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Germination of Seeds of Common Yarrow (*Achillea millefolium*) and Its Herbicidal Control[1]

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Abstract. Seeds of common yarrow (*Achillea millefolium* L.) germinated 99% with alternating temperatures of 15 and 25 C with concurrent dark and light periods. Germination was significantly higher when temperature was alternated, compared with a constant 15 or 25 C. Alternating light (8 h) and darkness (16 h) with either alternating or constant temperature significantly increased germination when compared with germination in the dark. After 9 yr, seed germinated over 41% under optimum conditions. Dicamba (3,6-dichloro-*o*-anisic acid) at 2.2 kg/ha reduced common yarrow infestations 90 to 95% in 3 of 4 yr, and 3,6-dichloropicolinic acid[3,4] (designated D-290 in this paper) at 0.6 to 2.2 kg/ha controlled yarrow 90 to 100%. Yields on plots treated with D-290 at 0.6 kg/ha were significantly higher than those on plots treated with all rates of dicamba. Dicamba caused injury to grass and reduced its yield. Triclopyr [(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid at 3.4 kg/ha was not effective on yarrow.

INTRODUCTION

Common yarrow is adapted to a wide range of habitats and occurs as a weed in pastures and rangelands throughout most of the United States and in the Canadian provinces from Newfoundland to British Columbia (2, 9). It has a pungent, aromatic odor and a bitter flavor and is generally rated unpalatable as forage. On grazing lands, its increase is an indicator of a deteriorating range, and under some conditions, common yarrow can become a strong competitor with more desirable plants.

The yarrows are circumboreal, polymorphic species with numerous intergradations of a number of subspecies of sexaploid (n = 27) or tetraploid (n = 18) genomes (1, 4). Two somewhat distinct subspecies of yarrow that are generally recognized in the United States are the hexaploid common yarrow, which is of European origin, and the tetraploid western yarrow (*A. lanulosa* Nutt.), which is native to North America.

A number of studies have been conducted on germination of yarrow seeds, with similar results. Maguire and Overland (6) tested common yarrow and obtained germination of 20% at 15 C in darkness and 60% at 15 C or 20 to 30 C in alternating light and dark, and Griswold (3) obtained 82% germination of western yarrow at 22 to 29 C with constant moisture and 98% with alternate moistening and rapid drying. Effects of light on germination were not evaluated.

Data on response of yarrow species to herbicides are sketchy. Klingman and Shaw (5), in a survey on susceptibility of common weeds to phenoxy herbicides, reported control of common yarrow to range from fair to none. May et al. (8) found that a western yarrow infestation was reduced 50% one year after treatment with 1.1 kg/ha of picloram (4-amino-3,5,6-trichloropicolinic acid). Dicamba at 2.2 kg/ha (7) was required for control of yarrow in another study. The species was not identified in the latter report.

The objectives of these studies on common yarrow were (1) to determine the effects of age, light, and different temperatures on germination of yarrow seeds, (2) to determine comparative effectiveness and optimum rates of selected herbicides in controlling yarrow infestations, and (3) to determine the effect of potential herbicides on yield of forage when adequate rates to control yarrow infestations were applied.

MATERIALS and METHODS

Germination trials. Seeds of common yarrow collected in 1963, 1971, and 1972 were taken from dry storage at room temperature in September 1972 and tested for germinability as affected by different temperature regimes and low intensity light (2.2 klux). Seeds were placed on filter paper moistened with distilled water in petri dishes each month for 12 months in a progressive study as follows:

15 C L-D:	8 h light and 16 h dark at constant 15 C.
25-15 C, L-D:	8 h light at 25 C and 16 h dark at 15 C.
25-15 C, D:	8 h at 25 C and 16 h at 15 C, both dark.
25 C, L-D:	8 h light and 16 h dark at constant 25 C.

Each petri dish contained 50 seeds, and treatments were replicated four times. Each trial was continued for 28 days. A seed was considered to be germinated when the radicle tip had emerged from the seed coat.

Actual percentage germination data for each year was subjected to analysis of variance as a completely randomized design and the means were compared by Duncan's multiple range test. Analysis of the combined data of all years to compare averages was made by transforming the percentages to the

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[3] The monoethanolamine salt of 3,6-dichloropicolinic acid was supplied by the Dow Chemical Co. as an experimental herbicide.

