Some factors affecting the germination of achenes of *Onopordum illyricum* L.

M.H. Campbell, W.J. Nielsen and **H.I. Nicol,** Agricultural Research and Veterinary Centre, NSW Agriculture & Fisheries, Orange, New South Wales 2800, Australia.

Summary

Germination of achenes of *Onopordum illyricum* L. was promoted by chilling, washing, gibberellic acid + potassium nitrate, light intensity and cutting 2 mm off the cotyledon end of the achene. Gibberellic acid + potassium nitrate promoted almost full germination of achenes collected from standing plants; subsequent cutting achieved full germination. Seeds from the soil failed to respond to gibberellic acid + potassium nitrate but responded well to subsequent cutting. It is possible that cutting may remove dormancy inducing chemicals in the achene coat and/or in tips of the cotyledons or may overcome mechanical constraint. Some management options for the control of *O. illyricum* in pastures are discussed.

Introduction

Illyrian thistle (*Onopordum illyricum* L.) infests large areas of southern New South Wales (Briese 1988). Efforts to control the weed by replacing it with improved pastures (Michael 1968) or by grazing with goats (Campbell and Holst 1987, 1990) depend on, respectively, controlling the recruitment of seedlings by competition and exhausting the seed bank through goats eating flowering heads and preventing seed set. Both control processes require an understanding of the germination characteristics of achenes of *O. illyricum*. The only Australian study (Groves and Kaye 1989) of this species showed that germination of *O. illyricum* achenes from Canberra under favourable temperature and moisture conditions was 58 to 75%. However, achenes from Boorowa had low germination (5 to 20%) under similar conditions. Investigations into the germination requirements of the closely related Scotch thistle (*O. acanthium* L.) in the U.S.A. showed responses to chilling, soaking, alternating temperatures (Scifres and McCarty 1969), washing, fluorescent light and potassium nitrate + gibberellic acid (Young and Evans 1972). Thus four experiments were undertaken to examine the effects of some of these, and other treatments, in order to gain an understanding of the germination characteristics of *O. illyricum* achenes from Boorowa.

Methods

In all experiments achenes of *O. illyricum*, collected at Boorowa, N.S.W., and stored at room temperature in the dark in a laboratory at Orange N.S.W., were germinated in petri dishes (50 to 100 achenes per dish) with two filter papers, one germination pad and 10 ml of deionized water. Seeds were collected from standing plants for Experiments 1 to 3 and from the soil for Experiment 4. There were four replications in each experiment and observations were made at three-day intervals. At the end of each experiment the ungerminated achenes remaining were cut open to ascertain the number empty so that germination could be expressed as a percentage of achenes that contained embryos. Gibberellic acid (GA) and potassium nitrate (KNO_3) were applied in all experiments at concentrations of 0.14 mmole L^{-1} (48 ppm) and 1.0 mmole L^{-1} (101 ppm) respectively. Experiments were carried out at temperatures (18°C to 25°C) shown by Groves and Kaye (1989) to be favourable for germination of *O. illyricum*.

Experiment 1.

The effect of washing, chilling and ± GA + KNO_3 on the germination of 9-month-old achenes (collected February 1988) of *O. illyricum* was ascertained in a laboratory at 18° to 25°C under constant fluorescent light (8 $\mu Em^{-2} s^{-1}$) for 49 days. Washed achenes were soaked in tap water for five hours, stirred occasionally, flushed, transferred to clean water, soaked again for 16 hours and flushed again. Unwashed seeds were as collected in the field after storage. Chilling was achieved by placing petri dishes with achenes and liquids (deionized water, GA, $KN0_3$) in a dark room at 2°C for seven days and then returning them to the laboratory. Meanwhile the non-chilled treatments had been in light in the laboratory with liquids added. Thus, after seven days both treatments had light and warmth.

Experiment 2.

The effect of light intensity (a mixture of fluorescent and incandescent at, high 210 $\mu Em^{-2} s^{-1}$, low 42 $\mu Em^{-2} s^{-1}$ and dark) and ± GA + KNO_3 on the germination of 3 and 15-month-old unwashed achenes of *O. illyricum* (collected February, 1988, 1989) was ascertained in a growth chamber at constant 25°C for 34 days.

Experiment 3.

The effect of cutting and ± GA + KNO_3 on the germination of 11-month-old achenes of *O. illyricum* (collected February 1989) was ascertained in a laboratory at 18° to 25°C under constant fluorescent light (8 $\mu Em^{-2} s^{-1}$) for 49 days. For the first 44 days a comparison of the germination of cut achenes (1 mm cut from the cotyledon end) and uncut achenes was made. On day 44 the cut achenes had a further 1 mm cut away and the uncut achenes had 2 mm cut away. Final germination was recorded on day 49.

Experiment 4.

