

# Grain yield implications of crop-topping pulses for late weed control in south-eastern Australia

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## Abstract

Crop-topping, the late application of a non-selective herbicide to prevent weed seed-set, is widely practiced in southern Australia for integrated weed control management. Pulse crops vary in suitability to this practice, and concerns exist over associated grain yield and quality implications.

Experiments were conducted on three annual winter pulse crops (chickpea, field pea and lentil) in southern Australia from 2008-2011 to identify genotypes and crop maturity timings with improved suitability to crop topping. Genotypes (16-20) varying in maturity ratings were examined under 3 application timings of paraquat (200g a.i./ha) compared to an untreated control. Application timings were based on annual ryegrass maturity; Recommended (ryegrass milky dough stage), and Early or Late, applied 10-14 days either side of Recommended. Grain yield response was measured.

Yield losses of up to 44% occurred at the Recommended crop-top timing, depending on crop, genotype and season. Field pea generally incurred the lowest yield loss and chickpea the highest and most consistent of the three crops. Earlier maturing genotypes were generally less affected than those maturing later.

Findings show crop-topping can reduce yield loss, leading to reductions in profitability in some genotypes in some seasons. Variability in suitability to this practice was observed both between and within pulse crop species and opportunity exists for plant breeders and growers to select genotypes which are better suited to this agronomic practice.

## Key Words

Crop-topping, weed control, pulses, field pea, lentil, chickpea, grain yield

## Introduction

Herbicide resistance is one of the biggest threats facing farmers in Southern Australia (Walsh & Powles, 2007). With the onset of herbicide resistance in various grass and broadleaf weeds, and the evolution of ever-shortening crop rotations across areas of southern Australia, effective weed control is becoming increasingly more important and harder to achieve in the pulse phase of the rotation (Walsh & Powles, 2007).

Crop-topping, the late application of a non-selective herbicide to prevent viable weed seed set, has become an integral tool for managing weeds in pulses (Mayfield & Presser, 1998). It is particularly useful for controlling seed-set of herbicide resistant and late germinating weeds where other in-crop chemical control options may reduce crop yield, for example damaging chemistries or sensitive growth stages eg flowering. Timing of crop-topping is generally aimed at the milky to soft dough stage of the target weed species, when maximum weed seed sterilisation is achieved but with minimal effect on crop yield (Meldrum, 2011). Crop-topping effectiveness varies across pulse species, largely depending on maturity, and it cannot be used in all pulse crops without incurring yield loss (Meldrum, 2011). Later maturing crops such as chickpea are generally considered poorly suited to crop-topping due to unacceptable yield losses, while earlier maturing crops such as field pea are considered well suited (Mayfield & Presser, 1998; Meldrum, 2011). Lentils are generally considered to have poorer adaptation than field pea but better than chickpea. However little is known about the variation in suitability of genotypes within a crop species to this practice.

Trials were conducted across South Australia and Victoria to compare the effect of crop-top timing on yield of a range of genotypes varying in their maturity profiles, with the aim of identifying genotypes within each species that can be crop-topped with minimum yield loss.

## Methods

### *Experimental design*

Field experiments were carried out from 2007 to 2011 comparing 16-20 genotypes representing the range of flowering and maturity timings currently within each species. These were conducted in the mid north (field pea) and Yorke Peninsula (lentil, chickpea) of South Australia and the Wimmera area of Victoria (lentil). Sowing dates were based on district practice for each crop and location. Paraquat was applied at 200ml

a.i./ha, at three timings; milky dough stage of ryegrass (Recommended or “Rec”) and 10-14 days either side of the Rec stage (named Early and Late). Ryegrass timing was based on plants found in the paddock immediately surrounding the trial to reflect local biotype, crop competition and impact of early control methods. Grain yield and quality measurements were compared to an untreated control. Experiments were constructed in a split-plot design, using replicate (3) as the main block and timing as sub-blocks. Sowing date, fertiliser and pesticide applications were targeted at the current recommended best management practice for each crop type (Mayfield et al. 2008).

### Measurements and Analysis

Start and end of flowering dates were recorded for all cultivars. Maturity and greenness scores were allocated at each treatment timing, and plant samples of selected genotypes were taken to determine grain moisture. All experiments were machine harvested and grain yields recorded. Grain weight measurements and germination tests were carried out on all harvested grain samples approximately five months after harvest to coincide with normal grower practice, but are not reported on here. All statistical analyses were conducted using Genstat (10<sup>th</sup> - 12<sup>th</sup> edition).