[4] This paper reports the results of research only. Mention of a trademark or propietary product does not constitute a guarantee or warranty of the product by the U.S. Dep. of Agric. and does not imply its registration under FIFRA or its approval to the exclusion of other products that may also be suitable.

arc sin scale for a single analysis because of preponderance of high germination of 1971 and 1972 seeds. Averages of transformations may differ in a greater or lesser amount when compared with averages of percentages. Actual means of percentages are presented in the tables.

Field trials of herbicides. Trials of selected herbicides on common yarrow were conducted in 1973 and 1974 at Harrington, Washington, and in 1975 and 1976 at Steptoe, Washington. All herbicides were applied in a volume of 187 L/ha and contained 0.5% (v/v) nonionic surfactant (alkylaryl polyoxyethylene glycols). Visual estimates of percentage control of yarrow were analyzed by analysis of variance on arc sin transformations, and comparisons of means of transformed data were made by Duncan's multiple range test. Data in tables are averages of actual percentage control estimates. Samples of grass yields at Steptoe were taken with a 0.9 m^2 hoop placed at random in an area not less that 0.5 m from a plot border. Grass yields were not sampled at Harrington.

Harrington trials. These trials were on a pasture that had been seeded to orchardgrass (*Dactylis glomerata* L.) and received irrigation. Natural precipitation was 30 to 36 cm per year. Many endemic plants, including common yarrow and low larkspur (*Delphinium nelsonii* Greene) were present and often abundant in scattered patches. The shallow soil was a Ritzville silt loam (Calciorthidic Haploxeroll, pH 7.6) overlying basalt on the edge of the channeled scablands of eastern Washington.

In mid-October, 1973, dicamba at 1.1, 2.2, or 3.4 kg/ha and silvex [2 (2,4,5-trichlorophenoxy)propionic acid] at 2.2 or 3.4 kg/ha were applied in four replicates to 3- by 6-m plots. Seed stalks of yarrow were dead, although a basal rosette of green leaves remained. Treatments were evaluated on May 8, 1974, and a new set of plots of the same dimensions was treated in three replicates with dicamba at 1.1, 2.2, or 3.4 kg/ha and silvex at 2.2 or 3.4 kg/ha. Yarrow plants were in the late rosete stage in the May 3 treatment. Percentage of control for the May treatment was estimated on July 2, 1974.

Steptoe trials. The trials at this location were on a Palouse silt loam overlying basalt (Pachic Ultic Haploxeroll, pH 6.5) receiving 40 to 46 cm of precipitation annually. Four replicates of 3- by 8-m plots were used each year. The area had been used as a horse pasture for many years and contained an unusually dense stand of common yarrow (average number of crowns in twenty 0.9 m^2 samples was 23.8 ± 12.6). A diversity of grass species was also present, including Kentucky bluegrass (*Poa pratensis* L.), which was the principal perennial species; redtop (*Agrostis alba* L.); and quackgrass [*Agropyron repens* (L.) Beauv.]; four species of winter annual bromes (*Bromus* spp.) with downy brome (*B. tectorum* L.) the principal species; and scattered plants of medusahead [*Taeniatherum asperum* (Sim.) Nevski]. Several other native and introduced broadleaf, herbaceous species occurred in minor numbers. The most prevalent of these were redstem filaree [*Erodium cicutarium* (L.) L'Hér]; coast fiddleneck (*Amsinckia intermedia* Fisch. & Mey.); flixweed [*Descurainia sophia* (L.) Webb]; and smallseed falseflax (*Camelina microcarpa* Andrz.). The principal perennial broadleaf species was red sorrel (*Rumex acetosella* L.).

Table 1. Mean percentage germination of common yarrow seeds harvested in three different years and tested progressively for 12 months at four temperature and light regimes.

Temperature & light regime	Seeds maturing in[a] 1963 (%)	1971 (%)	1972 (%)	Avg.[b] (%)
15 L-D	37.1 b	97.6 ab	98.1 ab	77.6 b
15-25 L-D	41.5 a	97.9 a	99.0 a	79.5 a
15-25 D	21.8 c	89.5 c	91.5 c	67.6 c
25 L-D	36.8 b	97.0 b	96.9 ab	76.9 b
Avg.[b]	34.3 b	95.5 a	96.4 a	75.4 –

[a]Numbers in each column, (except averages) not followed by a common letter are significantly different at the 5% level according to Duncan's multiple range test.
[b]Significant differences in averages were determined by analysis of arc sin transformations of combined data.

