The Varidome precision band sprayer for row crops

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Summary

There has been renewed interest in inter row band spraying in row crops driven in part due to the loss of post emergent herbicides in vegetable and other crops as well as the desire to reduce overall pesticide use as part of an IPM programme as promoted by the EU sustainable pesticide use strategy. The increasing adoption of precision farming techniques using GPS and other guidance techniques to accurately apply crop protection products to the crop or inter row has helped promote band spraying as a practical alternative to broadcast sprays in some situations. Band spraying offers the potential to reduce pesticide usage, particularly with herbicides, lower drift and environmental impact, improve efficacy and reduced costs. To effectively apply herbicides accurately in the crop inter row has required the development of purpose designed sprayer implements with independent ground following spray shields mounted on 3, 6 and 9 m toolbars. Dual spray line systems have been developed to simultaneously apply two tank mixes at the same time. With GPS and vision guidance systems now capable of guiding tractor implements to within 2‒3 cm accuracy combined with the ability to operate at higher forward speeds, the selective application of plant protection products in bands offers a practical solution for pest, disease and weed management in many arable and vegetable crops. The benefits of band spraying are logical as weeds can be targeted more accurately and a wider range of herbicides can be used particularly early season which can reduce dependence on the use of selective herbicides. In addition a band sprayer can also be used to deliver fertiliser, fungicides or insecticides directly over the row with a second spray line targeting these products more effectively with obvious economic and environmental benefits. These sprayers are now in commercial use in vegetable and arable crops where up to 60 ha per day have been sprayed and experience in Europe from applications in oil seed rape, sugar beet, maize and vegetable crops is discussed along with results from wind tunnel studies to assess spray drift confirming shielded hoods for band spraying are appropriate as a drift reducing technology (DRT).

Key words: Varidome precision band sprayer, precision farming techniques, GPS

Introduction

Recently there has been a resurgence of interest in band spraying to selectively apply herbicides in the crop inter row or to apply sprays directly to the row crop. This has been driven in part by the increasing use of precision guidance for drilling of the crop in precise rows but also by restrictions on herbicide use and national and European policies to reduce pesticide use in general. With GPS or vision guidance systems now capable of guiding tractor implements to within 2‒3
cm accuracy and the ability to operate at higher forward speeds, the selective application of plant protection products in bands offers a practical solution for pest and weed management in many arable and vegetable crops. The benefits of band spraying are logical as weeds can be targeted more accurately in the inter row and a wider range of herbicides can be used particularly early season which can reduce dependence on the use of selective herbicides. Previously research has focussed on the benefits of over the row band sprays in both reducing pesticide use and reducing drift through lower nozzle height (Lund & Jenson, 2002). Inter row mechanical hoeing to remove weeds in combination with band sprays on the row has also been investigated, however the Varidome sprayer development seeks to utilise shielded sprays for herbicide application within the row in combination with a second simultaneous spray over the row with separate spray line and tank mix. This would hopefully combine no till weed control in the crop inter row with a banded over row spray on the crop of selective herbicide, fertiliser, fungicide or insecticide and meet the objectives of overall pesticide reduction with improved targeting and less drift. Some preliminary results from wind tunnel studies to assess spray drift together with various field trials and commercial use are discussed.

The Varidome Band Sprayer Design

A range of 3, 6 and 9 m wide band sprayers (Micron Varidome TM S1, S3 and S5 respectively) have been developed utilising shielded spray hoods that can apply non selective herbicides within the crop inter row and simultaneously apply band sprays directly to the crop via a dual tanking system. The sprayer design uses a number of adjustable spray shields mounted on individual carriages with ground following wheels for independent operation.

Fig. 1. Detail of spray hood and carriage with ground following wheel and over row nozzles.

