Yield impacts and extension activities associated with simulated herbicide drift on a commercial cotton field

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ABSTRACT

Past research has shown cotton to be highly susceptible to the phenoxy group of herbicides. However, information is limited on the impacts of other herbicides used within the Australian farming system. Physical drift of non-cotton herbicides can be associated with either roadside weed control, or summer fallow weed management. The drift associated with fallow management can be from within (self-inflicted) or outside the farm boundary. External sources of drift are a problem that faces all cotton producers that either border public land or alternative agricultural enterprises. To minimize these off target impacts, an extension officer based in a multi-enterprise production region needs to increase the knowledge base of the wider community on the subject of herbicide drift. Field trials were conducted over three years, (1995-96, 1996-97 and 2001-02 production seasons). The aim of the treatments was to simulate herbicide drift in a cotton field and to monitor both visual symptoms and plant recovery rates. Herbicides not usually associated with a cotton production such as 2,4–D amine, fluroxypyr, triclopyr, MCPA amine, metsulfuron, glyphosate, dicamba and dichlorprop, were all assessed during the experiments. The treatment rates applied to the crop ranged from 0.001% to 30% of the recommended commercial rate commonly used in Australia. The timing of treatments varied between seasons, with applications occurring at 125, 95 and 85 days after sowing for respective seasons. Despite the variation in application timing, herbicide severity can be rated according to the resultant damage trends. Cotton treated at 85 days after sowing, in the 2001-02 season yielded as low as 13% of the untreated plots after the application of a 2,4-D amine/glyphosate tank mix at the 10% recommended rate (RR). Herbicides such dicamba, 2,4-D amine, dichlorprop, fluroxypyr at the 10% RR, applied individually also caused yield reductions between 57% and 81%. Glyphosate at the 10% RR, decreased yield by only 3%. Cotton can recover and produce reasonable yields after low levels of 2,4-D amine drift. An application of 0.1% RR of 2,4-D amine at 85 days after sowing, increased yield by 9% of the untreated plot yields. Yield damage is strongly linked to herbicide rate. This paper will focus on the yield component of the experiments as a measure of the cotton plants ability to recover from this simulated herbicide drift. Extension activities, which are associated with these experiments to educate both the cotton producer and the wider community in minimizing physical herbicide drift, are also discussed.

Introduction

Cotton is highly susceptible to the phenoxy group of herbicides (Smith and Weise, 1972; Smith and Geronimo, 1984). However, limited information exists as to the effects from 'off target drift' of alternative herbicide active ingredients used within the Australian farming system.

If herbicides are applied during unsuitable meteorological conditions, the result may be 'off target drift' which can be significant. This 'off target drift' is particularly evident in a mixed farming community where cotton producers may border public land, such as travelling stock routes or non-cotton producers. Gunnedah, located in the cotton production region known as the Upper Namoi Valley, NSW Australia reported in 1999-2000 season 720 ha of drift damage (personal communication, 2003). This damage was either caused by unintentional spray drift from a third party or self-inflicted due to applications on fields near cotton.

The introduction of glyphosate tolerant cotton into the Australian cotton industry is a current example of a potential increase in the incidence of 'off target drift' from the active ingredient glyphosate, especially from fields that border non-herbicide tolerant varieties.

The Upper Namoi Valley could be regarded as unique in terms of potential drift sources during the summer months. All of the producers within the valley are mixed farming operations and numerous producers bordered public land such as travelling stock routes (TSR). Travelling stock routes are lane ways that allow stock to be walked within the state of New South Wales. Associated with this intensive grazing pattern and movement of large herds of stock is the aspect of concentrated weed infestations. Local government agencies aim to maintain these access lanes in the summer months controlling a range of weeds species while still allowing grass production for erosion control and grazing. Historically auxin type herbicides such as 2,4-D amine and fluroxypyr have been the preferred control options.

