Anais da Academia Brasileira de Ciências (2009) 81(4): 873-879
(Annals of the Brazilian Academy of Sciences)
ISSN 0001-3765
www.scielo.br/aabc

Germination behaviour of seeds from herbicide treated plants of *Chenopodium album* L.

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Manuscript received on July 26, 2007; accepted for publication on August 2, 2009;
presented by ELIBIO L. RECH

ABSTRACT

The carry-over effect of sub-lethal herbicides was investigated on the germination of seeds collected from surviving *Chenopodium album* plants, which had received 1/8, 1/8 twice, 1/8 three times, 1/4, 1/2, 1/1 doses of either pre-emergence ioxynil or post-emergence bentazone in a previous onion (*Allium cepa*) crop. Seeds were also collected from surviving *C. album* plants, which had received 1/4, 1/2, 1/1 of either pre-emergence pendimethalin, propachlor and linuron, or 1/8, 1/8 twice, 1/8 three times, 1/4, 1/2, 1/1 of post-emergence ioxynil or linuron in a previous leek (*Allium porrum*) crop. Seeds of surviving plants were collected and tested for germination at temperature of 5, 10, 15, 20 and 25°C. The effect of different temperatures on the total number of germinated seeds was significant. Germination was minimum at low temperatures (5°C or 10°C). Herbicides did not show any effect on germination of *C. album* and resulted in the same final germination percentage as seeds collected from the unsprayed control plots.

Key words: herbicides, sub-lethal doses, onion, leek, germination.

INTRODUCTION

Chenopodium album is an annual Chenopodiaceae and a common weed in plant communities (Bassett and Crompton 1978) and soil seedbanks (Forcella et al. 1992) of many cropping systems. Peak germination (Baskin and Baskin 1977) of *C. album* usually occurs in early to mid-spring. It can tolerate a temperature ranging from 5–30°C and is better adapted to temperate zones and in tropics (Holm et al. 1977). This species has become serious in spring vegetables production areas of U.K., especially in onion and leek crops. The success of *C. album* as a competitive weed species is attributed to many factors, including seed germination in a wide range of environmental conditions (Henson 1970) and early emergence during the crop growing season (Ogg and Dawson 1984).

There are advices for using pendimethalin, ioxynil, propachlor and bentazone in *C. album* control in vegetables. Farmers are using application rates lower than the originally recommended ones, which may have effects on the subsequent germination of *C. album* seeds derived from herbicide treated weeds. It may be reflected in the success of future weed germination and changes the rate of input to the persistent seedbank. In such a situation more information is needed on the relationship between *C. album* germination and sub-lethal herbicide applications to the previous generation. This is because variation in seed traits may be determined not only by the genotype and environment of that individual, but also by maternal effects. This will result in maternal carry-over effects if seeds are used next time (Baskin and Baskin 1973). Although much has been published on germination of *C. album* at various temperatures, very little has been written about the germination of seed progeny collected from herbicide treated weeds.

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Fawcett and Slife (1978) found that viability of *C. album*, *Amaranthus retoflexus* L., *Datura stramonium* L. and *Setaria feberi* Herrum seeds produced by 2, 4–D and dalapon treated plants was not greatly different from control seeds. Reduced germination or viability due to herbicide application has also been reported by Singhal and Sen (1981), Doliner and Stewart (1992), Young et al. (1984), Kasera and Sen (1986), Catizone and Viggaiani (1990) and Don et al. (1990). In contrast, Hume and Shirriff (1989) reported an increase in germination in seeds from herbicide-treated plants.

Kintner and Aldrich (1984) applied sublevel rates of chlorsulfuron to *Abutilon theopbrati* Meidc. at flower bud formation and found that seed germination was reduced. However, chlorsulfuron applied post.em. at 140 g ha^{-1} to *Secale cereale* L. did not affect seed viability or germination (Zollinger and Evans 1985). Henzell et al. (1985) reported that soil – applied atrazine at sub-lethal rates reduced the germination of *Arabidopsis thathiana* (L.) Heynh (mouseear cress). Conversely, chlorsulfuron did not affect the mouseear cress seed.

Glyphosate and chlorsulfuron reduced seed germination of *A. theopbrasti* when applied at different stages of weed growth (Biniak and Aldrich 1986). Frank and Ralph (1987) reported a reduction of 64% in germination of *Salsola iberica* seed from plants treated with chlorsulfuron at 17.05 and 26 g ha^{-1} and paraquat at 560 g ha^{-1}. Isaacs et al. (1989) stated that the use of chlorimuron and imazaquim at 0.28 kg ha^{-1} in *Cassia obtusifolia* at early bloom and early fruit stages produced seeds incapable of emergence. Reduction in the germination of *Galium spurium* L. and *Thlaspi arvense* L. by subnormal doses of tribenuron-methyl (1/8, 1/4 and 1/2 of normal field dose) was reported by Andersson (1994). Germination was also reduced in *Fallopia convolvulus* by Methyl Chloro phenoxy Acetic acid (MCPA). Zhang and Cavers (1994) reported a significant reduction in the viability of seeds after maternal bentazone application to *Xanthium strumarium* L.