The position of the carriages is set on a toolbar with a quick release clamp to align with the crop inter row and the width of the spray band can easily be adjusted. Similarly if an over the row (OTR) spray application is applied to the crop the nozzles can be adjusted to direct spray on the crop only. OTR nozzles are unshielded and narrow angle mounted on an adjustable bracket on the main carriage to vary spray height and orientation. The spray shields for inter row herbicide sprays are typically set to spray 20–25 cm above the ground and a flexible rubber skirt deflects stones and lumps of soil. As the terrain varies each carriage can follow the ground with height variation achieved by parallelogram. It is important for each wheel to maintain contact with the ground at
all times without bouncing to avoid drift of material outside the shield. Different types of spray shield are offered with either low volume CDA (Controlled Droplet Application) rotary atomisers or pressure nozzles. This modular design allows different spray volumes and band widths from 10–80 cm to be used. The spray shields are also equipped with individual flow blockage sensors linked to a spray monitor in the tractor cab. The modular design of the sprayer allows configuration to different crop plantings according to planting distance, band width and number of rows. The 3 m implement is mainly used for intensively grown crops such as vegetables or ornamentals. The larger 6 m and 9 m wide implements have been used in arable crops such as maize, sugar beet, oil seed rape, or vegetable crops such as carrots, parsnips and onions. The sprayer implements can be mounted on the rear or front of a tractor with CAT 3 or CAT 2 three point hitch available. The sprayers are available with various tank sizes, either dual tank configurations or single. For the larger 6 and 9 m implements a dual (1050 L + 750 L) tank system is available with colour coded tanks (Yellow and Grey) and dual spray lines to easily identify OTR or inter row shielded applications.

Fig. 2. Varidome S5 with front mounted dual tank in oil seed rape.

The Varidome band sprayer can be steered manually, by vision guidance or GPS RTK (real time kinematic) guidance. Manual steering is really only suitable for slower forward speeds and shorter boom widths. Vision guidance systems using forward looking cameras and hydraulic side shift unit between the implement and tractor can be used to identify crop rows and guide the band sprayer between rows. These are appropriate where the crop may not have been drilled with GPS but rely on the crop being visible and suitable light conditions to identify the rows. With the increasing availability of GPS guided tractors with RTK correction services to achieve accuracies of down to 2–3 cm more and more growers are now planting crops with precision guided drills. Once the crop is established in this way it is relatively simple to use the same GPS RTK guidance for a band sprayer implement to apply non selective herbicides to the crop inter row to assist with early season crop establishment. If intra-row weed control is required then growers can simply use existing selective herbicides over the row through a second spray line.

Results

Wind tunnel drift studies
A series of wind tunnel tests were conducted at Silsoe Spray Applications Unit (SSAU part of NIAB), UK using LERAPS and DIX test protocols with the Varidome spray shields with different
nozzle types to evaluate drift measured in a 2 m s\(^{-1}\) wind speed at distances up to 7 m downwind. The spray shields were positioned as a worst case scenario perpendicular to the wind direction and spray drift collected on string samplers as per standard protocols. Results are presented in Table 1 and Fig. 3 illustrates the direct comparison of spray drift from the Varidome shield compared to the standard reference nozzle.

Table 1. *Drift as a fraction of reference nozzle*

<table>
<thead>
<tr>
<th>Sprayer Shield</th>
<th>Nozzle type</th>
<th>Pressure Bar Flow</th>
<th>Distance Downwind m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varidome</td>
<td>Hypro FF80</td>
<td>3</td>
<td>0.02 0.04 0.05 0.06 0.05 0.03</td>
</tr>
<tr>
<td></td>
<td>Teejet AI95-015 EVS</td>
<td>1.5</td>
<td>0.01 0.02 0.03 0.02 0.02 0.01</td>
</tr>
<tr>
<td></td>
<td>Teejet AI95-015 EVS</td>
<td>2</td>
<td>0.02 0.05 0.05 0.04 0.05 0.05</td>
</tr>
<tr>
<td></td>
<td>Teejet AI95-02 EVS</td>
<td>1.5</td>
<td>0.00 0.01 0.01 0.01 0.02 0.01</td>
</tr>
<tr>
<td></td>
<td>Teejet AI95-02 EVS</td>
<td>2</td>
<td>0.01 0.01 0.01 0.01 0.01 0.01</td>
</tr>
<tr>
<td></td>
<td>Teejet XR 80-02</td>
<td>1</td>
<td>0.01 0.02 0.03 0.03 0.04 0.03</td>
</tr>
<tr>
<td></td>
<td>Teejet XR 80-02</td>
<td>1.5</td>
<td>0.02 0.04 0.03 0.04 0.05 0.03</td>
</tr>
<tr>
<td></td>
<td>Teejet XR 80-02</td>
<td>2</td>
<td>0.02 0.05 0.05 0.04 0.05 0.03</td>
</tr>
<tr>
<td></td>
<td>BFS Bubblejet 015</td>
<td>1.5</td>
<td>0.02 0.04 0.05 0.06 0.05 0.03</td>
</tr>
<tr>
<td></td>
<td>BFS Bubblejet 015</td>
<td>2</td>
<td>0.02 0.04 0.06 0.04 0.03 0.01</td>
</tr>
<tr>
<td></td>
<td>Rotary</td>
<td>100 mL min(^{-1})</td>
<td>0.00 0.00 0.00 0.00 0.00 0.00</td>
</tr>
<tr>
<td></td>
<td>Rotary</td>
<td>300 mL min(^{-1})</td>
<td>0.01 0.00 0.00 0.00 0.00 0.00</td>
</tr>
</tbody>
</table>

