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Mechanised spraying systems for herbicide application

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Abstract
The control of competing vegetation is an important operation in the establishment of crops, and appropriate herbicide application can be a cost-effective weeding solution. Although the use of herbicides is now well established in agriculture practice, manual methods of application still predominate. Herbicides are one of the most important tools for managing weeds in direct-seeded rice systems. Herbicide use in these systems is expected to increase in the near future because of the non availability of labor at the critical time of weeding and high labor cost. Herbicide use is also very important where there is a morphological similarity between weeds and rice, especially in a broadcast crop. Depending on the country, various pre and post emergence herbicides are recommended and used in direct-seeded systems. Some of the pre-emergence herbicides for dry-seeded rice systems are oxadiazon, oxadiargyl, and pendimethalin. As rice seeds are broadcast on the soil surface in wet-seeded rice, pretilachlor (with safener) is usually recommended as a pre-emergence application. Various kinds of spray nozzles are used including a flat fan, even fan; flood nozzle, variable cone, and hollow cone. Flat fan nozzles are used in multiple-nozzle booms as the spray pattern is tapered from the centre to the edges. To achieve effective weed control, the use of pre-emergence herbicides is a must in direct-seeded systems, especially in dry-seeded ones.

Keywords: Herbicide, weed, DSR, pre-emergence and nozzle

Introduction
Direct-seeded rice systems have several advantages. Weeds, however, are considered one of the major biological constraints in these systems because there is no seedling size advantage as rice and weed seedlings emerge simultaneously and no standing water to suppress weed emergence and growth at crop emergence. Weeds in direct seeded systems can cause a substantial rice yield loss. Weeds are mainly controlled using herbicides or are manually controlled. However, manual weeding is becoming less common because of the non availability of labor at critical times and increased labor costs. Herbicides are replacing manual weeding as they are easy to use; however, there are concerns about the sole use of herbicides, such as evolution of resistance in weeds, shifts in weed populations, and concerns about the environment.
Mechanised spraying systems for use in agriculture are usually developed from models used in agriculture. They use a series of nozzles spaced equally along a boom and usually have a height adjustment system. The specific height varies with nozzle spray angle and spacing.
This paper describes the components of mechanised boom spraying systems and their application. Some components increase the sophistication of the system and are designed to deliver target volume rates as operating variables change. Other components are designed to reduce environmental and operator contamination and improve operator ergonomics.

Application Methods
Herbicide can be applied in a number of ways:
- Overall: application over the whole treatment area.
- Band: application in a band over or between crops.
- Spot: application to an individual spot or around a crop.
- Directed: application to hit a target weed and to avoid crop.

Standard mechanized spraying systems deliver overall and band applications. Mechanized spot application is possible but requires a specially designed sprayer. Accurate directed applications are not possible.

The majority of spraying equipment operated by the agricultural industry uses pressurized hydraulic (water based) spraying systems. This equipment can be used for:

- High volume application (HV): greater than 700 l/ha.
- Medium volume application (MV): 200 to 700 l/ha.
- Low volume application (LV): 50 to 200 l/ha.
- Very low volume application (VLV): 10 to 50 l/ha.
- Ultra low volume application (ULV): less than 10 l/ha.

Tables 1 and 2 illustrate some of the advantages and disadvantages of manual and mechanized operations, and high and low pressure spraying operations.

Factors Affecting Productivity

A number of factors influence the work rate of boom spraying:

- **Speed of the prime mover:** This is in turn influenced by ground conditions which affect boom stability, turbulence and deposition, especially as speed increases.
- **Boom width:** Increasing the width of the application strip reduces the number of passes required to cover an area thus increasing the productivity of the sprayer. However, it is more difficult to keep wider booms level and at the correct spraying height.
- **Spray management systems:** Within defined parameters, travelling speed can be matched to site conditions, which can improve output in easier travelling conditions.
- **Spray volume:** Using low application rates will reduce the frequency and duration of re-filling, increasing productivity. However, lower-volume application rates may reduce efficacy in some conditions.
- **Availability of water:** A system for supplying the required water volume at the site is essential for re-filling efficiency.
- **Tank capacity:** The dimensions of the tank are limited by the space available and the load capacity of the prime mover.

Table 1: Advantages and disadvantages of manual and mechanised boom spraying operations.