Shuma et al. (1995) reported that glyphosate at 0.44, 0.88 and 1.76 kg ai ha^{-1} applied 5 and 10 days after anthesis (DAA) significantly suppressed germination of *Avena fatua* seed with 1.76 kg ai ha^{-1} being the most effective rate. When applied to plants 15 DAA, only the highest rate significantly affected the overall germination. Andersson (1996) in a pot trial with plants of three broad-leaved species at five growth stages and two herbicides at four dosages, found varying effects on seed germination. Hald (1999) noted that *T. arvense* L. and *Sinapis arvensis* L. seeds from unsprayed controls had a high germination rate, but the proportion of seeds germinating was highest at low dosage (1/16) of isoproturon.

The aim of the present study was to investigate the germination behaviour of seeds of herbicide treated *C. album* under different temperatures and, importantly, to examine whether there are any correlations with the different herbicides and their rates in the previous generation.

MATERIALS AND METHODS

Plant Material

Seeds of *C. album* for this experiment were collected from plants that had survived after spraying onion (*Allium cepa*) and leek (*Allium porrum*) crops infested with a natural weed flora at Horticulture Research International, Wellesbourne, UK in 2002.

Chenopodium album seed was cleaned to remove the husk and other debris and was stored dry in tightly closed plastic bags at 4°C until the start of germination tests. The onion crop had been sprayed with pre-emergence bentazone and post- emergence ioxynil (see Table I for details of rates and application dates). Full rate for bentazon and ioxynil was 3 L ha^{-1} and 2.8 L ha^{-1}, respectively.

The leek crop had been sprayed with pre-em pendimethalin pre-em ioxynil and pre-em. propachlor pre-emergence linuron, post-emergence linuron (see Table II for detailed information on rates and application dates). The full recommended rates for pendimethalin, ioxynil, propachlor linuron (pre and post) were 3.3 L ha^{-1}, 2.8 L ha^{-1}, 9.0 L ha^{-1}, 1.7 L ha^{-1}, respectively.

Seed Germination

Chenopodium album seed collected at harvest from both the onion and leek crops were sown at Coventry University Plant Science Department in February 2003. Fifty seeds of *C. album* from each treatment were randomly placed in 9 cm dia Petri dishes, lined with two Whatman discs with filter paper No. 1 at the bottom.

TABLE I
Herbicide treatments for onion.

Herbicide treatments	Application rates	Number of applications
Ioxynil (post-emergence)	Full (3.00 L ha^{-1})	One
	Half (1.50 L ha^{-1})	One
	Quarter (0.75 L ha^{-1})	One
	Eighth (0.375 L ha^{-1})	One
	Eighth (0.375 L ha^{-1})	Two (11 days interval)
	Eighth (0.375 L ha^{-1})	Three (11 days interval)
Bentazone (pre-emergence)	Full (2.80 L ha^{-1})	One
	Half (1.40 L ha^{-1})	One
	Quarter (0.70 L ha^{-1})	One
	Eighth (0.35 L ha^{-1})	One
	Eighth (0.35 L ha^{-1})	Two (11 days interval)
	Eighth (0.35 L ha^{-1})	Four (11 days interval)
Control	None	
Planting date	26.6.2002	
Date of 1st spray	15.7.2002	

TABLE II
Herbicide treatments for leek.

Herbicide treatments	Application rates	Number of applications
Ioxynil (post-emergence)	Full (2.80 L ha^{-1})	One
	Half (1.40 L ha^{-1})	One
	Quarter (0.70 L ha^{-1})	One
	Eighth (0.35 L ha^{-1})	One
	Eighth (0.35 L ha^{-1})	Two (11 days interval)
	Eight (0.35 L ha^{-1})	Three (11 days interval)
Linuron (post-emergence)	Full (1.7 L ha^{-1})	One
	Half (0.85 L ha^{-1})	One
	Quarter (0.425 L ha^{-1})	One
	Eighth (0.2125 L ha^{-1})	One
	Eighth (0.2125 L ha^{-1})	Two (11 days interval)
	Eighth (0.2125 L ha^{-1})	Three (11 days interval)
Propachlor (pre-emergence)	Full (9.0 L ha^{-1})	One
	Half (4.5 L ha^{-1})	One
	Quarter (2.25 L ha^{-1})	One
Pendimenthalin (pre-emergence)	Full (3.3 L ha^{-1})	One
	Half (1.65 L ha^{-1})	One
	Quarter (0.825 L ha^{-1})	One
Linuron (pre-emergence)	Full (1.7 L ha^{-1})	One
	Half (0.85 L ha^{-1})	One
	Quarter (0.425 L ha^{-1})	One
Control	None	—
Planting date	25.06.2002	
Date of 1st spray	15.7.2002	

2.85 ml of Deionized water *per* dish was added at the time of seed sowing using a pipette. 2.85 ml of subsequent water *per* Petri dish was added when needed. Petri dishes were sealed with one-inch-dia core parafilm "M" and covered with plastic envelopes to minimize moisture loss. The germination dishes for this experiment were arranged in a completely randomized design (CRD) with four replications.

