Harvest weed seed control: the potential in rice crops

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Abstract

Herbicide resistant weeds are a major impediment to Australian grain production including rice and one of the newer methods used to reduce their impact is the collection and/or destruction of weed seeds at harvest, harvest weed seed control (HWSC). HWSC targets weed species with a potential weakness, in that they retain a large portion of their seed at maturity. While harvest can be a major factor in spreading weed seeds across a paddock, with HWSC we can now reverse this process to reduce seed bank inputs.

The suite of HWSC systems includes narrow windrow burning, chaff lining, chaff tramlining, chaff carts, Bale Direct system and the Harrington seed destructor (HSD). An important factor in many HWSC systems (eg. chaff carts, chaff lining and HSD) is that they only target the proportion of weed seed exiting the harvester in the chaff fraction.

This paper will examine the potential for the different HWSC systems to successfully target weeds of Australian rice crops.

Introduction

Herbicide resistant weeds have a major influence on the management of the major field crops in Australia, with rice being no exception. A survey of the rice growing regions of Australia in 1999 found high frequencies of resistance to the ALS-inhibiting herbicide, bensulfuron, in three major weeds (dirty dora, starfruit and arrowhead) (Broster *et al.* 2004). With these weeds being aquatic species this has resulted in the increased use of the only other major aquatic weed herbicide, benzofenap, a HPPD inhibitor, placing additional selection pressure for resistance development on this herbicide. Compounding this situation is the change to dryland sowing of rice crops which delays the emergence of aquatic weed species (*Cyperus difformis* and *Damasonium minus*) but favours barnyard grass (mostly *Echinochloa crus-galli*) (McIntyre *et al.* 1991).

There are few herbicides available for the control of weeds in Australian rice crops so alternatives are required to prolong the use of these herbicides. Many non-chemical management practices have been developed or adopted by Australian dryland cropping farmers for weed control. Mostly these are targeted at the prevention of weed seedlings interfering with the early growth of the crop (Sindel 2000). Of the $475 million spent by Australian dryland cropping farmers on integrated weed management, 65% ($306 million) was spent on seedling control and only 4% ($17 million) on HWSC (Llewellyn *et al.* 2016).

Harvest Weed Seed Control (HWSC) is different to many other non-chemical control methods in that it targets the mature plant with the aim of preventing its seed from entering the seed bank. Many weed species retain a large proportion of their seed at the time of crop harvest. These weed seeds then enter the harvester and are rewarded for their survival by being evenly spread across the paddock to become the weed problem in subsequent years (Walsh *et al.*

2013). In annual ryegrass (*Lolium rigidum*) a harvest height of 10 cm would collect 85% of seed across southern New South Wales and Victoria and 66% in Western Australia (Broster *et al.* 2015; Walsh *et al.* 2016).

HWSC is a suite of many different management systems that include narrow windrow burning, chaff carts, bale direct, tram lining and the Harrington Seed Destructor (HSD). All of these have similarities in that they rely on the weed seeds entering the harvester, being collected or directed to a specific location and then being destroyed either immediately or later. Most of these systems were developed to control annual ryegrass and therefore primarily target the chaff fraction as 95% of annual ryegrass seed exit the harvester in this fraction (Broster *et al.* 2016). The exceptions are narrow windrow burning and the bale direct system that target both the chaff and straw fractions. When tested these systems have been shown to deliver a similar level of control of annual ryegrass (Walsh *et al.* 2014).

The HWSC systems

Narrow windrow burning

This is the most widely adopted form of HWSC (Figure 1) and for those using other methods was often the starting point, due to its simplicity and low cost. A chute is placed on the harvester to concentrate all of the exiting chaff and straw in a 500-600mm wide windrow. The windrows are later burnt in such a way that the remainder of the paddock is not burnt. The concentration of harvest residues in the windrow increases both the temperature and duration of the fire, resulting in a higher kill of weed seeds, up to 99% for annual ryegrass and wild radish (*Raphanus raphanistrum*) (Walsh and Newman 2007; Walsh *et al.* 2013).