System	Advantages	Disadvantages
Manual	• Low capital cost. • Suitable for small areas. • Less complex. • Suitable for post-plant spraying where guarded application is desirable. • Can be used on sites with irregular spacing. • Within reason, can be used on sites with obstacles or poor machine access.	• Low output rates. • Not suitable for large areas pre- or post-plant programmes. • Operator can be exposed to contamination with some systems. • Operator ergonomics can be less than optimum.
Mechanised	• High output rates. • Suitable for large areas. • Can make the best use of limited weather ‘windows’. • Potential for reduced operator contamination. • Improved operator ergonomics.	• Not suitable for small areas. • Can be restricted by terrain and other site conditions. • High capital cost. • Not suitable for post-plant applications where guarded application is essential.

Table 2: Advantages and disadvantages of high and low pressure spraying systems.

System	Advantages	Disadvantages
Low pressure	• Relatively inexpensive. • Lightweight. • Multi-role use. • High outputs. • Usually low volume: a single tankful can cover a large area.	• Cannot adequately penetrate and cover dense foliage due to their low pressure and usually low volume. • Most use hydraulic agitators so wettable powder formulations often settle out. Mechanical agitators can be a solution.
High pressure	• High pressure sprayers are useful for many roles. • Adequate pressure to direct spray through heavy vegetation. • Durable and reliable construction. • Standard piston pumps resist wear from gritty or abrasive materials. • Standard mechanical agitators keep wettable powders in solution. • Can be used with long hoses for remote targets.	• Strongly built, can be heavy and costly. • Can use large amounts of water. • Pesticide can be misdirected, causing drift and off- target contamination.

A basic sprayer relies on a set forward speed being maintained at a set pressure for an accurate application rate. Spray management systems fitted to sprayers can detect changes in travelling speed and adjust mixing rates and/or operating pressures to maintain the correct volume rate. However, increasing the spraying pressure reduces the droplet size, which can lead to a risk of increased drift. Spray management systems can compensate for slight variations in speed, but they must not be expected to cope with extreme variations. High forward speeds can result in poor crop penetration and greater turbulence behind the sprayer leading to potential drift problems.

Mechanised spraying systems for agriculture use must be strong, reliable and adequately guarded. Protecting exposed components is especially important to reduce downtime caused by damage and breakdowns.

Boom suspension and stability

The boom sprayer (Figure 1) is designed to hold a number of nozzles at a pre-determined spacing pattern. Depending on the system and nozzle holders used, some adjustment of nozzle spacing is possible. The boom system should:

- Keep the nozzles at the correct height at all times.
- Be adjustable to meet tree crop/nozzle height needs.
- Have a safety break-back system to avoid damage from contact with the ground/tree stumps.
- Be capable of folding for transportation.

The boom height adjustment systems should preferably be controllable. This will reduce the potential for operator contamination and assist with the negotiation of obstacles, improving output and reducing sprayer system damage. For agriculture use, nozzle adjustment to match variable row spacing is essential in some conditions.

Boom stability is governed by machine and boom suspension. Irregular movement of the boom reduces the accuracy of the spray pattern. Improved boom stability gives a more uniform spray pattern and more sophisticated suspension systems enable rougher ground to be sprayed. The backward and forward swing of the boom, known as yawing, can result in under-application on the forward swing and over-application on the backward swing. The falling and rising of the boom, known as rolling, also disrupts the spray pattern, resulting in over and under-application.

Sprayer components

Tank

The tank should have sufficient capacity to enable an extended period of spraying, reducing the frequency of re-filling. It should have a sight gauge (and preferably a cab-mounted tank level gauge) so that diluents level can be assessed. The lower section of the tank should have a sump to ensure that the herbicide mixture (or water with direct injection systems) is directed to the delivery system without interruption. An agitator should be used to maintain the homogeneity of the mix.

The tank should also be partitioned with baffles to reduce liquid surge, which will improve machine stability and reduce the creation of foam caused by mixture agitation. Tank protection and design should be adequate to prevent spillage if the vehicle overturns.

Pump

The pump must be reliable and resistant to corrosion caused by herbicides. It should have an output capacity 20% to 25% higher than that required, so that it is not working at maximum capacity, which can lead to accelerated wear and overheating. Three types of pump are available, diaphragm (most common), piston and centrifugal. Table 3 identifies pump characteristics.