Germination was evaluated for one month at five stable temperatures of 5, 10, 15, 20 and 25°C using separate incubators. Germinated seeds from individual Petri dishes were counted and removed every day at an interval of 24 hours along one month. Germination was defined as when the radicle protruded more than 2 mm from the seed. All data were analysed statistically using the statistical package GENSTAT (Payne et al. 1995).

RESULTS AND DISCUSSION

GERMINATION OF *C. album* AT DIFFERENT TEMPERATURES

The results obtained with seed placed at different temperatures between 5 and 25°C are presented in Figure 1. There was a significant difference among the different temperatures regarding germination of *C. album* seed collected from onion field. *Chenopodium album* had the highest germination (45.34%) at 20°C followed by 31.91% at 25°C. Germination was minimum (16.83%) at 5°C and did not differ significantly from 18.42% at 10°C.

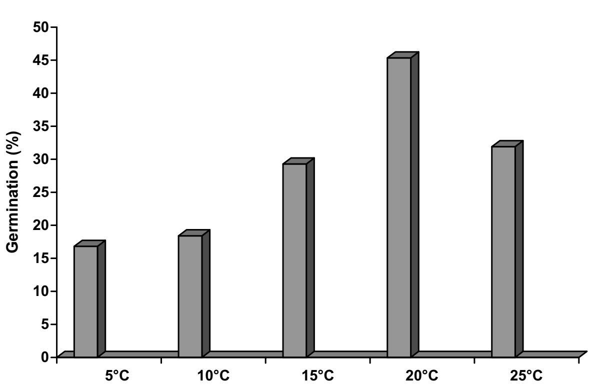

Fig. 1 – Effect of temperature on germination of progeny of *C. album* seed collected from Onion field.

There was significant variation ($P < 0.001$) amongst germination percentage of *C. album* seed collected from the leek field, at different temperatures (Fig. 2). Maximum germination (38.94%) was recorded at 15°C, which was statistically on a par with germination (37.29%) at 25°C. Germination of *C. album* at 25°C did not differ significantly from that at 20°C. The significantly minimum germination (10.84%) was recorded at 5°C.

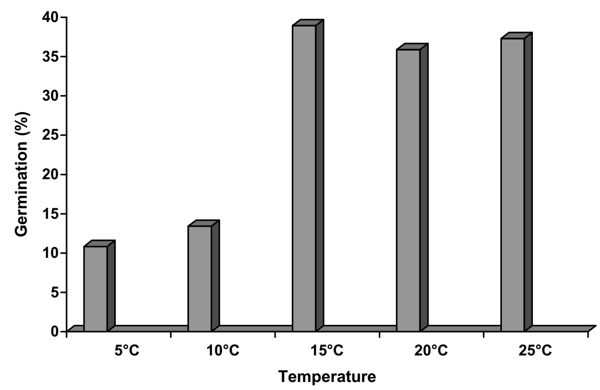

Fig. 2 – Effect of temperature on germination of progeny of *C. album* seed collected from Leek field.

Germination of *C. album* seed is very fast at relatively high temperatures, but slows down as the temperature decreases. Low temperatures slowed down germination by increasing the time to onset of germination, reducing the germination rate and lowering the final germination percentage.

GERMINATION OF *C. album* SEED COLLECTED FROM PLANTS TREATED WITH DIFFERENT RATES OF HERBICIDES

Germination of *C. album* seed collected from the previous onion crop (Table III) sprayed with post-emergence ioxynil and pre-emergence bentazone (each at eighth rate sprayed either once, twice or three times, quarter, half and full recommended rate) did not differ from the unsprayed control (left weedy). However, germination of *C. album* seed was generally higher at higher rates of both herbicides than at lower rates. Germination of *C. album* seeds from plants treated with herbicides was also higher than the control.

The effect of three pre-emergence herbicides (namely pendimethalin, propachlor and linuron); and post-emergence linuron on percentage germination of *C. album* seeds collected from the leek field was not significant in comparison with the control (Table IV).

TABLE III

Effects of pre and post-emergence herbicides on the germination (%) of the *C. album* seed progeny collected from the onion field.