### Results & Discussion

Timing of crop-topping was significantly correlated with grain yield ( $P < 0.01$ ) in all experiments. All pulse crops examined showed a general decrease in yield as crop-top timing was brought earlier (Tables 1-3). The interaction between genotype and timing was significantly correlated with grain yield ( $P < 0.05$ ) in 15 of the 16 trials conducted.

Crop-topped field pea generally showed highest yield losses in later maturing genotypes (Table 1). Genotype yields ranged from 70 to 130% of their untreated control at the Rec timing. Occurrence of yield losses ranged from 3 to 6 out of 7 trials across all genotypes at the Early timing and 0-3 at the Rec timing. No significant yield losses were generated by Late crop-topping of field peas.

A number of early maturing genotypes showed no yield losses from crop-topping at the Rec timing.

However, the later maturing genotypes Parafield, Alma and Glenroy showed yield losses in 2-3 of 6 trials at the Rec timing. These genotypes also showed the highest average yield loss (Glenroy averaging 58%) from crop-topping at the Early timing.

Alma and Glenroy were the only genotypes to show an average yield less than 90% of the control yield at the Rec timing, and also showed the lowest average yield at the Early timing. Although these genotypes are later in maturity than the mid maturing Parafield, they showed fewer incidences of significant yield loss from crop-topping at the Rec timing (Table 1). This is likely because yield of later maturing species are often penalised in southern Australia by a rapid termination of the season masking the complete effect of crop-topping the plants prior to physiological maturity.

**Table 1. Summary of crop-top timing effect on yield of field pea cultivars from 2008 to 2011. Cultivars are ranked in order of maturity. Most common commercial cultivar in bold.**

Variety	Flower Onset Rating <sup>^</sup>	Maturity Rating <sup>^</sup>	Number Of Trials	Incidence of significant yield losses (# trials)			Average Yield [Range] (% of Control)		
				Early	Rec.	Late	Early	Rec.	Late
PSL4-RESEL	VE	VE	7	3	0	0	74 [54-87]	102 [94-112]	97 [93-113]
SW Celine	E	VE	6	5	0	0	72 [48-82]	103 [86-130]	101 [90-110]
PBA Twilight	E	E	7	5	0	0	73 [43-80]	101 [91-112]	98 [95-107]
PBA Gunyah	E	E	7	5	0	0	67 [39-87]	102 [90-116]	103 [96-120]
PBA Oura	M	E-M	7	5	0	0	72 [42-77]	101 [89-127]	102 [92-121]
<b>Kaspa</b>	<b>L</b>	<b>M</b>	<b>7</b>	<b>6</b>	<b>0</b>	<b>0</b>	<b>59 [31-74]</b>	<b>92 [81-105]</b>	<b>99 [94-107]</b>
Yarrum	L	M	6	3	1	0	65 [32-87]	104 [72-112]	109 [98-129]
Sturt	M	M-L	7	5	0	0	66 [33-77]	99 [86-105]	104 [98-122]
<b>Parafield</b>	<b>M-L</b>	<b>L</b>	<b>6</b>	<b>6</b>	<b>3</b>	<b>0</b>	<b>60 [45-80]</b>	<b>99 [73-119]</b>	<b>105 [94-127]</b>
Alma	L	L	6	6	2	0	56 [40-79]	88 [70-99]	92 [84-111]
Glenroy	L	VL	6	6	2	0	42 [25-65]	86 [74-98]	92 [85-101]

<sup>^</sup> Source: Averaged ratings from all crop topping trials and Pulse Breeding Australia Stage 3 trials in Southern Australia 2008-2011

The earliest maturing genotype PSL-RESEL incurred the lowest amount of yield loss from Early crop-topping (3 out of 7 trials), indicating that it is better suited to this practice than other genotypes. The mid

maturing genotype Yarrum also showed a low incidence of yield loss at the early timing (3 out of 6 trials), but did however show yield loss in one trial at the Rec timing. Yarrum was developed for northern Australian and is noted for a variable maturity response across seasons in southern Australia.