The results show that in all positions drift was reduced by between 95–100% of the reference nozzle value. Interestingly with the rotary CDA atomiser configuration no drift deposit was found on almost all downwind collectors bar one. This was most likely due to the better drop size control in comparison to both hydraulic pressure nozzles or air included nozzles and lower internal air disturbance within the shield with lower spray volumes and droplet velocities.

Fig. 3. % Drift from Varidome CDA shield compared to the reference nozzle.
Van de Zande et al. (2008) reported significant drift reductions over 2 m from the point of emission with unshielded band sprayers in maize and sugar beet crops spraying the row at low nozzle heights of around 10 cm from the crop. However, with an inter row band sprayer applying a non selective herbicide it is perhaps more important that we also eliminate as far as possible any lateral spray displacement to avoid crop damage which requires control of spray displacement within say 5–10 cm hence a spray shield is essential.

Field results

In the UK trials were conducted during the Autumn of 2011 and 2012 in winter sown oil seed rape (OSR) in conjunction with Agrovista UK Ltd on various sites with rows planted mostly at 50 cm spacing. Shielded inter row herbicide applications were made at the 4–6 leaf stage applying a contact acting non selective weed killer (Diquat). Band spraying in OSR is of interest to control difficult weeds such as charlock (*Sinapis arvensis*) or volunteer rape that competes with the main crop. Crops were drilled manually and with volunteer OSR it was often difficult to see the crop rows on some sites. Nonetheless weed control in the crop inter row was reported as excellent with virtually no crop damage where rows were well defined. (Agrovista, 2012) Further trials are planned with crops that are precision drilled to improve suitability for band sprays.

Commercial spray applications have also been made on OSR and sugar beet in the UK to target resistant black grass (*Alopecurus myosuroides*) problems, which can be particularly problematic when sugar beet is rotated with cereal crops. Initial applications again used Diquat to spray the crop inter row with selective herbicides in the intra row over the crop. Again crops were drilled at 50 cm row spacing in both OSR and sugar beet but using a precision guided drill with GPS RTK guidance. The Varidome band sprayer implement was integrated with a Trimble IQ guidance system with all sprayer controls operated through a CAN Isobus module so that the application rate was automatically controlled according to vehicle speed and which boom sections were active. A 6 m bout was sprayed using 13 spray shields on the crop inter row and 12 over row nozzles with the two outer spray shields operated alternatively according to spray direction. Savings of up to 60% on herbicide inputs were achieved on over 400 ha of commercially grown rape and sugar beet with no reported crop damage and excellent weed control in the crop inter row. Forward speeds of 10 km h$^{-1}$ were possible and up to 40 ha per day treated with a 6 m sprayer. The grower was also able to selectively apply foliar fertilisers and fungicides to the crop adding to overall chemical savings. (Arable Farming, 2013).

![Fig. 4. Weed control in precision drilled sugar beet following band application.](image-url)
Commercial band spraying with a Varidome band sprayer has also been made in sugar beet in Sweden where only mixtures of selective herbicides were applied to the crop inter row as there are currently no non selective herbicides approved for use post emergence. Three applications were made in beet crops drilled with a 6 m precision guided drill so it was not possible to use the full 9 m width due to mismatch errors between drill bouts. Tillet & Hague (2005) first reported this issue highlighting that drill bouts and band sprayer need to be matched. The sprayer was therefore operated on only 6 m widths again using a Trimble IQ GPS guidance system with RTK. The crop was planted at 50 cm and it was possible to use a 30 cm band width inter row. Some adjustments on initial setup were required to make sure the shields matched the drill settings and the three point linkage locked to avoid implement side movement particularly on slopes. The Varidome has also been commercially introduced on a 2000 hectare maize crop in Romania. The maize is planted at 75 cm row spacing so inter row band sprays are highly appropriate early season. Both diquat and glyphosate herbicides have been applied to the crop inter row as total weed killers with considerable chemical savings and improved weed control. Band spraying with the Varidome system have also been practised in a variety of other crops in the UK including commercially grown carrots, onions and parsnips grown on raised beds, leeks, lavender, asparagus, roses and cut flowers. Not all growers were using precision guidance systems so many use manual steering with the smaller 3 m wide Varidome unit in more intensively grown crops using lower forward speeds, however in crops grown on raised beds or ridge and furrow system manual steering can be easier because of well defined rows.

