Control of Bathurst burr (*Xanthium spinosum*) in irrigated soybeans in southern New South Wales

J.A. Andrews, Department of Agriculture, Yanco, NSW 2703, Australia.

Summary

Field studies were conducted to determine the relative efficacy of imazaquin and bentazon applied post emergence on Bathurst burr (*Xanthium spinosum* L.) in irrigated soybeans (*Glycine max* (L.) Merr.) in southern New South Wales. Bathurst burr biomass was significantly reduced by imazaquin at 400 g a.i. ha^{-1} at all sites, at 300 g a.i. ha^{-1} and 200 g a.i. ha^{-1} at three sites and by bentazon at 960 g a.i. ha^{-1} at three of the four sites. Imazaquin gave significantly more control of Bathurst burr than bentazon in the 1987/88 season when there were many late season burr germinations compared to 1988/89 when fewer late season germinations occurred. Imazaquin did not control Bathurst burr when applied after the formation of the three pronged spines. The greater season-long control provided by imazaquin make it the preferred herbicide.

Introduction

Bathurst burr is the third most troublesome weed of soybeans in southern New South Wales. It is common on all soil types throughout the Riverine Plain being especially plentiful on old cultivated paddocks and irrigated pastures (Leigh and Mulham 1965). Seed in the soil is long lived, farmers frequently report viability of up to 20 years where the soil has not been disturbed. Martin and Carnahan (1983) report that although seeds of Bathurst burr germinate rapidly, a large proportion of seeds remain dormant: of the two seeds contained in each burr, usually only one germinates, the other seed remaining dormant. Cunningham *et al.* (1981) report that prolific stands may occur after summer rains or flooding. They found that seed is able to survive under waterlogged conditions. Merrin (personal communication) reports that after desilting a dam into which mature Bathurst burr plants had been thrown nine years previously, burr seed germinated in the silt removed from the dam. Martin and Carnahan (1983) found that in over 15 months field storage, few seeds had germinated or decayed. They report that *X. spinosum* is associated with disturbed soils of heavy texture and high fertility. Cunningham *et al.* (1981) state that soil disturbance brings buried seed to the surface. Andrews (unpublished data) recorded burr populations of 120 plants m^{-2} in recently cultivated ground. Germination is seldom synchronous, plants continuing to emerge over the summer period. Flowering and seeding continue from mid summer until the plants die in autumn or winter. Late season burr germinations are able to survive under the soybean canopy. Rapid growth of these plants from the beginning of soybean senescence can result in large burr numbers being present at harvest. Milvain (1983) reports that plants emerging later in the summer will produce seed when only a few weeks old. Considerable contamination of harvested grain can result from these late season burr germinations.

Besides depressing yield, contamination of the grain with more than one burr per litre results in dockage. Grain may be rejected when contaminated with more than 1% of burr seed (Australian Oilseed Federation 1989). Burrs are similar in size to soybean seed therefore grading is difficult and has to be done over a gravity table which can cost up to \$60 t^{-1}.

Contamination also precludes sales to the premium human consumption market. In addition contaminated seed may not be suitable for feed grain. McBarron (1977) cites reports of loss of egg production and early moult in poultry where feed was contaminated with Bathurst burr. Thus grain from badly contaminated crops could be unmarketable.

Bentazon is registered for use in soybeans for the control of Bathurst burr at 960 g a.i. ha^{-1}, however due to its contact mode of action it is unable to give adequate season-long control especially where there are many late season germinations. Variations in the degree of control with bentazon had been experienced by users. Hogue *et al.* (1986) reports inconsistent control of *Xanthium* sp. at the five to eight leaf growth stage. Preliminary research showed that the time of application was critical, viz. at or before the four leaf burr growth stage for maximum control i.e. before the formation of the three pronged spines (Andrews 1988). The efficacy of bentazon was enhanced by the addition of a crop oil that contained a surfactant (Spencer personal communication).