In both years yarrow was in the late rosette stage of growth at the time of treatment, and many crowns did not produce floral stems. On May 8, 1975, the following herbicides were applied: dicamba at 2.2 or 3.4 kg/ha, triclopyr at 3.4 kg/ha, and D-290 at 0.6, 1.1, or 2.2 kg/ha. Grass samples were taken for yield on June 25 and percentage of yarrow control was estimated on July 14.

On May 6, 1976, a new trial was made adjacent to the 1975 plots. All plots treated with herbicides were fertilized with 34 kg/ha of N as ammonium nitrate. One of two sets of control plots was fertilized and one set was unfertilized. On May 13, herbicide plots were treated with dicamba at 1.1, 2.2, or 3.4 kg/ha, triclopyr at 3.4 kg/ha, or D-290 at 0.6, 1.1, or 2.2 kg/ha. Percentage yarrow control was estimated and grass yield samples were taken on June 23.

RESULTS and DISCUSSION

Germination studies. After 9 yr in dry storage at room temperature, common yarrow seeds collected in 1963 had about one-third of the germination shown by 1972 and 1971 seeds (Table 1) 2 to 14 months, respectively, after harvest. It appears from the data that germinability is probably lost at a relatively uniform rate for at least 10 yr. The characteristic odor of leaves and seeds of common yarrow had almost disappeared from the 1963 seeds in that time. The relationship, if any, that exists between the aromatic compound and germination is unknown. Comparison of the four light-temperature regimes indicated that temperature alternation significantly increased germination, and that light also had a significant effect on germination. These results are in general agreement with those of Maguire and Overland (6).

Germination of seeds, month by month, over temperature and light regimes, is detailed in Table 2. At maturity (July 31), 1972 seeds tested at 15-25 C, L-D, germinated 64%. When the monthly trials began, germination of 1972 seeds had increased to 96%, indicating a short period of post-maturity dormancy or after-ripening. The most recently harvested seeds (1971 or

Table 2. Percentage germination at monthly intervals, over four temperature and light regimes, of common yarrow seeds harvested in three different years.

Month	Seeds maturing in[a] 1963 (%)	1971 (%)	1972 (%)	Avg.[b] (%)
September	42.1 ab	92.5 gh	96.0 b-h	76.9 a-f
October	45.4 a	94.1 d-g	94.8 e-j	78.1 abc
November	39.8 abc	92.4 gh	92.6 j	74.9 b-h
December	32.6 de	93.1 gh	96.1 b-g	73.9 e-h
January	31.6 de	91.2 h	94.6 e-j	72.5 h
February	35.0 cd	98.0 abc	98.4 ab	77.1 a
March	32.1 de	96.0 a-f	97.9 a-d	75.3 b-h
April	35.0 cd	96.6 a-d	95.6 b-i	75.7 a-e
May	29.0 de	98.8 a	99.4 a	75.7 ab
June	28.0 e	98.5 ab	96.5 a-e	75.3 a-g
July	30.4 de	96.1 a-e	96.2 b-f	74.2 e-h
August	30.4 de	98.5 ab	98.2 abc	75.7 a-d
Avg.[b]	34.3 b	95.5 a	96.4 a	75.4 –

[a]Numbers in each column (except averages) not followed by a common letter are significantly different at the 5% level according to Duncan's multiple range test.
[b]Significant differences in averages were determined by analysis of arc sin transformations of combined data.

Table 3. Mean estimated percentage herbicidal control of common yarrow in a 4-yr trial in eastern Washington.

Herbicide	Rate (kg/ha)	Location and year[a] Harrington 1973[b] (%)	Harrington 1974 (%)	Steptoe 1975 (%)	Steptoe 1976 (%)
Silvex	3.4	90 ab	70 abc	–	–
	2.2	70 b	50 cd	–	–
Dicamba	3.4	95 a	100 a	100 a	100 a
	2.2	95 a	90 ab	95 a	75 ab
	1.1	85 ab	45 d	–	50 b
D-290	2.2	–	–	100 a	100 a
	1.1	–	–	100 a	90 a
	0.6	–	–	100 a	90 a
Triclopyr	3.4	–	–	5 b	5 c
Control	–	0	0	0	0

[a]Numbers in each column not followed by a common letter are significantly different at the 5% level according to Duncan's multiple range test.
[b]Treatments applied in October, evaluated the following May. All other years, treatments applied in May and evaluated 6 or 7 weeks later.