Alternative sources of 'off target drift' during the cotton production season include weed control operations in summer fallow and 'in-crop' herbicides used in the production of the various summer groups produced across the valley. Such summer crops include sorghum, maize, sunflowers, mungbeans, lentils, white french millet and various vegetable crops.

After visually assessing numerous incidences of damaged cotton caused by either third party or self-inflicted 'off target drift' it was evident there was a need for an extension program to address this issue. The program was aimed at the general public, and herbicide applicators from both within and outside the cotton community. The extension program was focused on two aspects: Firstly, how to prevent the physical drift of the herbicide and secondly, from a growers / adviser perspective, what were the visual symptoms and impact on yield resulting from the drift.

The first component will be covered under the heading of extension activities, while the visual and yield impacts were assessed in conjunction with the co-authors by conducting three years of drift simulation experiments. Core sets of treatments were tested each year in combination with a selection of alternative products that reflected the usage pattern in the local Australian farming system. This paper will report on the yield results of the 2001-02 season and outline the extension program that has been undertaken since it was developed.

Background to experiments

Replicated small plot experiments were established in three separate seasons: 1995-96, 1996-97 and 2001-02. At each site, a known quantity of herbicide active ingredient was applied to a cotton crop using a hand-held 3 m boom. Cotton plants were then assessed for visual symptoms, and yield recovery. The aim of the treatments was to simulate a herbicide drift pattern as a result of fine droplets physically drifting onto the crop. Treatment rates that were used were zero, 0.001, 0.01, 0.1, 1, 3, 10 and 30% of the commonly recommended rate for that herbicide. In 2001-02, the number of rates was reduced to zero, 0.1, 1, 3, and 10% of the recommended field rate. Given the complexity of herbicide options that may be used within a mixed farming enterprise, it was decided that the herbicides and associated rates listed in Table 2 where the most likely options.

Treatments were visually scored on five occasions and photographed for symptoms at 23 days after the herbicide application. A subjective scoring system of 1 to 5 was used to score the visual damage of the herbicides. A score of 5 represent total death of plants. Table 1 outlines the varieties and timing of treatment application. Yield assessment of the treatments was completed by harvesting with a small-plot-single-row cotton picker. The experimental plots were within a commercial field and therefore general agronomic management (insecticides, irrigations etc.) were applied to the experiment in accordance with commercial management decisions of the field.

Results

Visual symptoms

The following descriptions of plant symptoms are based on of applying 10% of the nominated rate of the respective herbicide. Growers can use these descriptions to help identify damage from different herbicides. Descriptions relate to damage at 23 days after treatment. Depending on the herbicide damage, symptoms may change over time or may persist throughout the growing period of the crop. Symptoms will vary with stage of cotton development, herbicide rate and following weather conditions (Storrie *et al.*, 1998).

2,4-D amine Leaf strapping with tightly crinkled and blistering margins. Flowering is reduced with squares aborting following the application. Disfiguration of the plant is not confined a one organ. Leaves, flowers, squares and petioles are all affected. New terminal growth is clawed in appearance and pale green/yellow. Slight plant stunting and red blotching of fully expanded leaves.

Fluroxypyr (Trade name- Starane® 200, Tomigan®) Severe abortion of squares, with new growth tips either burnt/dead and severely cupped. The dominant feature is the downward bending of the petioles parallel to the stem, with later growth then twisting upwards. The plants also suffer a significant height reduction. Reddening of stems and petioles is very prominent with some stems/petioles blistered or slightly cracked.

Dicamba Leaf damage is confined to the leaf margin with cupping downwards. Color of the leaf damage is red to bronze and some yellow patches. Leaf blades appear wavy. New terminal and young leaf growth appears 'claw-like' but with no blistering. Dicamba symptoms on leaves are less severe then those from 2,4-D amine. Plants tend to regrow normally.

Dichlorprop (Trade name: Lantana®, DP 600) Severe leaf blotching on the older leaves. Color of blotches range from red to bronze to almost purple. The new growth exhibits yellowing with some necrosis and square abortion. Plants appear noticeably stunted, with a compacted growth habit. Plants tend to regrow normally.