Imazaquin is reported to control cocklebur (*X. italicum, X. pensylvanicum*) in the USA. Paxman *et al.* (1985) report that imazaquin, a broad spectrum herbicide with residual activity belonging to the imidazolinone family, inhibits the acetohydroxyacid synthase which is necessary for the biosynthesis of the amino acids, valine, leucine and isoleucine. Imazaquin is absorbed through both the foliage and roots and translocated through the xylem and phloem to the meristematic regions. With foliar application, susceptible plants stop growing soon after treatment and die within two to four weeks depending on species and size. With soil application some susceptible plants may emerge and persist as stunted plants before they die.

The objective of this study was to determine whether the systemic mode of action and residual activity of imazaquin would control more late germinating Bathurst burr plants than bentazon and provide greater season-long control.

Materials and methods

Trials were conducted in southern New South Wales at Leeton Field Station in 1987/88 and 1988/89, and with farmer co-operators at Coleambally in 1987/88 and Tabbita in 1988/89. Leeton trials were conducted on a Birganbigil clay loam (van Dijk 1961) at pH 6. Plots consisted of four hills 75 cm apart. Soybeans cv Chaffey were sown by precision planter at the rate of 80 kg ha^{-1} on 19.11.87 and 2.12.88. Plots were furrow irrigated to 65 mm allowable depletion and end trimmed to between nine and ten metres at soybean maturity. Grass weeds were controlled by trifluralin at 804 g a.i. ha^{-1}. Each year Bathurst burr seed was broadcast by hand and incorporated by machine to five centimetres depth with the trifluralin.

The Coleambally trial was conducted in a Wunnamurra clay (Stannard 1970) at pH 6.7. Plots consisted of two 150 cm beds sown with cv Bowyer, two rows on each bed, by precision planter at the rate of 80 kg ha^{-1} on 3.12.87. Plots were furrow irrigated to 50 mm allowable depletion and end trimmed to between nine and ten metres at soybean maturity. Grass weeds were controlled by trifluralin at 804 g a.i. ha^{-1} Bathurst burr seed was hand broadcast and incorporated by rake to supplement the naturally occurring population.

The Tabbita trial was conducted in a Riverine clay pH 8. Plots were sown with cv Chaffey by combine, with 18 cm row spacing, at the rate of 80 kg ha^{-1} on 25.11.88. Plots three meters wide were irrigated by border check to a 65 mm allowable depletion and end trimmed to between nine and ten metres at soybean maturity. Grass weeds were controlled by aerial application of sethoxydim at 186.8 g a.i. ha^{-1} to which 1% Ampol D-C-Trate was added.

The experimental design used for all trials was a Latin square with six replications. Imazaquin was applied as the sodium salt at 200 g a.i. ha^{-1}, 300 g a.i. ha^{-1} and 400 g a.i. ha^{-1} on 17.12.87 and 22.12.88

at Leeton, 21.12.87 at Coleambally and 14.12.88 at Tabbita. Bentazon as the sodium salt was applied at 960 g a.i. ha^{-1} mixed with the adjuvant Ampol D-C-Trate at 1526 g a.i. ha^{-1}. Applications were made at the same time as imazaquin. Also included were two additional treatments which did not receive herbicide. Bathurst burr was allowed to grow in one of the treatments while the other was handweeded until soybean canopy closure. All weeds other than Bathurst burr were handweeded from all plots until canopy closure. Final handweedings were 18.1.88 and 26.1.89 at Leeton, 12.1.88 at Coleambally and 13.1.89 at Tabbita. All herbicides were applied with an LP gas sprayer from a boom using 8001 and 8002 Teejet® nozzles, the equipment being mounted on a handcart. The volumes of aqueous carrier used were 110 L ha^{-1} for imazaquin and 220 L ha^{-1} for bentazon mixture. All treatments were applied post emergence when plants were actively growing. Applications were made when burr plants had reached the four leaf growth stage, before the formation of the three pronged spines. At the Tabbita site some plants had formed spines. This coincided with the third trifoliate leaf stage of the soybeans.