Herbicide	Rate	Germination (%)
Ioxynil post-em.	Eighth	24.47
	Eighth (twice)	25.47
	Eighth (3 times)	27.65
	Quarter	26.42
	Half	33
	Full	30.65
Bentazone pre-em.	Eighth	25.78
	Eighth (twice)	29.66
	Eighth (3 times)	29.32
	Quarter	25.49
	Half	30.39
	Full	33.48
Control (weedy check)		26.11
SED (df = 212)		2.55
P value		NS

***Significance at the $P \leq 0.001$ level. / NS = not-significant.

TABLE IV

Effects of pre and post-emergence herbicides on the germination (%) of the *C. album* seed progeny collected from the leek field.

Herbicide	Rate	Germination (%)
Pendimethalin (pre-em.)	Quarter	30.57
	Half	33.21
	Full	37.12
Propachlor (pre-em.)	Quarter	23.14
	Half	29.14
	Full	29.97
Linuron (pre-em.)	Quarter	21.81
	Half	20.25
	Full	25.37
SED(df = 252)		1.83
P value		NS
Linuron (post-em.)	Eighth	25.01
	Eighth (twice)	25.18
	Eighth (3 times)	26.8
	Quarter	24.59
	Half	24.19
	Full	25.54
Control (weedy check)		29.72
SED (df = 252)		1.78
P value		NS

***Significance at the $P \leq 0.001$ level. / NS = not-significant.

Among the pre-emergence herbicides, germination of *C. album* seeds from plants treated with pendimethalin was generally higher. *C. album* seeds also showed higher germination when their parent plants were treated with full rate of herbicides compared with half or quarter rate of three pre-emergence herbicides.

Greater germination was recorded from seed where eighth rate of post-emergence linuron was sprayed three times compared with the other rates. This was followed by full rate. Germination of *C. album* seeds collected from unsprayed plots (control) was higher than that from different rates of pre-emergence propachlor, linuron and post-emergence linuron, but lower than different rates of pendimethalin.

However, whilst trends were observed; the generally non-significant differences in germination of *C. album* seeds indicate that seed germination responded similarly to the different herbicide rates. The results of this experiment seem to follow those of Fawcett and Slife (1978). They found that viability of *C. album*, *Amaranthus retoflexux*, *Dtaura stramonium* and *Setaria feberi* seeds produced by 2, 4–D and Dalapon treated plants were not greatly different from control seeds. Similar results were reported by Zollinger and Evans (1985). Non-significant differences in germination percentage indicate that there was no carry-over effect of herbicides sprayed to parent plants on germination of progeny seed in terms of final percentage germination. However, there may be effects on the germination rate that have so far not been analysed. The results of present study are in contrast to those of Biniak and Aldrich (1986), Frank and Ralph (1987), Isaacs et al. (1989), Andersson (1994), Zhang and Cavers (1994) and Shuma et al. (1995), who reported decreased germination of different weed species as a result of herbicides application to parent plants. This contradiction could be attributed to the use of herbicides of different chemical nature, on different weed species at different times, in present and previous study. Clearly generalities cannot be made.

Finally, we can conclude that the possibility of competition between *C. album* grown from seeds of herbicides treated parent plants and crop plants is likely to be the same as weeds from seed of untreated plants. This is due to the similar final germination percentages of seeds observed from herbicide treated and untreated plants.

ACKNOWLEDGMENTS

This study was conducted in the laboratory of School of Science and the Environmental Sciences, Coventry University, Coventry, UK.

RESUMO

Avaliou-se o efeito residual de doses sub-letais de herbicidas sobre a germinação de sementes de plantas de *Chenopodium album* sobreviventes em uma cultura prévia de cebola (*Allium cepa*), que recebeu 2x, 3x, 1/4, 1/2 ou a dose recomendada de ioxynil em pré-emergência ou bentazone em pós-emergência. As sementes foram também coletadas de plantas de *C. album* sobreviventes de um campo de alho-porró (*Allium porrum*) que havia sido tratado com 1/4, 1/2 ou a dose recomendada de pendimethalin, propachlor e linuron em pré-emergência, ou ainda 2x, 3x, 1/4, 1/2 ou a dose recomendada de ioxynil ou linuron em pós-emergência. As sementes destas plantas sobreviventes foram coletadas e testadas quanto à germinação a temperaturas de 5°C, 10°C, 15°C, 20°C e 25°C. Verificou-se que o efeito das temperaturas na germinação destas sementes foi significativa. A germinação foi mínima a baixas temperaturas (5°C e 10°C). Os herbicidas não causaram nenhum efeito na germinação das sementes de *C. album* tendo resultado no mesmo nível daquelas das plantas controles de culturas não pulverizadas.

Palavras-chave: herbicidas, doses sub-letais, cebola, alho-porró, germinação.

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