Filters

Filters are essential to trap unwanted particles and help prevent nozzles and pumps becoming blocked. They are usually situated at several different points in the spraying system: at the filler opening, on the suction line; between the pump and the pressure regulator or in the nozzle body. Filter aperture size is between 0.08 mm and 1 mm (20 to 200 mesh – the number of openings per linear inch). Larger filters are installed downstream from the pump, and become increasingly fine nearer the nozzles. Nozzle filters should have smaller openings than the nozzle orifices themselves.

Control systems

Components for controlling flow and pressure include on/off valves, gauges and pressure regulators. A constant pressure at a specified setting is an indicator that the sprayer system is working satisfactorily. The operator should therefore be able to read the pressure gauges and operate the control valves from inside the cab. Figure 1 shows the components of a modern mechanised spraying system.

The sprayer must be calibrated before the start of operations, checking the variables of swathe width (controlled by height) and travelling speed. Travelling speed is affected by site conditions and spray management control systems should be adjusted so that the flow of herbicide matches this speed.

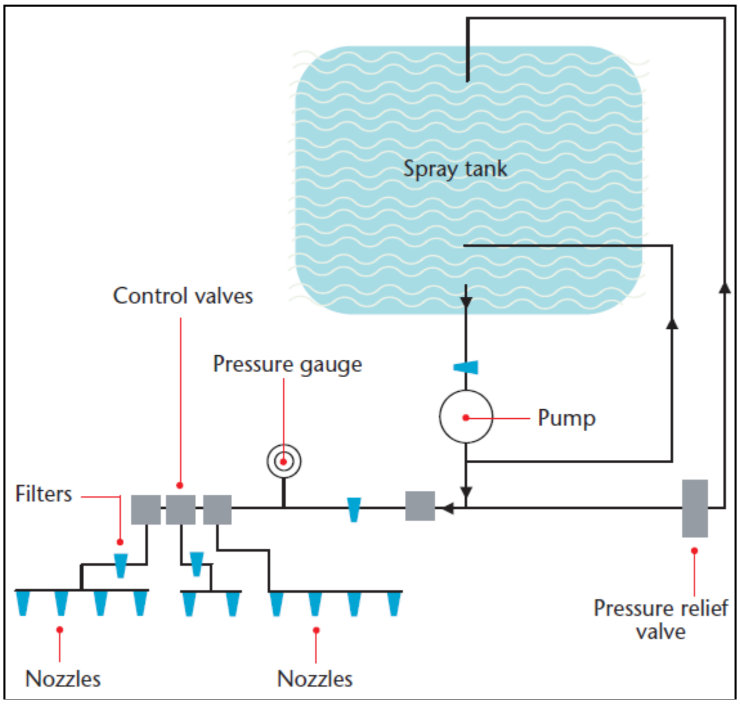

Fig 1: A model of a modern mechanised spraying system

Table 3: Characteristics of pumps suitable for spraying systems.

Characteristic	Diaphragm	Piston	Centrifugal
Pressure (bar)	40	50	5
Maximum flowrate (l/min)	360	80	500
Relative durability	High	Low	High
Relative cost	High	High	Medium
Displacement where used	Positive	Positive	Not positive
Formulation types	All	Not wet table powers	All

Herbicide Delivery System

Nozzle function and fitting

Nozzles play an important role in herbicide delivery. A number of nozzles are available for a range of spray patterns, flow rates and pressures to match site and application variables. In agriculture, large volumes of water are generally used to obtain adequate coverage; therefore nozzles that handle large flows at low to medium pressures are more suitable. It is always advisable to check that nozzle type is suitable for the product, crop and target application rate.

The size and arrangement of the nozzles, the form of the spray pattern and the operating pressure will determine the size of droplets, trajectory, coverage and rate of application. The number and characteristics of nozzles must be matched to the capacities of the sprayer pump and tank.

Nozzles can be made of stainless steel, brass or plastic. Nozzle wear can be identified by an increase in flow rate, often indicated by a slight drop in system pressure and a deterioration of the spray pattern. Nozzles should be changed when their flow rate (compared with new) increases by 10%.

Screw or bayonet fitting mechanisms are generally used to attach hydraulic nozzles to the caps within the seating bodies, which are connected to the boom herbicide supply pipes. Multi-head bodies with rotating caps facilitate quick nozzle changes. Self-aligning caps ensure that nozzles are always fitted in the correct alignment, relative to the boom, with appropriate offset to avoid interference between adjacent fan nozzle spray patterns. Diaphragm check valves (DCV) are usually fitted to the nozzle bodies,

to prevent herbicide drip from the boom and to ensure a quick non-drip start and stop of herbicide spray in response to operator control.

