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Differential Response to Glyphosate and Growth Patterns of Red Fescue (*Festuca rubra*)

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ABSTRACT

Three cultivars and 62 plant introductions of red fescue (*Festuca rubra* L.) from 14 countries were evaluated for tolerance to glyphosate [*N*-(phosphonomethyl)glycine] in the field at Prosser, Washington. The 35 cultivars and plant introductions that were adapted to growing conditions at Prosser were differentially tolerant to 1.1 and 2.2 kg/ha of glyphosate applied in May when plants were partially to fully headed. An introduction from Poland was most tolerant to spring applications. None of the plants tolerated the 2.2 kg/ha rate applied in the fall. Leaf length, lateral spread of rhizomes and amount of new seasonal growth in early April did not differ among adapted cultivars and plant introductions. In general, the poorly adapted plant introductions were shorter, spread less by rhizomes, and initiated new growth later in the spring than the adapted plant introductions.

Key words: vegetation management, ditchbank vegetation, herbicide tolerance, ditchbank stabilization, weed control, adaptation.

INTRODUCTION

The banks of more than half of the 230,000 km of canals in the Western United States are infested with weeds (14). These weeds may reduce the water-carrying capacity of canals and ditches to less than one-half of the design capacity, and therefore must be controlled (11, 14). If such infestations are controlled by mechanical or chemical means without further vegetation management, many of the ditchbanks either revert to weedy vegetation or erode.

Adapted low-growing, perennial plants established on ditchbanks after weeds have been controlled could stabilize the banks and help maintain longterm, economical weed control. Usually such vegetation cannot compete successfully with tall-growing invader species, such as reed canarygrass (*Phalaris arundinacea* L.), over long periods of time without some selective external force being applied periodically to favor domination by the desirable species. Plants that meet the physical and biological requirements for stabilizing ditchbanks without hindering the flow of water (or that do not have other objectionable qualities) and that also are tolerant of herbicides suitable for use in and around water would be ideal candidates for ditchbank stabilization and weed control.

Red fescue and glyphosate are a grass-herbicide combination that we have found to be promising for vegetating ditchbanks in the Pacific Northwest. Red fescue has an extensive fibrous root system, is relatively short, and is adapted to a wide range of soil moisture, texture and fertility levels (3, 7). It is more tolerant of glyphosate than many other grasses, but it too is injured moderately to severely by rates required to kill the other grasses (1, 2). Bingham et al. (1) did not state the cultivar of red fescue used in their studies while Comes et al. (2) and Marquis et al. (12) evaluated only the "Boreal" cultivar.

Cultivars and ecotypes of a number of crop plants and weeds respond differently to a given herbicide (4, 5, 6, 10, 13). No one has determined if there is a differential tolerance to glyphosate within the red fescue population. If such a difference exists, the strain that is most tolerant could be selected for use in revegetating ditchbanks and other conservation areas where red fescue is adapted. If tolerance is found in a strain that is not agronomically desirable, the required tolerance and desired agronomic characteristics might be recombined to produce a herbicide-tolerant, short, rhizomatous, competitive cultivar that would be suited to the ditchbank environment.

The objectives of this study were to compare the susceptibility of several red fescue cultivars and plant introductions (hereafter referred to collectively as entries) to glyphosate and to determine the suitability of these entries as vegetation to replace troublesome weeds on ditchbanks.

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MATERIALS AND METHODS

A field study was conducted from 1976 to 1979 on Warden fine sandy loam at the Irrigated Agriculture Research and Extension Center, Prosser, Washington (46° 15′ N latitude 119° 45′ W longitude, 275M altitude). Each year the field was fertilized according to recommendations by Washington State University for irrigated pasture grasses, as determined by soil tests. The experimental design was a split block with four replications. Main blocks (65 grass entries) were 10 m long and 1 m wide (one row), and subplots (herbicide treatments) were 2.5 m long and 1 m wide.

Sixty-two of the entries evaluated were plant introductions (PI) from 13 European, mid-Eastern, and North American countries and three were named cultivars. The PI's were selected from 287 introductions evaluated and maintained by the Western Regional Plant Introduction Station at Pullman, Washington. Those chosen for this study were perennial, erect, winter hardy types (8).

Three or four seeds of each entry were planted in 8 by 8 cm peat pots in the greenhouse. Emerged seedlings were thinned to one per pot. They were retained in a greenhouse for 6 weeks, then placed in a lath house for 2 weeks, and finally transplanted 25 cm apart within the row in field plots on May 5 and 6, 1976 (160 plants per entry). The plants were irrigated at the time of transplanting and at approximately 1-week intervals during the growing season for the next 4 years. No herbicides were applied during the year of establishment.

Glyphosate at 1.1 and 2.2 kg/ha in 560 l/ha of water was applied with a shielded compressed air sprayer to all entries on May 19, 1977 (spring), and at 2.2 kg/ha to a different set of subplots on October 5, 1977 (fall). Because of seed limitations for PI's, sufficient plant material was not available to evaluate both rates in the fall. All treatments were reapplied to the same plots on May 17 and October 4, 1978. In both years, all entries given in Table 1 were in the mid- to fully-headed stage of development when glyphosate was applied in the spring. Seed had matured but foliage of all entries was still entirely green when plants were treated in October.

