Managing herbicides for sustainable cotton production and water quality protection

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Herbicides and cotton production

The cotton industry is one of the largest user of pesticides among the Australian agricultural sector. It has been estimated that endosulfan and pyrethroids account for 70% of all insecticides. In addition to insecticides, herbicides are also used extensively to control the weed menace in cotton. However, reliance on herbicides to control weeds in cotton production system has the potential to cause concern about their presence in the environment and contamination of waterways. Recent monitoring conducted by the New South Wales Department of Land and Water Conservation (Cooper and Muschal 1998) show that residues of some herbicides are also being transported into rivers in cotton growing areas. The herbicides atrazine, diuron, prometryn and fluometuron have been detected consistently during last three years of monitoring program in Northern New South Wales.

The challenge for the industry is to cope with the public demand for clean and safer agricultural practices, reducing the environmental damage that is mainly on the excessive use of pesticides, while maintaining profitability. In this article, as part of a new CRC research project we provide information that can help growers select herbicides that will have a minimum impact on water quality and sustainable cotton production. Some elements support for best management practices needed to sustain favourable environment to grow cotton is also presented.

Factors affecting herbicide selection

Soil acts as a major sink for herbicides which added through soil incorporation or aerial application. The behaviour of pesticides in the soil environment is governed by many factors including soil and pesticide properties. Some of the factors that should be considered when selecting herbicides with minimal impact on environment and water quality are:

Herbicide properties:

(i) The sorption coefficient, Koc, describes the relative affinity or attraction of the herbicide to soil particles and therefore its mobility in soil. (ii) The chemical or biological degradation half-life, $t_{1/2}$, is a measure of persistence of the herbicide in soil. (iii) The Australian drinking water lifetime health guideline level, is a measure of health risk to humans of pesticide contaminated drinking water. (iv) Aquatic toxicity, LC_{50}, is a measure of the ability of the pesticide to cause 50% mortality in aquatic test species.

Soil properties:

(i) Hydraulic permeability or conductivity is a measure of the soils ability to allow water to percolate through the soil profile. (ii) Organic matter and clay are the important soil properties that provide sites for pesticides to bind, thus reducing their mobility and increasing their opportunity to be degraded by soil microorganisms. (iii) Slope affects the potential for water to runoff the land surface.

Management practices:
(i) Herbicide application frequencies and rates determine the total amount applied. For example, lower frequencies and rates reduce the potential for contamination. (ii) Application method (band spraying) affect the amount of pesticide subject to transport by water. For example, if applied directly to soil, there is a greater probability that more of the applied pesticide will be available for leaching or runoff than if applied to the foliage. If the herbicide is incorporated into the soil, leaching may be the most important loss pathway. Herbicide applied to the foliage may be lost to the atmosphere or decomposed by sunlight thereby reducing the amount available for wash-off and transport to water bodies. Irrigation practices can also determine the loss pathways of pesticides. Herbicides often move with water, so the less excess water that is applied, the less potential there is for a herbicide to move past the crop root zone or to runoff in surface water. Excess rainfall also can wash off significant quantities of herbicides from the treated zone.

Herbicide selection for minimum impact on water quality
Continuous reliance on herbicides to control weeds in cotton production system is causing great concern with regards to surface and groundwater contamination. This motivates cotton growers to select herbicides with least potential to cause water quality problems. Unfortunately, information that allows growers to select herbicides with less impact on water quality has not been readily available. Our goal is to provide information that can help growers select herbicides with a minimum adverse impact on environment and water quality. The procedure considers the following: (i) soil properties of the test site, (ii) transport characteristics of the herbicides and (iii) toxicity of herbicide in water to humans and aquatic species. Information contained in this paper can help cotton growers to make better decisions about the herbicide that they use.

Growers guide for herbicide selection
The method consists of a two-tier procedure similar to the Florida Cooperative Extension Service methodology. In this method not only the leaching and/or runoff losses but also toxicological impacts are also considered. Table 1 contains the two important indices, the Herbicide Leaching Potential Index (HLPI) and the Herbicide Runoff Potential Index (HRPI) and two toxicological parameters (Australian lifetime health guideline levels and aquatic toxicology) for the herbicides used in cotton production systems in Australia. Both indices are relative and are briefly presented below:

Herbicide Leaching Potential Index (HLPI) defines the relative attenuation (reduction in mass as it moves through the soil profile) of each herbicide in soil, and therefore its potential to leach to groundwater. The index is calculated by multiplying the ratio of the sorption coefficient (Koc) and the degradation half-life by 10. The index is integer. This ratio defines the relative attenuation of herbicides over a wide range of soils. There is some uncertainty in the data used to calculate this index. However, since the values are relative they can still be used. It is important to note that the smaller the HLPI, the greater is its potential to leach.

Herbicide Runoff Potential Index (HRPI) defines the relative immobility of each herbicide in soil, and therefore its potential to remain near the soil surface and be subject to loss in runoff either sorbed to eroded sediment or in the aqueous phase. This index represents the combined sediment and aqueous phase runoff potential and is calculated as follows:

I. If Koc is > 1000 mL/g, then the HRPI is the ratio of 1 000 000 and the product of sorption coefficient times the degradation half-life.

II. If the Koc is < 1000 mL/g, then the HRPI is the smaller of the values calculated in I or the HLPI. This index is integer. There is some uncertainity in the data used to calculate this index. However, since the values are relative they can still be used. The smaller the HRPI, the greater is the potential to be lost in runoff. Both the leaching and runoff potential indices were developed by evaluating the results of long-term (30-50 years) simulations using validated pesticide fate models to predict the probability of leaching or runoff of pesticides for a range of soil and pesticide properties.