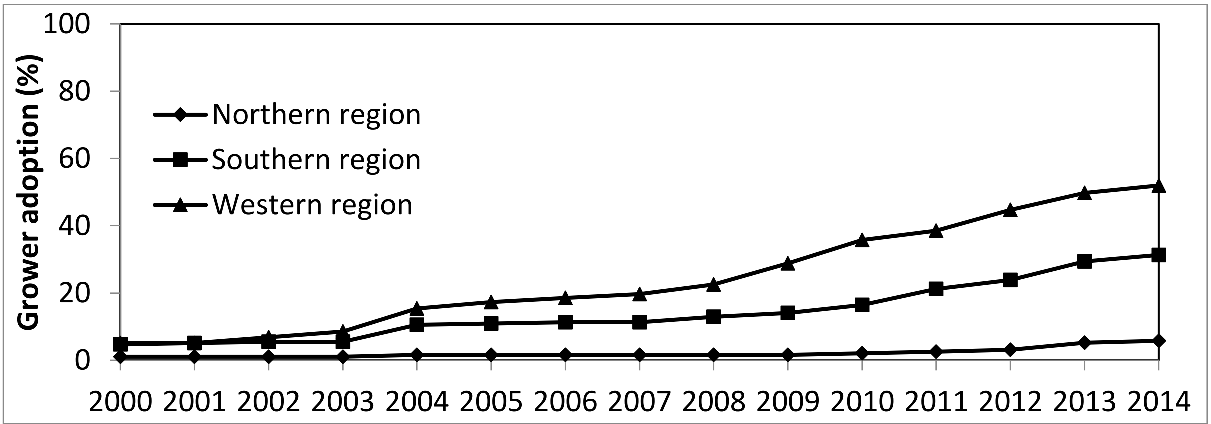

Figure 1: Adoption curve for narrow windrow burning by Australian grain growers. Regions relate to those of the Grains Research and Development Corporation. Adapted from Llewellyn *et al.* (2016) .

Chaff carts

A collection bin towed behind the harvester with a chaff collection and transfer system is used to collect the chaff residues directly from the harvester during crop harvest. The bins are emptied at set intervals so that lines of chaff heaps are formed across the paddock. These chaff heaps are subsequently destroyed by burning, grazed in situ or removed for use in feed-lots.

Bale Direct

A large square baler attached to and powered by the harvester utilises both straw and chaff fractions to produce bales for livestock feed. The lack of markets for the bales produced has limited the uptake of this system.

Tramlining
In controlled traffic management system the weed seed bearing chaff fraction can be placed on dedicated wheel tracks (tram lines). In many cases there is no further need for control due to the mulching effect of the residue on the seeds, the level of weed seed control is dependent upon, both the level of residue present, rainfall amount and pattern as well as disturbance of this chaff material. In cases of low residue levels and/or low rainfall, additional control methods such as burning or spraying of these tramlines may be required.

Harrington Seed Destructor (HSD)
To process the chaff fraction sufficient to destroy weed seeds during harvest a cage mill with its own power supply and along with chaff and straw transfer systems are mounted on a trailer towed by the harvester. However, subsequent development has led to a version of this system that can be retro fitted into the rear of and powered by the harvester (iHSD) to process chaff material exiting of the top sieves. The original HSD was able to destroy at least 95% of weed seeds entering the mill, with similar findings for the iHSD (Walsh *et al.* 2013).

Considerations for HWSC in rice cropping systems

The major issues that will impact the ability to use HWSC in rice paddocks are the irrigation bays and flood water. The irrigation bays create the equivalent of many smaller paddocks with large banks and irrigation furrows between them meaning the logistics of towing another item of machinery behind the harvester are difficult, this would limit the uptake of chaff carts, the bale direct system and the HSD. The large numbers of bays within a paddock would mean that if a chaff chart was used the resulting chaff dumps may need to be placed within individual firebreaks rather than a single firebreak for all chaff dumps within a paddock as occurs in dryland paddocks.

The movement of water on and off the bays may limit the use of systems such as narrow windrow burning and tram lining. If the bays were irrigated for any reason before they were burnt or the mulching had its full effect the material, and associated weed seeds would be floated across the irrigation bay.

Narrow windrow burning would only be suitable after drill sown crops. In these crops the bare earth between rows reduces the risk of the fire escaping from the windrow and burning the entire bay or paddock. In aerially sown or dry broadcast crops there are no rows, therefore the potential for the fire to escape the windrow is much higher. However, in many situations where the famer was planning to burn the stubble anyway this is of minimal impact as the windrows created will still burn slower and hotter killing the weeds seeds present.

The amount of dry matter produced by a rice crop is much higher than that of a dryland wheat, barley or canola crop and this would also create its own problems. It is most likely that as with the dryland crops, to collect the optimal amount of weed seeds, the harvest height would have to be lower, therefore increasing the amount of dry matter passing through the harvester. Harvester setup then becomes important in allowing the suitable separation of chaff and weed seeds from straw. However, the lodging of rice crops is common, with growers forced to harvest at low heights to ensure grain collection. Therefore, there is some grower experience with low harvest heights.

The need to harvest lower may however be an advantage. The reduced stubble height may enable sowing machinery to pass through the remaining stubble easier negating the need to burn the stubble to sow the next crop or pasture. An increasing number of farmers are using stripper fronts in rice crops (M. Taylor pers. comm.), the increased stubble height left after harvest may exclude the use of narrow windrow burning as an option. However, if they are set at a low height to strip the rice grain they may also be collecting the seed from a number of the weed species present.