The most widely grown cultivar in Australia, Kaspera, showed low average yield figures compared to the control at the Early and Rec treatment timings. It was the only variety beside Alma and Glenroy to average less than 99% of the control yield at the Rec timing, and less than 60% at the Early timing. Kaspera is not as well suited to crop-topping as other genotypes with similar maturity ratings. Importantly however, recent “Kaspera type” releases PBA Gunyah and PBA Twilight showed improved suitability to crop-topping with no incidence of yield loss at the Rec timing in all experiments (Table 1).

Similarly to field pea, yield losses from crop-topping lentils were greatest in later maturing genotypes (Table 2). Incidence of yield losses was more frequent for lentil than for field pea, particularly at the Early timing, and some later maturing genotypes showed yield loss at the Late timing, which was not evident in field pea. However this may be due to differences in season length and pattern at the different sites where these experiments were held.

The incidence of significant yield losses compared with the untreated control in lentil showed the most differentiation between genotypes at the Rec timing, and ranged from 1 to 4 out of 5 trials. Yield of lentils at this timing ranged from 68% to 112% of the untreated control. PBA Blitz, the earliest flowering genotype in these experiments, incurred the lowest incidence of yield loss at the Rec and Early treatment timings (1 and 4 out of 5 trials, respectively). It was also the only lentil genotype not to show significant yield loss in all experiments at the Early timing, showing better suitability to crop-topping than all other genotypes. The latest maturing lentil CIPAL501 showed the highest incidence of yield loss at the Rec treatment timing (4 out of 5 trials), and the highest yield loss compared to the untreated control across all experiments at both Early and Rec timings (83% and 32%, Table 2).

The mid maturing genotype PBA Jumbo incurred lower levels of yield loss at the Rec timing than other genotypes, even though it has a similar or even later maturity rating than these. The reasons for this improved suitability to crop-topping over other mid maturing cultivars in this trial is unknown but may be linked to its significantly larger grain size allowing for some compensation.

Later maturing genotypes Nipper, Boomer, Nugget and CIPAL501 showed significant yield losses compared to the untreated control at the Late treatment timing in at least one trial (Table 2), suggesting they have increased sensitivity to crop-topping than other genotypes. Nipper and Nugget have been the most widely grown commercial lentil varieties in southern Australia.

**Table 2. Summary of crop-top timing effect on yield of lentil cultivars from 2008 to 2011. Cultivars are ranked in order of maturity. Most common commercial cultivars in bold.**

Variety	Flower Onset Rating <sup>^</sup>	Maturity Rating <sup>^</sup>	Number Of Trials	Incidence of significant yield losses (# trials)			Average Yield [Range] (% of Control)		
				Early	Rec.	Late	Early	Rec.	Late
PBA Blitz	E-M	E	5	4	1	0	56 [25-82]	94 [89-101]	102 [93-115]
PBA Flash	E-M	E-M	5	5	2	0	49 [30-70]	92 [80-112]	100 [88-109]
Aldinga	M	M	3	3	1	0	53 [24-81]	88 [77-101]	102 [91-108]
PBA Bounty	M-L	M	5	5	2	0	49 [33-82]	91 [74-108]	98 [85-105]
PBA Jumbo	M	M	4	4	1	0	52 [33-82]	98 [92-102]	103 [98-110]
<b>Nipper</b>	<b>M-L</b>	<b>M</b>	<b>5</b>	<b>5</b>	<b>2</b>	<b>1</b>	<b>47 [34-65]</b>	<b>89 [80-98]</b>	<b>92 [70-108]</b>
CIPAL607	M-L	M-L	4	4	3	0	43 [27-70]	85 [76-93]	97 [90-102]
Boomer	E-M	M-L	5	4	2	1	57 [29-84]	83 [74-94]	97 [84-113]
<b>Nugget</b>	<b>M</b>	<b>M-L</b>	<b>5</b>	<b>5</b>	<b>2</b>	<b>1</b>	<b>39 [28-63]</b>	<b>84 [75-95]</b>	<b>93 [78-109]</b>
CIPAL501	M	L	5	5	4	2	43 [17-68]	81 [68-98]	95 [78-117]

<sup>^</sup> Source: Averaged ratings from all crop topping trials and Pulse Breeding Australia Stage 3 trials in Southern Australia 2008-2011