The lifetime health guideline level provides a measure of pesticide toxicity to humans. The guideline level is the concentration of pesticide in drinking water that is not expected to cause any adverse health effects over a lifetime of exposure (70 yr), with a margin of safety. The values used are the Australian drinking water guideline values given by National Health and Medical Research Council (NHMRC) and the National Occupational Health and Safety Commission. The smaller the value the greater is the toxicity to humans.

The aquatic toxicity provides a measure of pesticide toxicity to aquatic species. The values used are the lethal concentration (96-hr exposure) at which 50% of the test species die (LC_{50}). In most cases the test species was rainbow trout (*Oncorhynchus mykiss*). The smaller the value the greater is the toxicity to aquatic species.

A Herbicide Selection Worksheet is also attached that can be used by the growers to organise the information needed to select a particular herbicide to reduce the contamination of water in cotton production system. The details for using the worksheet are outlined below:

1. Target weed: Correct identification of a particular weed that need to be controlled is essential. Check with local weed Agronomist or weed research group so that a proper diagnosis can be made. Misdiagnosis results in the wasteful use of unnecessary herbicides and needless increase in production cost. List the target weed to be controlled in column 1 of the herbicide selection worksheet.

2. Recommended herbicide: Use the current weed control guide or obtain necessary information from the local weed agronomist to identify the herbicide that control the weeds of concern. List these herbicides in column 2 of the herbicide selection worksheet.

3. Herbicide properties: For each herbicide listed in column 2 on the herbicide selection worksheet, copy of the numeric value for Koc, HLPI, HRPI, AHGL, and aquatic toxicity from Table 1 into columns 3, 4, 5, 6 and 7 of the herbicide selection worksheet.

4. Selection of herbicides: When herbicides need to be used, selections should be influenced by the specific characteristics of each field. The selection criteria encourages the grower to move away from the worst case as defined by the smallest HLPI, HRPI, AHGL and aquatic toxicity values rather than defining the best choice.

Best Management Practices for sustainable cotton production

Best Management Practices (BMPs) in the context of this discussion, are defined as practices which reduce the potential for herbicides moving into water ways either by surface runoff or by leaching. Although not an inclusive list, the following BMPs are suggested for incorporation when designing a cotton farm:

- Practice Integrated Weed Management (IWM)
- Select herbicides that are labelled for intended application site.
- Consider soil characteristics (soil texture, organic matter , slope etc.).
- Reduce off-target drift.
- Leave buffer zones around sensitive areas (one kilometer or aerial applications strictly controlled by wind direction and other meteorological conditions).
- Minimise the number of herbicide application.
- Reduced rates and combination products.
- Retention runoff. Ideally no irrigation water runoff should leave the farm.
- Consider impact of weather and irrigation.
- Use protective equipment and clothing.
- Store pesticides safely and securely.
- Dispose of wastes safely.

The CRC for Sustainable Cotton Production's research program approaches risk assessment using currently available data that will be validated on the next two years by tests using actual soils used in cotton growing.

References

Cooper, B. and Muschal, M. (1998). Monitoring the fate of pesticides in the riverine environment - a case study. In Pesticides in Soil, Water and Produce: Analysis, Environmental Monitoring and Remediation. Eds. Kennedy, I.R., Baskaran, S. and Sanchez Bayo, F. Proceedings of the one-day symposium, University of Sydney, July 3.

Table 1. Cotton herbicide selection guide based on herbicide parameter matrix for water quality protection

Herbicide		Rate of application (L/ha or kg/ha)	Sorption coefficient Koc (ml/g)	half-life (days)	Relative losses		Toxicity	
Common name	Trade name				Leaching (HLPI)	Runoff (HRPI)	Australian health guideline level (ug/L)	Aquatic LC_{50}
Amitrole	Weedazol	1.3-4.6	100	14	71	71	10	100
Dalapon-sodium	Shirpon Grasskiller	10-44	1	30	1	1	nd	100
Dicamba	Banvel	0.4-1.4	2	14	1	1	100	28
Diquat	Reglone	1.5-3.0	1000 000	74	135135	1	5	10
Diuron	Aguron, Diurex	70-144	480	90	53	23	30	4.9
Fluazifop-butyl	Fusilade	0.75	5700	15	3800	11	nd	1.3
Fluometuron	Cotoran	1.3-2.8	100	85	11	11	50	3
Glyphosate	Roundup	0.5-9.0	24000	47	5106	1	1000	8.3
Metolachlor	Dual	2.0	200	90	22	22	300	2
MSMA	Daconate	1.3-4.3	250	55	45	7	nd	167
Norfluazuron	Zorial	2.5-5.0	700	180	39	47	nd	6
Paraquat	Gramoxone Nuquat	1.5-3.0	1000 000	74	135135	1	30	15
Pendimethalin	Stomp	3.0-9.0	5000	90	555	2	300	0.140
Prometryn	Gesagard	1.1-4.5	400	60	66	41	30	2.5
Sethoxydim	Sertin	1.0	100	5	200	200	nd	170
Trifluralin	Tridan, Yield	1.4-2.8	8000	60	1333	2	50	0.041

Herbicide selection worksheet

Farmer:
Soil description:
Crop:

Farm name:
Site description:

Target weed	Recommended herbicide	Sorption (Koc)	Relative losses		Toxicity			
			Leaching HLPI	Runoff HRPI	Australian health guideline level	Aquatic toxicity	Selected herbicide	Comments

If the Koc is 100 or less or if the HLPI is 10 or less, then the herbicide has a high potential for leaching and should be used with extreme caution. Alternative herbicide or reduced rates should be considered if possible. Apply herbicide during periods with low potential for rainfall if possible.