MCPA amine New leaves are "strappy" in appearance with tightly wrinkled leaf margins. Both flowering and plant height are significantly reduced.

Definition: ***"Strappy"*** *leaves result from the inter-veinal areas of the leaf contracting, so those veins are almost parallel. This abnormal elongation of the leaf blade results in a highly wrinkled, and "claw-like" leaf blade.*

Phytotoxicity scores

Figures 1 to 5, represent the typical visual damage scores that resulted from the treatment up to 74 days after treatment. These scores are subjective and assess the overall appearance of the plants treated. It accounts for biomass and/or height reductions, plant symptoms, fruit loss and the general appearance of the plant. A subjective ranking of two or less indicates low herbicidal damage being expressed and plants are likely to regrow normally. The range in the scores can

Figures 1a and 1b, show persistence of 2,4-D amine hormonal damage even after 74 days since exposure for the drift rates of 3 to 10%. Figure 2 represents fluroxypyr. This product recorded the highest damage score at 23 days after treatment. However, plant recovery was evident by a reduction in phytotoxicity scores at 45 and 74 days after treatment Figure 3 illustrates dicamba only the 10% treatment causing major visual symptoms. However, impact was dissipated after 30 days from application. Finally, Figure 4 records the impact of dichlorprop. Dichlorprop followed a similar pattern as fluroxypyr. Plants re-grew normally. Glyphosate did not cause any major visual damage as seen by Figure 5.

Yield impacts

Yields for the 2001-02 season are presented in Figures 6a and 6b. These yields mirror the visual assessment rankings as outlined in Figures 1 to 5. The treatments having higher visual damage scores also resulted in lower harvested yield. Based on these results fluroxypyr is less damaging than 2,4-D amine at the lower rates. However, at higher rates, fluroxypyr was as damaging as 2,4-D amine. For these treatments, significant yield reductions ($p=0.05$) at the 10% treatment rate recorded a reduction of 81% and 80% respectively when compared to the controls. Dichlorprop followed a similar trend to fluroxypyr. Significant yield losses of 70% were recorded for the 10% fluroxypyr rate ($p=0.05\%$). Tank mixtures of glyphosate and 2,4-D gave an almost identical response curve to 2,4 D amine alone. Similarly all yields were significantly reduced ($p=0.05$) for rates 0.1 % to 10%. Dicamba at low rates allowed recovery, however at the 10% treatment rate was significant at the 5% level and reduced the yield by 57%. Glyphosate produced in an almost flat response curve. Glyphosate treatment yields did not differ significantly at any herbicide rate. Cotton yield is tolerant to glyphosate at the lower application rates.

Extension activities

Producers require two answers once damage appears in their crop. What has caused it and will the crop recover? Both these answers can be provided based on the experiments conducted. However, a more significant question is can physical drift be prevented?

To answer the latter question, an education process for the whole farming community is required. The cotton industry realizes that prevention of any 'off target 'movement of any product is a major issue. One program that is in place is the Australian Cotton Best Management Practice (BMP) guidelines that originally were developed to minimize the impacts of pesticides in the riverine environment. In conjunction with this set of guidelines, an extension publication was produced called SPRAYpak (2003). This is a book that outlines all the principles behind correct chemical applications and the factors that need to be considered for both aerial and ground rig applications.

At a regional level, it was decided to utilize the information in both these publications to develop an extension program that targeted a multi-cropping community. This program initially consisted of establishing the simulated herbicide drift experiment in 1995-96. This was a direct response to the commercial damage that was occurring in the field. Towards the end of that season, a field day was held. With personal invitations sent to all prominent agronomists and cotton consultants within the Upper Namoi. The purpose of the day was to train this group of key personnel to identify the different visual symptoms and yield impacts associated with 'off target drift' of these products.