As for the other pulse crops, average yield losses of crop-topped chickpea were highest amongst the later maturing genotypes (Table 3). Incidence of significant yield loss was more frequent than for both field pea and lentil. All genotypes showed yield loss compared with the untreated control from the Early crop-topping in all experiments, and some later maturing genotypes also showed significant yield losses at the Rec treatment timing. However only one chickpea genotype showed significant yield loss compared to the untreated control at the Late timing. Chickpeas have the latest maturity timing of these three pulse crops, and their yield potential is often reduced by the generally rapid finish to the season in southern Australia. It is

possible that the pattern of genotype senescence was similar between unsprayed control plots and Late treatment plots due to the premature maturity that often occurs on the relatively shallow soils of many parts of southern Australia.

Grain yield of chickpea ranged from 56 to 114% compared to the untreated control at the Rec timing (Table 3). The earliest maturing chickpea genotype in the trial (01-482\*03HS009) showed the lowest average yield losses at all three treatment timings. The later maturing cultivars generally showed the highest yield losses with the most widely grown cultivar Genesis090 the only genotype to show yield loss in all experiments at both the Early and the Rec timings. Genesis090 also showed the lowest average yield (percentage of control) at the Rec and Late treatment timings, suggesting it has poor suitability to this practice.

**Table 3. Summary of crop-top timing effect on yield of chickpea cultivars from 2008 to 2011. Cultivars are ranked in order of maturity. Most common commercial cultivar in bold.**

Variety	Flower Onset Rating <sup>^</sup>	Maturity Rating <sup>^</sup>	Number Of Trials	Incidence of significant yield losses (# trials)			Average Yield [Range] (% of Control)		
				Early	Rec.	Late	Early	Rec.	Late
01-482*03HS009	VE	E	4	4	2	0	58 [41-85]	90 [83-96]	104 [97-110]
CICA0603	E	E	4	4	2	0	49 [31-68]	81 [74-93]	94 [90-100]
Genesis079	E	E	4	4	3	0	48 [25-81]	82 [71-96]	102 [94-109]
Genesis509	E-M	E-M	4	4	2	0	47 [32-73]	82 [71-98]	96 [91-100]
CICA0717	M	M	4	4	3	0	54 [36-79]	84 [78-93]	98 [87-105]
PBA Hatrick	M	M	4	4	2	1	44 [23-67]	83 [56-114]	99 [73-137]
PBA Slasher	M	M	4	4	3	0	45 [30-64]	78 [65-91]	102 [94-118]
<b>Genesis090</b>	<b>M</b>	<b>M</b>	<b>4</b>	<b>4</b>	<b>4</b>	<b>0</b>	<b>40 [25-61]</b>	<b>77 [64-84]</b>	<b>96 [90-100]</b>
Genesis114	M-L	M-L	4	4	3	0	38 [17-57]	81 [65-94]	102 [97-114]

<sup>^</sup> Source: Averaged ratings from all crop topping trials and Pulse Breeding Australia Stage 3 trials in Southern Australia 2008-2011

## Conclusion

Previous studies have found differential responses to crop-topping between pulse crop types, with field pea generally the best suited, followed by lentil, and high yield losses reported in chickpea (Mayfield & Presser, 1998; Meldrum, 2011). These studies supported these findings. However, these studies also showed variation between genotypes in response to crop-top application timing. Earlier maturing genotypes generally showed less yield loss than later maturing types.

A number of commonly grown cultivars for each crop were not as well suited to crop-topping and incurred yield loss, particularly at earlier timings, which may result in reduced profitability. A number of field pea and lentil genotypes with better suitability to crop topping are now available (eg field peas PBA Gunyah and PBA Twilight, and lentils PBA Blitz and PBA Jumbo). There are currently no chickpea genotypes suited to crop-topping, however genotypic variation to this practice was identified and further breeding may result in improved adaptation in this crop.

Variation between genotypes in all three pulse crops indicates that opportunity exists for growers and plant breeders to select cultivars with better suitability to this practice. However, consideration should also be given to the effect of crop-topping on seed quality, particularly for retained seed or seed sold into sprouting markets, or in production of kabuli chickpea, where premiums are paid on seed size. Further work is required to understand why some genotypes have improved suitability to crop-topping over others genotypes despite a similar or even later maturity rating.

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