**Discussion**

Band spraying is not a new concept and has been widely practised in row crops in the past with some success; however productivity has generally been low due to slow forward speeds and limited boom widths. As broadcast boom sprayers have increased in size commonly up to 36 m or more in arable crops in Europe band spraying has tended to only be used in more intensively grown crops such as vegetables, herbs or ornamentals on smaller areas. However there is a need for more selective spray application to minimise chemical costs and usage, to target spray more effectively, minimise spray drift and off target run off. Indeed recent EU legislation as part of the Sustainable Pesticides Use Directive requires this and there are also increasing restrictions on when certain herbicides can be applied to minimise run off into water ways particularly Autumn sprays where the ground is wet. May (2008) proposed a simple conversion of existing boom sprayers to apply plant protection products in bands using narrow angle nozzles and lowering boom height and demonstrated reasonably consistent spray coverage within the band using even spray nozzle tips. Often selective herbicides have been applied over the crop with mechanical cultivation between rows as practiced in corn and soya crops in North America (Tessier & Leroux, 2010) With the growing adoption of accurate precision guidance systems that permit operation at higher forward speeds and the development of wider spray booms this addresses to some extent concerns over productivity with work rates of up to 60 ha per day now possible with a 9 m band sprayer. Band sprays with shields also allow the use of non selective herbicides in the crop row and so provide another tool for the management of resistant weed species or where certain non selective products are withdrawn from use and there are few alternatives.

Jensen & Lund (2006) investigated whether band spraying in combination with mechanical cultivation could be an alternative to broadcast boom sprays to target inputs more efficiently. They looked at the distribution of spray deposit across a band in both static and dynamic tests to replicate the influence of sprayer forward speed on unshielded sprays and concluded that an even spray nozzle type provided the most consistent spray distribution across the band. Interestingly in studies on biological efficacy they found narrower bands less than 20 cm were less effective compared to broadcast sprays applied at the same unit area dose rate. This appeared to be a
consequence of high spray volumes as at very narrow band widths with a flat fan nozzle it is difficult to apply less than 400 mL min\(^{-1}\) and hence run off and poor spray retention becomes more of an issue. If Varidome CDA spray heads are fitted this allows for application at lower spray volumes as these can operate at flows down to 100 mL min\(^{-1}\). Fig. 5 uses a ‘traffic light’ colour code system to aid growers in selecting the appropriate volume rate for the intended band width and forward speed according to which nozzle type is used. The red zone is where flow is too low hence application volume needs increased, the orange where CDA rotary nozzles can be used, the green where pressure nozzles are appropriate and the blue zone where lower volume rates should be considered.

Fig. 5. Flow rate selection tool for band spraying with the Varidome.

The volume rates shown above refer to the area under the band or treated area as it is known. This means that an application volume of 100 L ha\(^{-1}\) in the treated band with a width of 30 cm in a crop planted at 50 cm equates to only 60% of the actual area hence 60 L of tank mix per field hectare reducing the number of tank refills. Perez- Ruiz \textit{et al.} (2013) also investigated using over row band sprays and inter row cultivation with RTK GPS guidance using an innovative side shift mechanism in Spanish sugar beet and concluded herbicide use could be reduced by up to 50% compared with existing broadcast sprays. Collins & Roche (2002) examined control of ryegrass in lupins using shielded sprays to apply herbicide to the crop inter row and achieved best results when using these in combination with an over row spray of selective herbicide to treat the crop inter row. More recently as part of the ENDURE (European Network for the Durable Exploitation of Crop Protection Strategies) programme research investigating band spraying in maize crops 70% reduction in herbicide use was achieved with an over row application of selective herbicides in combination with inter row cultivation.

Conclusions

The use of band spraying in combination with accurate guidance systems offers growers the prospect to apply selective herbicides, fertiliser, fungicide or insecticide over the crop or to treat the weeds in the crop inter row simultaneously with two different tank mixes. This offers significant reductions in chemical usage and more accurate targeting of products while minimising spray drift and improved efficacy. Field trials in a number of crops have demonstrated the viability of the technique. To fully realise the potential of modern band praying practices growers require a wider selection of products registered for band application in different crops.
References