Nozzle types

All nozzles are designed to give a set spray pattern and droplet size at a particular pressure and working height.

The hydraulic pressure nozzle is the most commonly used type. It is designed to receive a pressurized flow of herbicide and to deliver the herbicide in a set spray pattern, which then breaks into a defined range of droplets. Other nozzle types such as the rotary atomizer, which produces a controlled droplet size, and the twin fluid nozzle, which incorporates air into the droplets, are also used.

To minimize the risk of spray drift, nozzles classed as medium or coarse, in terms of droplet size and as described in the ASAE Standard S572 should be used. The classification of any nozzle can be compromised by a change in the pressure of the spraying equipment. Nozzle suppliers can provide information on droplet classification for their products. Low drift hydraulic nozzles are available. Table 4 uses ASAE terminology to describe spray quality, droplet size and drift potential.

A large range of hydraulic nozzles (spray tips) is available. The spray pattern produced by each nozzle type is termed the 'footprint'. Abrasive spray formulations or careless handling can also easily damage nozzles, so they must be regularly inspected, to ensure they are providing the specified spray pattern.

Nozzles most commonly used on boom sprayers are:

- Regular flat fan.
- Twin fan.
- Even flat fan.
- Solid (or full) cone.
- Hollow cone.

Table 4: Drift potential of different spray qualities.

Spray quality	Droplet size (μm)	Drift potential
Very fine	< 119	Very high
Fine	119–216	High
Medium	217–353	Moderate
Coarse	354–464	Low
Very coarse	> 464	Very low

Spr Ayer Maintenance

Sprayers must be thoroughly cleaned and maintained prior to storage. All components should be checked before and after storage. Guidance on maintenance of the main boom sprayer components is provided in Table 5.

Table 5: Boom sprayer components: key requirements for maintenance.

Components	Essential maintenance
Tank	Ensure that tank is clean, inside and out. Check for cracks and other signs of visible damage. Ensure that tank is fixed in the main frame and that any securing systems are in good order.
Pump	Check for signs of leakage and that the pump rotates without hindrance, this can be done manually or by running at low speed. Check lubrication levels, flow rates and pressure settings.
Hoses	Check for signs of cracking and splitting, particularly where the boom folds. Check connections to ensure that they do not leak. Look for signs of routine wear and tear, especially where the hose can chafe against parts of the sprayer.
Filters	Ensure that all the necessary filters are in place and that they are not damaged or blocked. Check that seals and other constituent parts are present and that the filter does not leak.
Controls	Test all controls: electrical, hydraulic or air, to ensure they are fully operational. Check for leaks.
Pressure gauge	Replace faulty pressure gauges. Contact the dealer or manufacturer if there are any doubts.
Boom	Ensure that all shock absorbers, pivot points and other moving parts operate correctly and that there is no undue wear. Test folding mechanism(s) for smooth operation. Check that the height adjusting system and break back system are working correctly. Check all the boom pipes and hoses for splits, chafing, cracks and leaks.
Anti-drip valves	Test under pressure to detect any leaks and to assess cut-off performance. Check diaphragms and valve seating's.

Conclusions

Mechanization of herbicide spraying operations can result in:

- Lower unit costs;
- Reduced operator contamination;
- Improved operator ergonomics;
- Improved efficiency;

- Improved tree establishment.

The use of mechanized spraying systems will be influenced by:
- Site and terrain conditions;
- Operating costs;
- Size, distribution and type of work programmes;
- Availability of selected system and/or components.

Pre-season and regular maintenance is essential.

Recommendations

It is recommended that boom sprayers are:
- Mounted on multi-wheel drive prime movers that are guarded and suitable for agriculture use.
- Fitted with boom suspension and break back systems to improve performance in agriculture conditions.
- Fitted with spray management systems that enable moderate changes of travelling speed to take place without affecting target volume rate application.
- Used with systems or methods to monitor the accuracy of machine travel (and the area the herbicide is applied to) across the site.
- Fitted with herbicide handling/mixing systems that reduce the risk of operator and environmental contamination.
- Used in a manner to minimize drift.
- Fitted with herbicide handling and cab systems that improve operator ergonomics.

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