A visual assessment was made of crop injury and recorded on a five point scale: 0 = no injury, 5 = death. Soybean plant height was recorded in 1987/88. As no height differences were observed, no measurements were made in 1988/89. Permanent 1 m^2 quadrats were marked out in each plot except the handweeded control plots in 1987/88. Plant counts of Bathurst burr were taken before treatment, 7 days and 14 days post treatment and at soybean harvest maturity. Soybean harvest maturity was 12.4.88 at both Leeton and Coleambally, 8.5.89 at Tabbita and 17.5.89 at Leeton.

Bathurst burr biomass was determined by hand harvesting the above ground portions of all Bathurst burr plants over the whole plot in all trials, except Leeton in 1988/89 when the two centre rows only were cut, immediately before soybean harvest. This method gave a more accurate assessment of the season-long efficacy of imazaquin than plant numbers as imazaquin often fails to completely kill Bathurst burr plants. Harvest commenced on 12.4.88 and 17.5.89 at Leeton, 19.4.88 at Coleambally and 8.5.89 at Tabbita.

Soybean yields were determined by harvesting each plot with a small plot harvester, except Coleambally where the early onset of winter rains prevented crop harvest. Soybean yields were adjusted to 12% moisture.

Preliminary examination of Bathurst burr data showed that the variance of high yielding plots was greater than the variance of low yielding plots. To ensure valid tests of significance, data were converted by calculating log(yield+1). Analysis of variance was calculated for the transformed data and treatments compared using a LSD test at the 5% significance level.

Results

Bathurst burr control

Biomass was significantly reduced at all sites and by all herbicide rates except imazaquin at 200 g a.i. ha^{-1} and 300 g a.i. ha^{-1} at Tabbita and bentazon at Coleambally (Table 3).

In 1987/88 imazaquin reduced Bathurst burr biomass by >85% at all rates on both sites. Imazaquin at 300 g a.i. ha^{-1} and 400 g a.i. ha^{-1} at Leeton and 200 g a.i. ha^{-1} and 400 g a.i. ha^{-1} at Coleambally gave significantly better control than bentazon. Imazaquin at 300 g a.i. ha^{-1} and 400 g a.i. ha^{-1} at Leeton gave significantly greater control than the handweeded control (Table 4).

In 1988/89 imazaquin controlled Bathurst burr at all rates at the Leeton site but only the 400 g a.i. ha^{-1} rate gave control at the Tabbita site. Temperature and relative humidity differed between the sites at the time of herbicide application being 31°C, 70.6% RH at Tabbita and 20°C, 37% RH at Leeton. Bentazon controlled Bathurst burr at both sites (Table 4).

Initial control of Bathurst burr by bentazon was good on all sites for both seasons. Reduced efficacy of bentazon on Bathurst burr in 1987/88 compared to the 1988/89 season was due to the greater burr seed germinations later in the season (Table 3).

Soybean yield

No herbicide treatments in any year resulted in significant soybean yield loss. Yield loss occurred at Leeton in 1987/88 in the weedy plot (Table 1). Burr numbers were greater in this trial. Coleambally, Tabbita and Leeton 1988/89 being 55.9%, 28.6% and 21.8% respectively of the Leeton 1987/88 burr numbers (Table 2).

Soybean injury

Crop injury occurred although none of the treatments applied in any year caused either soybean stand or height reduction. All cultivars in all trials showed both chlorosis and necrosis with

Table 1. Yield of Soybeans treated with imazaquin or bentazon.

Treatment	Rate ha^{-1} a.i.	Leeton 1987/88 kg ha^{-1}	Leeton 1988/89 kg ha^{-1}	Tabbita 1988/89 kg ha^{-1}
Control weedy		1520	2121	2603
Imazaquin	200	2353	2121	2952
Imazaquin	300	2517	2043	2896
Imazaquin	400	2421	2165	2923
Bentazon + D–C–Trate	960 + 1560	2353	2195	3434
Control (handweeded)		2410	2199	3187
LSD (0.05)		290	251.8	807

Table 2. Average Bathurst burr plant counts from 1 m^2 permanent quadrants.

