induction nozzles. In many trials, no differences can be detected between air-induction and conventional nozzles, but occasionally the weed control with air induction nozzles is inferior. Reduced efficacy is more likely to occur with contact-only herbicides, but these are rarely used in modern sugar-beet weed control. With tank mixes of products employing various modes of action, differences between nozzle types are likely to be small. Where some reduction in efficacy occurs with air-induction nozzles, it is most likely with the air-induction nozzles that produce the coarsest spray. Small nozzle sizes applying very low volumes should also be avoided; in addition to a possible reduction of efficacy, they also increase the risk of practical difficulties with blockages and uneven spraying (Rice, 1993).

Given this pattern of results, it would be sensible to continue using conventional fan or cone nozzles for sugar beet spraying whenever conditions allow. But, in practice, it is sometimes necessary to spray when conditions are less than ideal. If weeds are getting too big, a choice sometimes has to be made between waiting for calmer weather or getting on a timely spray. In these situations, which are likely to occur frequently in Ireland, air induction nozzles are a very useful fall-back. In selecting a nozzle make, those which produce a very coarse spray should be avoided. If a large (not less than 03) size is selected, results in most cases will be as good as with conventional nozzles, but more even spraying and less drift will be achieved even in moderately windy conditions.

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