The germination of achenes taken from 400 soil cores (7.5 cm deep) in 4 heavily infested paddocks at Boorowa in April 1989 was examined in a laboratory at 18° to 25°C in constant fluorescent light (8 $\mu Em^{-2} s^{-1}$) one month after collection. Achenes were in the presence of GA + KNO_3 for the first eight days of the experiment. On the eighth day 2 mm of the cotyledon end of the achenes was cut off and final germination recorded on day 12.

Results

Experiment 1.

Washing, chilling and the addition of GA + KNO_3 all improved ($P < 0.05$) the germination of *O. illyricum* (Table 1); there were no significant interactions. The addition of GA + KNO_3 to the substrate had the largest effect. Maximum germination (80%) was achieved by a combination of washing, chilling and GA + KNO_3 and minimum germination (7%) with no washing or chilling or GA + KNO_3 (detailed results are not presented). Of the achenes that germinated, more than 90% had done so in each treatment within 12 days. Of the achenes sampled from standing plants in 1988, 51% had embryos.

Table 1. Effects of chemicals, washing and chilling on the germination of achenes of *Onopordum illyricum* in 49 days.

Treatment		% germination of seeds with embryos
Chemicals:	GA + KNO_3	75a[A]
	Water	19b
Washing:	Washed	53a
	Unwashed	41b
Chilling:	Chilled	51a
	Unchilled	43b

[A]Values, within comparisons, not followed by a common letter differ significantly ($P < 0.05$).

Table 2. Effect of light intensity and GA + KNO_3 on the germination of achenes of *Onopordum illyricum* in 34 days

Age of achenes	GA + KNO_3	Light intensity High	Low	Dark
15 months	+	97a[A]	91ab	83ab
	-	43c	10e	19de
3 months	+	98a	90ab	80b
	-	42c	38c	33cd

[A]Values not followed by a common letter differ significantly ($P < 0.05$).

Table 3. The effect of GA + KNO_3 on the germination of cut (1 mm from cotyledon end on day 1) and uncut achenes of *Onopordum illyricum* on day 44 and of the same achenes, cut 1 mm on day 1 and 1 mm on day 44 and 2 mm on day 44, on day 49.

GA + KNO_3	Cutting on: Day 1	Day 44	Germination (%) on: Day 44	Day 49
+	1 mm	1 mm	88a[A]	89a
+	Uncut	2 mm	75b	94a
-	1 mm	1 mm	61c	84a
-	Uncut	2 mm	6d	51b

[A]Values not followed by a common letter differ significantly ($P < 0.05$).

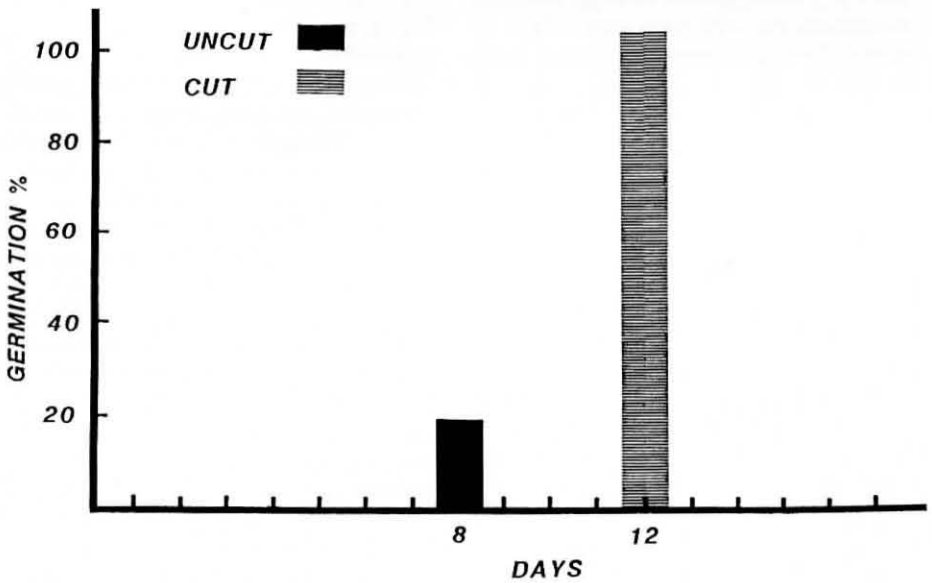

Figure 1. Effect of cutting 2 mm off the cotyledon end of achenes of *O. illyricum* on day 8, after treatment with GA + KNO_3 on day 1.

Experiment 2.
Both three and 15-month-old seeds responded ($P < 0.05$) to increasing light intensity, the 15 month old achenes in the absence of GA + KNO_3 and the 3 month old achenes in the presence of GA + KNO_3 (Table 2).

Experiment 3.
At day 44, cutting improved ($P < 0.05$) the germination of achenes with and without the influence of GA + KNO_3; cutting was much more effective in promoting germination in the absence than in the presence of GA + KNO_3 (Table 3). Additional cutting on day 44 promoted further ($P < 0.05$) germination of three of the four treatments by day 49. Of the achenes sampled from standing plants in 1989, 71% had embryos.