Rice crops can be prone to lodging, dependent upon variety and nitrogen inputs. Approximately 30% of the crop lodged for the 2016 harvest (J. Fowler pers. comm.) and these were, by necessity, harvested as low as possible. This would allow the capture of a large proportion of weed seeds.

Weeds of Rice

There could be considered to be four major weeds of rice in Australia. Barnyard grass (mostly *Echinochloa crus-galli* but also other *Echinchloa* species), dirty dora (*Cyperus difformis*), starfruit (*Damasonium minus*) and arrowhead (*Sagittaria montevidensis*), the last three being aquatic species. Also present in lesser numbers or more localised distribution are water plantain (*Alisma plantago-aquatica*) and silver top (*Leptochloa fusca*).

The level of seed production from these weeds is extremely high with arrowhead capable of producing up to 20,000 seeds per plant, dirty dora 50,000, barnyard grass 100,000 and starfruit up to 125,000 seeds per plant (Norris 1992; Sanders 1994; Graham 1999; Flower 2003). Compounding the issue for water plantain is that as well as germinating from seeds, water plantain is a perennial that regenerates from a below ground corm (Ransom and Oelke 1988).

The impact of HWSC is greater in weed species with short lived seed banks. One of the factors of rice weeds that will complicate the determination of the suitability of HWSC for rice is that in the absence of ideal conditions many aquatic weeds of rice retain dormancy but then germinate in large numbers when conditions are suitable (flooded bays) (Graham 1999; Ravindran 2007). High levels of germination have been recorded in some of these species within 12 months under ideal conditions suggesting short seedbank lives (Flower 2003; Ravindran 2007). However in the absence of suitable conditions for their germination they can also remain viable for many years suggesting the potential for the seed bank to have a longer life (Graham 1999; Flower 2003; Heylin 2006).

To be susceptible to HWSC systems the weed seeds need to be collected and processed by the harvester. A survey of 431 rice seed samples collected from the Rice Growers Mill Laboratory at Leeton in 1998 found barnyard grass in 86% of the samples, starfruit in 20%, dirty dora in 10% and arrowhead in one sample (Flower 2003). While no data were collected on what percentage of the seed produced by the various weed species entered the harvester this data does show the potential for HWSC in rice. Additionally, while barnyard grass seeds, especially the less common *E. oryzoides*, are similar in size to rice grain, seeds of the other species are either much smaller or lighter and should be separated from the rice grain in the harvester and it could be expected be in larger numbers in the chaff fraction.

The only research to look at seed retention at harvest time was for water plantain and found on average 50% of seed was still on the plants, with a range of from 10-90% (Heylin 2006). Older plants had the lower seed retention levels with the remaining seeds higher on the plant. Heylin

(2006) found no water plantain seeds below 29cm and all seeds were removed from the plant during harvest. While no details studies were conducted into where the weed seeds finished, seeds were found amongst chaff at the rear of the harvester, for both conventional and stripper fronts.

Required research

Before any research is undertaken it needs to be established which of the weeds species the farmers would most like, or need, to target with HWSC. If for example it is barnyard grass and there is high seed retention then growers will be more likely to adopt the practice regardless of the retention of the other species.

The first step in the research required to determine the potential for HWSC in rice is to determine the level of seed retention for the major weed species. This is similar to the work by Heylin (2006) described above but can be conducted in conjunction with the collection of more detailed data on the height of the weed seeds in the crop canopy similar to work previously undertaken for wheat crops and annual ryegrass to determine the optimum harvest height (Broster *et al.* 2015; Walsh *et al.* 2016). Crop biomass data would also be collected at the same time enabling the impacts on harvester operation to be described.

Once it has been determined which species can be collected at harvest then additional research can be undertaken to establish where the weed seeds finish. Again, this work has been done in wheat for annual ryegrass (Broster *et al.* 2016). As mentioned previously several species, especially barnyard grass but also starfruit and dirty dora, are found in the grain screening samples at the Rice Growers Mill Laboratory and therefore we know they enter the harvester. What is unknown is what percentage that enters the harvester ends up in each of the grain, chaff and straw fractions. With the differences in seed size compared to rice then the seed should exit in the chaff fraction. With the increasing use of stripper fronts at harvest the decreased dry matter that needs to be processed compared with a conventional front may improve the efficiency of getting the weed seeds into the chaff fraction which most HWSC systems target.

Additionally it needs to be determined if the weed seeds can then be destroyed by the various HWSC methods. The reason for narrowing the windrow is to enable the temperatures at the soil surface are hot enough, for long enough, to kill the seeds from targeted weed species (Walsh and Newman 2007). This work would have to be repeated for the different weed species in windrows of rice stubbles to ensure that all weed seeds from the species in questions were destroyed. The ability of the HSD or iHSD to destroy seeds of the various species would need to be determined as has also been done for the dryland cropping weeds (Walsh *et al.* 2012).