In addition to this field day, series of open invitation workshops were held at night, dealing with the issue of improved pesticide application, in particular, minimization of drift and how best to target a pest within the plant structure. The workshop consisted of both aerial and ground applications and utilized a fluorescent dye that glows under a UV light at night to illustrate droplet placement. Both cotton and non-cotton producers attended these workshops.

To complement this initial approach, a series of local media releases were written to supply the wider community with some technical information in a user-friendly form. The articles explained the difference between volatilization and physical drift. As an example of the user-friendly language it was often claimed, "that even a house brick would drift, if the wind was strong enough". This statement highlights the issue that there is more to drift minimization that just increasing droplet size.

In subsequent seasons past, simulation experiments were repeated and more extensive field days and workshops open to the whole community were held. As with the initial experiments, visual identification of damage symptoms by product and the resultant yield/lint quality implications were the focus. At each of these workshops, factors that could minimize drift were discussed. As a result of these simulated drift workshops and fluorescent dye workshops numerous producers reported to the senior author how they had purchased a new set of nozzles for their groundrig after attending the workshops. Portable weather monitoring equipment was purchased to assist in identifying suitable application conditions. This complemented the Australian cotton industry's Best Management Practice program, which is an environmental management system being implemented in cotton nationally and encourages cotton growers to keep detailed spray application records. Finally, a change in products used in sensitive areas was achieved. Weed control officers responsible for travelling stock routes and railway lines within the area started to select dicamba as the preferred herbicide option over fluroxypyr and 2,4-D Amine, which historically were used.

Conclusions

The extension program has contributed to increasing the farming community's knowledge base regarding minimization of pesticide drift, leading to better spray practices in the Upper Namoi Valley. It must be remembered; despite this increased knowledge within the community, non-target crop and pasture drift will still accidentally occur. To minimize this situation, the education process should be on going.

The simulated herbicide drift experiments have confirmed that yield reductions are possible from commonly used herbicides in this region. For some products the reduction occurs even when the active ingredient drifting onto the crop is at a very low rate. As an outcome of the program, advisers and growers used the information generated from these experiments to make objective management decisions regarding the future of affected crops. To aid advisers and growers in determining this management decision, an extension publication demonstrating the various plant symptoms and rate combinations that are likely to be associated with a yield reduction is planned for the near future.

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Table 1. *Experiment details.*

Year(s)	Site location	Variety	Days after sowing when treatments were applied	
1995-96	Narrabri	Sicala V2	125	"Cutout"
1996-97	Gunnedah	Siokra V15	95	Early Flowering
2001-02	Boggabri	NuCOTN 37	85	Early Flowering

Table 2. *Herbicide products and rates assessed.*

Herbicide active ingredient		Trade Name	Field rate/ha	Cotton season that contained this product in the experiment
2,4-D Amine	(800g/kg)	Baton®	1 kg	1995-96, 1996-97 & 2001-02
MCPA amine	(500g/l)		1 l	Only 1996-97
Fluroxypyr	(200g/l)	Starane® 200	750 ml	1995-96, 1996-97 & 2001-02
Triclopyr	(600g/l)	Garlon® 600	100 ml	1995-96, 1996-97
Glyphosate	(450g/l) (Plus non ionic wetter)	Glyphosate 450	1 l	1995-96, 1996-97 & 2001-02
Metsulfuron	(600g/kg)	Ally®	5g	1995-96, 1996-97
Dicamba	(200g/l)	Dicamba 200®	700 ml	Only 2001-02
Dichlorprop	(600g/l) DP 600®		6 l	Only 2001-02
Glyphosate (450) + 2,4 D Amine (800)		Tank mixture	1L + 1 kg	Only 2001-02

Table 3. *Subjective visual scoring code.*

Ranking Score	Apparent damage indicated by the score
0	No visual impact assessable
0.1 to 1.0	Slight trace of herbicide activity.
1.1 to 2.0	Low herbicide effects evident.
2.1 to 3.0	Moderate herbicide effects evident.
3.1 to 4.0	Severe herbicide damage. Occasional plant death4.
1 to 5.0	Extreme herbicide damage. Causing death of all plants