Treatment	Rate ha^{-1} a.i.	Leeton 1987/88				Coleambally 1987/88				Leeton 1988/89				Tabbita 1988/89			
		a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Control weedy		20.0	29.7	22.3	22.0	16.8	17.0	15.2	12.3	12.0	11.3	10.8	4.8	10.5	11.0	10.0	8.5
Imazaquin	200	29.8	20.2	6.0	6.0	22.7	19.2	15.2	12.3	12.0	8.6	4.8	1.0	6.4	6.0	5.7	3.8
Imazaquin	300	31.5	17.2	0.7	0.7	12.5	11.2	8.0	1.0	9.4	6.5	3.2	0.5	8.7	7.5	5.7	1.8
Imazaquin	400	29.0	14.2	0.3	0.4	13.8	11.2	7.7	1.5	10.0	8.0	4.3	0.4	13.2	11.7	7.5	0.3
Bentazon +D-C-Trate	960+1526	29.0	12.0	5.0	12.0	15.2	10.3	7.4	0.5	9.8	2.8	3.0	0.7	13.4	3.0	2.0	1.5
Control (handweeded)*	–	–	–	–	–	–	–	–	–	9.0	0.0	0.5	0.0	12.2	2.0	3.5	1.0

* handweeded to canopy closure
a – at herbicide application
b – 7 days post herbicide application
c – 14 days post herbicide application
d – at soybean maturity

Table 3. Total biomass production of Bathurst burr when imazaquin and bentazon were applied at various rates.

Treatment	Rate ha^{-1} a.i.	Average Dry Matter Production (g) Leeton 1987/88	Leeton 1988/89	Coleambally 1987/88	Tabbita 1988/89
Control Weedy		10956	4553	12280	3797
Scepter	200	1204	318	804	1572
Scepter	300	65	184	1056	1256
Scepter	400	17	151	823	581
Basagran + D-C-Trate	960+1526	1927	112	4323	333
Control (handweeded)*		196	3	111	54

Table 4. Control of Bathurst burr in irrigated soybeans with imazaquin and bentazon.

Treatment	Rate ha^{-1} a.i.	DMW Bathurst burr (log kg ha^{-1}) Leeton 1987/88	Leeton 1988/89	Coleambally 1987/88	Tabbita 1988/89
Control Weedy		7.88	7.95	7.89	7.32
Scepter	200	5.29	3.82	4.34	6.25
Scepter	300	1.93	3.31	5.30	6.05
Scepter	400	1.35	4.37	4.32	5.52
Basagran+D-C-Trate	960+1560	6.16	2.67	6.57	4.30
Control (handweeded)*		3.82	0.72	3.10	2.81
LSD (0.05)		1.34	2.15	1.51	1.34

bentazon treatments, scoring three on the visual scale. Recovery was rapid, plants outgrowing injury within fourteen days. Imazaquin treatments resulted in a mild chlorosis, visual score of one, which plants outgrew in seven days.

Discussion

Imazaquin was more efficacious than bentazon where there were many late season Bathurst burr germinations. This was most apparent at the Leeton site in 1987/88 where imazaquin at 300 g a.i. ha^{-1} and 400 g a.i. ha^{-1} gave significantly greater control of Bathurst burr than the handweeded control (Table 4). The greater season-long control of Bathurst burr by imazaquin is probably due to the reported residual activity of this herbicide. Bentazon, having a contact mode of action, is not able to control these later germinating plants.

Imazaquin gave significantly greater season-long control of Bathurst burr in the 1987/88 season than in the 1988/89 season. Several factors could have influenced this result. Application of herbicide after the most highly sensitive growth stage of Bathurst burr, particularly at the Tabbita site, probably contributed most to the reduced control. Bathurst burr growth in 1988/89 was unusually rapid, the three pronged spines being formed at the two leaf growth stage rather than the more usual four leaf growth stage. Various authors, Andrews (1988), Martin and Witt (1983), Price and Lang (1982), Trammell *et al.* (1986), Hogue *et al.* (1986), report that better control is obtained in *Xanthium* sp. at early growth stages. Barrentine (1989) and Barrentine and McWhorter (1989) found that higher rates of imazaquin were required to control *X. strumarium* at later growth stages.