Potential Results

Harvest Weed Seed Control is not a 'magic bullet' it requires planning and skill and is not a stand-alone system but part of a suite of management practices (eg. herbicides, hygiene of machinery and banks). Some of these may provide major decreases in weed numbers in subsequent years while others only provide small decreases. It is the combination of the various practices and potential synergies that make the system work. In Australia there are a limited number of rice herbicides available therefore there is an opportunity to be proactive and maintain or increase their life before resistant weed populations become or as has been the case in many regions of Australia be forced to adopt HWSC as there are no or minimal herbicides left due to resistance.

For example the high level of resistance to bensulfuron has led to an increase in combine sown or dry broadcast crops. This has placed increased emphasis on the control of barnyard grass. Two of the major barnyard grass herbicides are cyhalofop and profoxydim, both ACCase inhibiting herbicides. The ACCase inhibiting herbicides are considered to be a high risk group for herbicide resistance development. What happens when there are a large number of weed populations resistant to both of these herbicides limiting control options? Can HWSC be utilised to reduce the selection pressure for resistance to these two herbicides enabling farmers to continue to successfully control their barnyard grass populations.

While herbicides are very good at reducing weed numbers, weeds can still survive and set seed. A number of paddocks in the northern Western Australian cereal cropping region have been monitored since 2001 with ryegrass numbers counted every spring (Figure 2). While the use of herbicides alone has reduced annual ryegrass numbers by 97% (187 to 5/m^2) since 2001 the addition of harvest weed seed control has reduced the number of ryegrass present even further, to one plant per metre squared or less for the last six years (Figure 2).

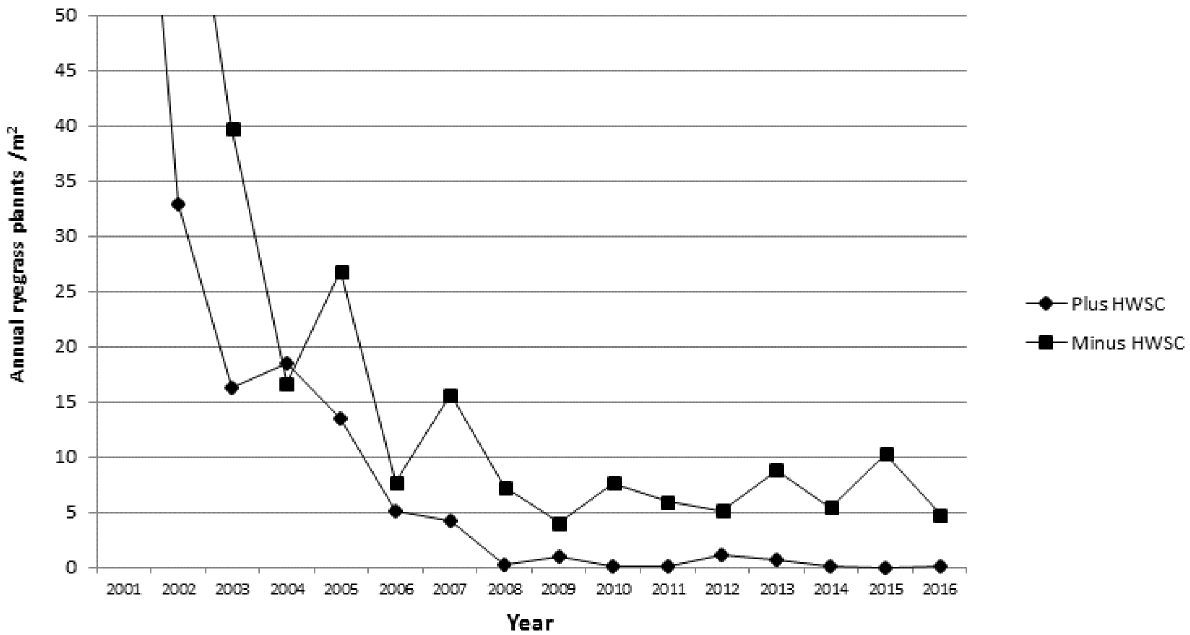

Figure 2: Ryegrass plant numbers since 2001 for 26 paddocks divided into those whose use HWSC (12 paddocks) and those who don't use HWSC (14 paddocks). Adapted from Walsh *et al.* (2013), additional data from P. Newman (pers. comm.)

The above data for ryegrass are from an area with high levels of herbicide resistance. Could HWSC be just as successful in the rice growing regions of Australia while the majority of weeds are susceptible to herbicides?

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