Figure 1. *a) 2,4 D Amine and b) Glyphosate + 2,4 D Amine.*

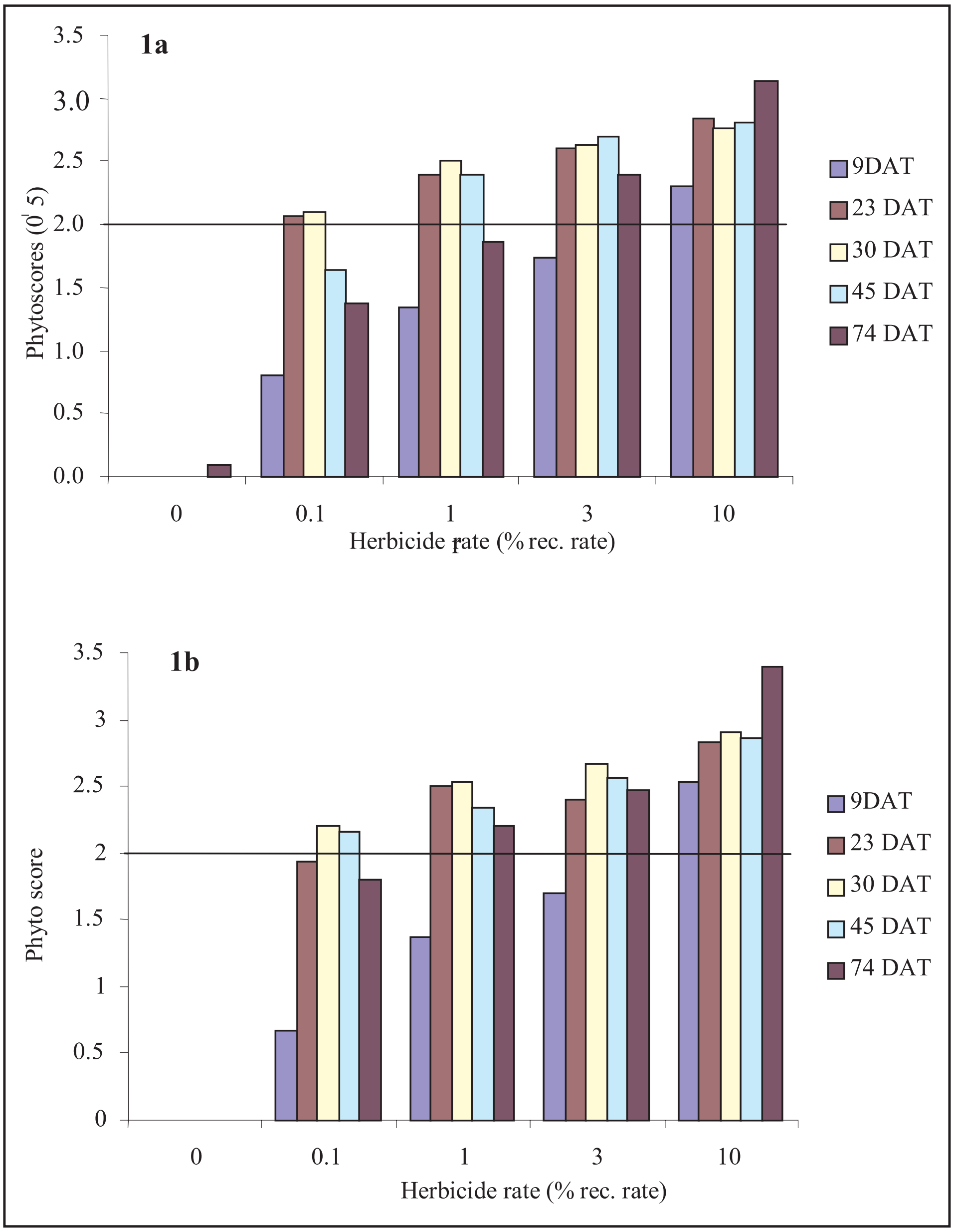

Figure 2.
Fluroxypyr.