McWhorter *et al.* (1990) report that it is generally agreed that the epicuticular waxes of plants constitute a major barrier to the absorption and subsequent translocation of foliar applied pesticides. The increased efficacy of bentazon on Bathurst burr with the addition of Agridex® (Andrews 1988) suggests that the waxy cuticle of Bathurst burr is a major barrier to the uptake of foliar applied herbicides.

The composition of the epicuticular wax on the burr plants at the formation of the spines may differ from the younger plants as cuticular wax is known to change quantitatively and qualitatively with age making plants harder to kill. Baker *et al.* (1983) found that in aqueous formulations the droplets dried quickly after impaction after which there was no further spread. In contrast oil formulations spread to various degrees after impaction. Temperatures and humidity at the time of application in 1988 differed between the Tabbita and Leeton site. It is possible that imazaquin droplets dried much faster than bentazon droplets and were thus not so readily available for uptake by the leaves. McWhorter and Barrentine (1988) found that reduced rates of diphenylether herbicides were able to control Johnsongrass when using paraffinic oil as the carrier. They suggest the paraffinic oil dissolved the leaf surface wax and that this might be a mode of entry of the herbicide. Ampol state that the adjuvant D-C-Trate gives greater coverage and contact with the leaf surface compared to a water based formulation. It also partially dissolves the waxy cuticle resulting in an increased uptake of herbicide. The action of D-C-Trate on the epicuticular wax may account for some of the differences in efficacy between bentazon and imazaquin at the Tabbita site viz. the adjuvant allowed a greater uptake of bentazon.

As the soybeans had not produced a complete ground cover when the imazaquin was applied, herbicide falling on bare ground could act as a pre-emergent application. Renner *et al.* (1988) reports that imazaquin should be available for plant uptake within the range pH 5.5 to pH 8. Soils on all sites were within this range so soil pH should not have been responsible for reduced availability of imazaquin in the soil. However watering regimes differed between sites. Leeton and Coleambally sites were furrow irrigated. Soil was moist in the root zone at all times, the soil surface seldom being at field capacity. The Tabbita site, in contrast, was irrigated by border check, where the ground dried down to a 65 mm allowable depletion before it was flood irrigated. Consequently this soil was subjected to alternating periods of field capacity and temporary drying. Goetz *et al.* (1986) report that temporary drying and returning to field capacity generally increases imazaquin adsorption. Thus that portion of the imazaquin that was retained in the soil under flood irrigation may have been less available to the plants than in the furrow irrigated trials.

Andrews (1990) found that burr populations exceeding sixteen plants in a 10 metre row significantly reduced soybean yield. This study found that burr populations of 22.3 plants m^{-2} can significantly reduce yield. The burr population was not uniform at the Coleambally site. An isolated area affecting one of the imazaquin 300 g a.i. ha^{-1} treatments had many burr germinations after the herbicide application. This may have contributed to the lack of a rate response at this site.

Whilst initial control of Bathurst burr was good with bentazon, later burr germinations were not controlled. Therefore to provide season-long control several applications of bentazon would be required thus reducing the profitability of the crop. The increase in season-long control provided by imazaquin at 300 g a.i. ha^{-1}, where there are many late season germinations, make it the preferred herbicide. Imazaquin needs to be applied before the formation of the three pronged spines for effective Bathurst burr control. The addition of a crop oil containing a surfactant, such as D-C-Trate, would probably improve the efficacy of imazaquin for Bathurst burr control.

Acknowledgments

The author thanks Mr. W. Lill for statistical advice and the analysis of results. Mr. J. Laurie and Bunker Pastoral Company for providing trial sites. Mr. J. Whitely and Mr. P. Caffery for assistance with the trial and Mrs. D. Thornton for assistance with the manuscript. Schering, BASF and Ampol for supplying the herbicides. This project was supported by the Oilseeds Research Council and NSW Agriculture.

References

Andrews, J.A. (1988). Time of application of Basagran for control of Bathurst burr. *Australasian Field Crops Newsletter* 23, 207.

Andrews, J.A. (1990). Competition between soybeans and Bathurst burr. *Australian Weeds Research Newsletter* 39, 23-4.