Experiment 4.
Achenes of *O. illyricum* from the soil did not respond to treatment with GA + KNO_3 (day 1) but responded well to subsequent cutting on day 8 (Figure 1). Only 54% of achenes had embryos.

Discussion

These experiments show that some of the factors (washing, chilling, GA + KNO_3, cutting) that influenced the germination of *O. acanthium* achenes in studies undertaken in the U.S.A. (Scifres and McCarty 1969; Young and Evans 1972) also influenced the germination of *O. illyricum* achenes from Boorowa. With *O. illyricum*, there were small responses to washing and chilling but large responses to GA + KNO_3 and cutting. Scifres and McCarty (1969) attributed the effect of washing to the removal of a water soluble inhibitor from the achene coat of *O. acanthium*; this substance depressed shoot growth of *Cucumis sativis* seedlings. They also concluded that the germination regulating mechanism which responds to chilling is located in some tissue region other than the embryo of *O. acanthium*. In the experiments of Young and Evans (1972) and those reported here, once the light, temperature and GA + KNO_3 requirement were supplied, germination was not influenced by washing or chilling. Thus the GA + KNO_3 treatment was the most potent influence on germination of both *O. acanthium* and *O. illyricum*.

Young and Evans (1972) attributed the effect of GA + KNO_3 in enhancing germination of *O. acanthium* to a chemical substitution for light quality. In our experiments GA + KNO_3 promoted germination of *O. illyricum* in the light as well as the dark. Thus the light supplied was not of sufficient quality, even at the high intensity of fluorescent and incandescent light applied in Experiment 2, to promote full germination.

Even with light and GA + KNO_3 supplied, germination of *O. illyricum* responded to removal of part of the seed coat. There was a marked response to cutting 2 mm off the cotyledon end of the achene in Experiment 3, which was indicative of a mechanical constraint limiting germination. Scifres and McCarty (1969) came to the opposite conclusion with *O. acanthium* but they cut 1 mm from the radicular end of the achene. Our results, with *O. illyricum*, show that a 1 mm cut is not as effective as a 2 mm cut in promoting germination and that cutting the cotyledon end, although reducing the size of the cotyledons, had little or no effect on the health of the resultant seedling, contrary to the results of Scifres and McCarty (1969) where cutting the radicular end severely damaged seedlings of *O. acanthium*.

The failure of *O. illyricum* achenes recovered from soil in the field to respond to GA + KNO_3 in Experiment 4 agrees with the findings of Young and Evans (1972) with *O. acanthium*. They attributed poor germination of achenes from the soil to induced dormancy acquired in the field. Evidence that cutting may overcome this induced dormancy is presented in Experiment 4 where almost full germination resulted from cutting 2 mm off the cotyledon end of *O. illyricum* achenes that had

been in the soil for some time. The mechanism involved is not clear but it is possible that cutting may remove dormancy inducing chemicals in the achene coat and/or in tips of the cotyledons that materialize under storage in the soil or cutting may overcome a heightened mechanical constraint brought on by residence in the soil.

Variation in response to treatments could occur in achenes of *O. illyricum* collected in different seasons or from different regions. In Experiment 2, there was a slight variation in response of achenes collected in 1988 and 1989 to light intensity. This could also be explained by shading affecting light quality which in turn affected germination behaviour. In addition Groves and Kaye (1989) found only minor responses to either GA (10 ppm) or KNO_3 (1 mmol L^{-1}) in achenes collected at Canberra in 1982 in contrast to the major responses observed here.

In practice landholders have little control over factors that influence the germination of *O. illyricum* in the field. They can reduce grazing pressure and increase the level of pasture cover to shade achenes from light and thus reduce germination. Alternatively, high grazing pressure could expose achenes to light to promote germination which could result in the reduction of the seed bank if the resultant seedlings were controlled by subsequent cultivation, herbicide application or competition from improved pastures (Michael 1968).

Exposing achenes to light to promote germination, followed by grazing with goats to prevent flowering, could exhaust the seed bank if repeated over a number of years; three years was sufficient to exhaust the bank of saffron thistle (*Carthamus lanatus* L.) seeds in Western Australia (Peirce 1987). Similar goat management in New South Wales has resulted in substantial reductions in the seed bank and plant populations of *O. illyricum* after three years (Campbell and Holst 1990). Periodic heavy grazing could be used to promote germination and to assist seed eating biological agents (Cullen and Delfosse 1990) to exhaust the seed bank of *O. illyricum*. A combination of grazing by goats and seed eating biological agents could provide a two-pronged attack on the seed bank. However, if storage of seed in the soil results in induced dormancy as Young and Evans (1972) suggest, it appears any management strategy aimed at exhausting the seed bank would have to take place over a very long period to be successful.

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