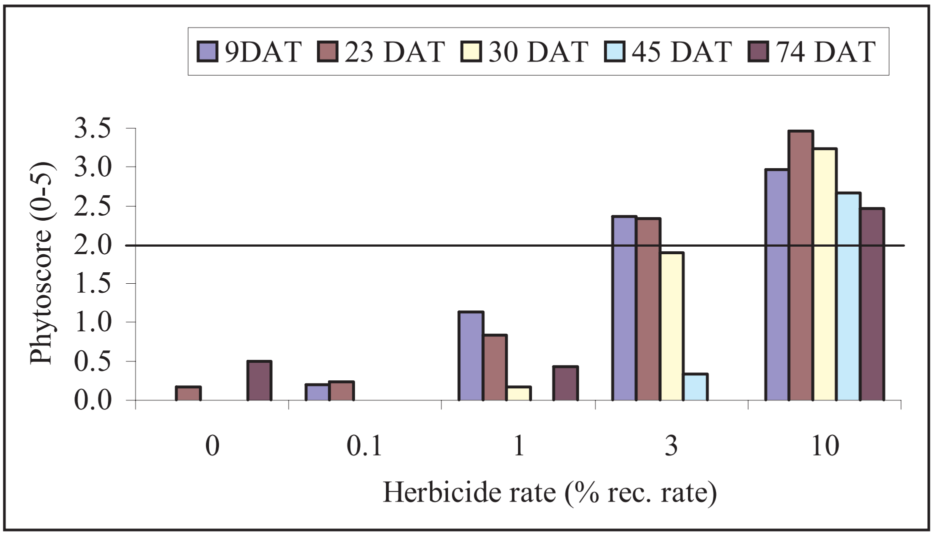

Figure 3.
Dicamba.

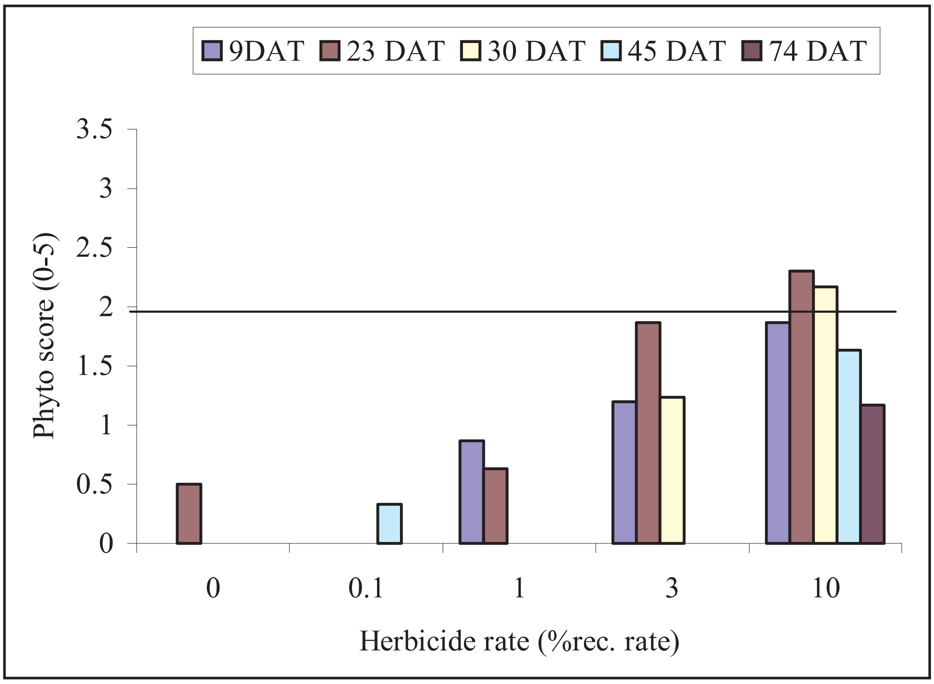

Figure 4.
Dichlorprop.