1972 harvest) had highest germination in May, although it was not significantly higher than that occurring in some other months. Lowest germination tended to be in late autumn and early winter. The minor trend toward periodicity of germination in younger seeds appeared to have been lost or shifted with aging. Highest germination of the seed harvested in 1963 occurred in the autumn months, with little difference among the other seasons. Although significant differences occurred within years and among the averages of months over years, no practical importance can be attached to these differences, but the ability of yarrow seeds to survive for an extended period may partially explain its distribution from regions of abundant precipitation into semiarid and arid regions.

Herbicide trials–Harrington. The highest rates of dicamba and silvex (3.4 kg/ha) appeared to control common yarrow comparably in the trials at Harrington (Table 3). The lowest acceptable rate of dicamba in 1974 was 2.2 kg/ha. However, control with 1.1 kg/ha of dicamba was not significantly less effective than that obtained with 3.4 kg/ha of silvex in the autumn 1973 application, or the 2.2 kg/ha rate of silvex in the spring of 1974. It is possible that a longer interval between the time of application and evaluation of control would have shown greater or lesser differences, but the results cited by Klingman and Shaw (5) do not encourage the use of the chlorinated phenoxys for yarrow control.

Herbicide trials–Steptoe. There was no significant difference in control of yarrow among the various rates of dicamba and D-290 in 1975 (Table 3). The lowest satisfactory rate of dicamba for yarrow control in 1976, as in 1974 at Harrington, was 2.2 kg/ha, which is in agreement with the results reported by May et al. (8). Plots treated with all rates of D-290 had excellent yarrow control in both 1975 and 1976, and those treated with 0.6 kg/ha had significantly higher yields of grass in 1976 and in the average yield of 1975 and 1976 than plots treated with dicamba (Table 4). Plots treated with 0.6 kg/ha of D-290 also had a significantly higher yield of grass than the

Table 4. Grass yields as affected by herbicidal treatments in 1975 and 1976 trials at Steptoe, Wash.

Herbicide	Rate (kg/ha)	Grass yields[a] 1975 (kg/ha)	1976[b] (kg/ha)	Avg.[c] (kg/ha)
Dicamba	3.4	600 a	3,900 bc	2,250 bc
	2.2	1,000 a	3,020 c	3,140 bc
	1.1	–	3,710 bc	–
D-290	2.2	860 a	4,260 bc	2,560 bc
	1.1	1,020 a	5,290 ab	3,160 ab
	0.6	1,020 a	6,570 a	3,800 a
Triclopyr	3.4	980 a	3,700 bc	2,340 bc
Untreated + N	–	–	4,100 bc	–
Untreated, no N	–	810 a	3,630 bc	2,220 c
Avg.[c]	–	900 b	4,240 a	–

[a]Numbers in the same column, except for averages between years, which are compared between columns, not followed by a common letter are significantly different at the 5% level according to Duncan's multiple range test.
[b]N at 34 kg/ha in ammonium nitrate applied to all plots treated with herbicides; one of two sets of untreated control plots received N, and one set received no N.
[c]Averages compared by analysis of combined data for both years.

control plots with or without added N in 1976. The highest rate of D-290, when compared with the lowest rate, appears to have prevented an increase in grass yield in 1976, and there was also a significant difference between the 2-year average yield. Overall results indicate a superiority of a low rate of D-290 for control of yarrow in pastures without adverse effect on grasses.

The amount of N applied (34 kg/ha) was not sufficient to cause significant differences in yield between the untreated + N and untreated, no N, plots in 1976. However, the significant difference in yield between 1975 and 1976 is believed to be due both to the additional available N and higher precipitation during the spring months of 1976. Competition of early growth and higher yield of grass in 1976 also tended to suppress growth of yarrow and other broadleaf weeds.

Some redstem filaree survived the 1.1 kg/ha rate of dicamba, but no broadleaf weeds survived the 2.2 or 3.4 kg/ha rates. Coast fiddleneck appeared to be somewhat resistant to 2.2 kg/ha of D-290. At rates up to 2.2 kg/ha of D-290, there was some survival of all broadleaf species previously noted.

Triclopyr was ineffective on yarrow and other broadleaf species, and it caused no significant change in grass yield.

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