Australian Oilseeds Federation (1989). Oilseeds 1989; Technical and trading standards. Australian Oilseeds Federation. pp. 2.

Baker, E.A., Hunt, G.M. and Stevens, P.J.G. (1983). Studies of plant cuticle and spray droplet interactions: a fresh approach. *Pesticide Science* 14, 645-8.

Barrentine, W.L. (1989). Minimum effective rate of chlorimuron and imazaquin applied to common cocklebur (*Xanthium strumarium*). *Weed Technology* 3, 126-30.

Barrentine, W.I. and McWhorter, C.G. (1989). Chlorimuron and imazaquin rates for post-emergence control of common cocklebur in soybeans. Research Report Mississippi Agricultural Forestry Experiment Station 1989 14, 93 p.

Cunningham, G.M., Mulham, W.E., Milthorpe, P.L. and J.H. Leigh (1981). 'Plants of Western NSW'. pp. 727-8. (Soil Conservation Service, Sydney.)

Goetz, A.J., Wehtje, G., Walker, R.H. and Hajek, B. (1986). Soil solution and mobility characterization of imazaquin. *Weed Science* 34, 788-93.

Hogue, C.W., Barr, G.G. and Lee, S.D. (1986). Bromoxynil (Buctril) plus atrazine combinations for control of broadleaf weeds in grain sorghum. Proceedings Southern Weed Science Society 39th Annual Meeting 1986, Raleigh, North Carolina. pp. 43.

Leigh, J.H. and Mulham, W.E. (1965). 'Pastoral plants of the Riverine Plain'. pp. 143. (Jacaranda Press, Brisbane).

Martin, J.R. and Witt, W.W. (1983). Postemergence tank mixtures for broadleafed weeds in soybeans. Proceedings Southern Weed Science Society 36th Annual Meeting 1983, Raleigh, North Carolina. pp. 74.

Martin, R.T. and Carnahan, J.A. (1983). The effect of field storage and laboratory conditions on germination of five *Xanthium* species. *Australian Journal of Agricultural Research* 34, 249-60.

McBarron, E.J. (1977). Medical and veterinary aspects of plant poisons in New South Wales. pp. 181. (Department of Agriculture, New South Wales, Sydney).

McWhorter, C.G. and Barrentine, W.L. (1988). Spread of paraffinic oil on leaf surfaces of johnsongrass (*Sorghum halpense*). *Weed Science* 36, 111-17.

McWhorter, C.G., Paul, R.N. and Barrentine, W.L. (1990). Morphology, development and recrystallization of epicuticular waxes of johnsongrass (*Sorghum halpense*). *Weed Science* 38, 22-33.

Milvain, H. (1983). 'Bathurst burr'. Agfact p. 7.6.14. (New South Wales Agriculture, Orange).

Paxman, R., Annand, A.M., Lee, S.C., Orwick P.L. and Peoples, T.R. (1985). The imidazolinone herbicides. Proceedings of the 38th New Zealand Weed and Pest Control Conference, 13 - 15th August 1985. pp. 73-7.

Price, J.H. and Lange, R.T. (1982). Comparison of postemergence application techniques for acifluorfen-sodium in soybeans. Proceedings North Central Weed Control Conference 1982, Indianapolis. pp. 11.

Renner, K.A., Meggitt, W.F. and Penner, D. (1988). Effect of soil pH on imazaquin and imazethapyr adsorption to soil and phytotoxicity to corn (*Zea mays*). *Weed Science* 36, 78-83.

Stannard, M.E. (1970). Morphological description of soils occurring in Coleambally Irrigation Area, Sydney: Water Conservation and Irrigation Commission. pp. 42.

Trammell, C.A., Bates, M.R., Nichols, R.L., Shepard, H.E. and Taylor, F.R. (1986). Lactofen efficiency related to weed size at the time of application. Proceedings Southern Weed Science Society 39th Annual Meeting 1986, Raleigh, North Carolina. pp. 97.

van Dijk, D.C. (1961). Soils of the southern portion of the Murrumbidgee Irrigation Area. CSIRO Soils and Land Use Series. No. 40.