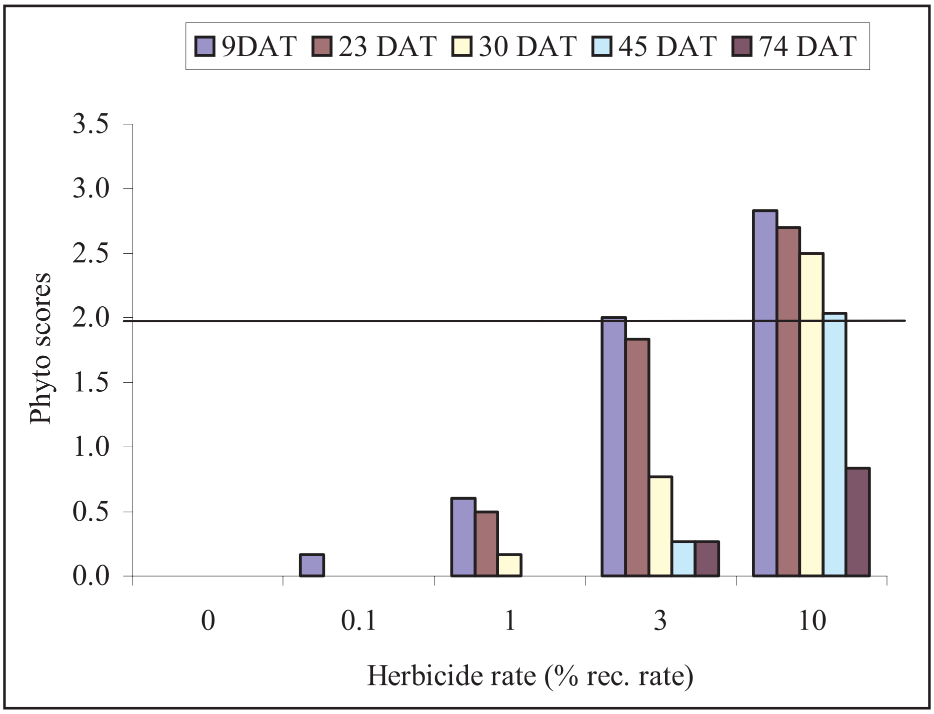

Figure 5. Glyphosate.

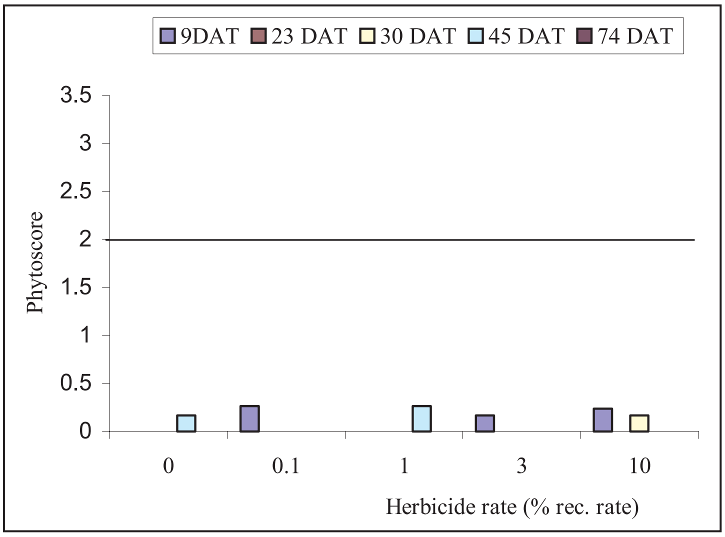

Figure 6. Commercial yield response curves (a & b) incurred from simulated drift (2001-02 season).