Plant stand was rated visually by the same two individuals two or more times per year in 1977, 1978, and 1979. The stand of each entry given in Table 1 is relative to the stand in untreated plots. Plant characteristics recorded in 1978 included length of leaves, horizontal spread of rhizomes between rows, and dormancy. Dormancy was rated in February and April using a scale of 1 to 5, where 1 equalled no green foliage and 5 equalled 75% or more of the area in the row with green foliage. Differences between treatment means and between plant characteristic means were determined at the 5% and 1% levels of probability, respectively, using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

One or more entries from each country or state of origin (Table 2), except those from Alaska, Sweden, and Switzerland, remained in a full stand throughout the study. Those entries whose stand decreased by 10% or more in untreated plots were considered not to be adapted to growing conditions at Prosser, and their response to glyphosate is not included in Table 1.

TABLE 1. PERCENT STAND (COMPARED TO NON-TREATED PLANTS) OF RED FESCUE ENTRIES 1 YEAR AFTER ONE OR TWO ANNUAL SPRING APPLICATIONS[1] OF TWO RATES OF GLYPHOSATE IN THE FIELD AT PROSSER, WASHINGTON.[2]

Origin	Plant introduction (No.)	Stand after applying 1.1 kg/ha Once	1.1 kg/ha Twice	2.2 kg/ha Once	2.2 kg/ha Twice
		(%)			
Canada	303005	98 ab	88 b-f	85 c-e	46 c
Canada	303006	95 a-c	79 g-i	70 ij	41 cd
Canada	278703	95 a-c	94 ab	93 b	11 n-p
Canada	236839	93 bc	63 m-p	73 h-j	29 g-j
Canada	236845	95 a-c	71 j-l	78 f-h	30 f-i
Czechoslovakia	182856	75 e	69 k-m	63 k	26 h-k
Denmark	217418	100 a	88 b-f	78 f-h	38 d-f
Finland	189285	85 d	65 l-o	68 jk	9 op
Germany	234778	95 a-c	80 f-i	78 f-h	26 h-k
Iran	230240	90 c	50 r	55 l	25 h-k
Netherlands	237181	100 a	90 b-d	78 f-h	23 i-k
Netherlands	266208	98 ab	56 p-r	83 d-f	16 l-n
Netherlands	302999	95 a-c	85 c-g	78 f-h	8 p
Poland	267056	95 bc	80 e-h	85 c-e	31 e-h
Poland	255171	95 a-c	86 b-g	83 d-f	31 e-h
Poland	287543	98 ab	60 o-q	68 jk	19 k-m
Poland	287546	95 a-c	74 i-k	90 bc	41 cd
Poland	287547	98 ab	90 b-d	83 d-f	39 de
Poland	287548	93 bc	64 m-o	85 c-e	22 j-l
Poland	287550	100 a	81 e-h	88 b-d	35 d-g
Poland	287552	95 a-c	94 ab	88 b-d	63 b
Poland	255880	98 ab	79 g-i	75 g-i	14 m-o
Spain	237802	93 bc	90 b-d	73 h-j	22 j-l
Spain	237803	95 a-c	93 bc	80 e-g	38 d-f
Spain	302895	93 bc	61 n-p	63 k	14 m-o
U.S.	300968	95 a-c	86 b-g	75 g-i	30 f-i
U.S.	300969	95 a-c	80 f-i	85 c-e	13 m-p
U.S.S.R.	251687	100 a	100 a	80 e-g	39 de
Yugoslavia	255422	90 c	69 k-m	90 bc	26 h-k
Yugoslavia	255424	98 ab	54 qr	88 b-d	14 m-o
Yugoslavia	255428	95 a-c	89 b-e	68 jk	31 e-h
Yugoslavia	255469	95 a-c	83 d-h	58 k	24 h-k
Cultivar					
Boreal	—	95 a-c	68 k-n	75 g-i	25 h-k
Fortress	—	98 ab	79 g-i	80 e-g	39 de
Novarubra	—	95 a-c	76 h-j	75 g-i	35 d-g
Average over all selections		95	77	78	28

[1]Glyphosate applied in May 1977 and repeated on the same plots in May 1978.
[2]Means followed by the same letter within each column are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Stands of the adapted entries were affected differentially by glyphosate applied in the spring (Table 1). One year after the first spring application of glyphosate, the number and magnitude of differences in plant stands were much more pronounced at 2.2 kg/ha than at 1.1 kg/ha. Stands of only PI 182856 from Czechoslovakia and PI 189285 from Finland were reduced more than 10% by 1.1 kg/ha and only nine entries were significantly different from untreated plant populations. Even though the stands of all entries were reduced significantly by the 2.2 kg/ha rate compared to untreated plants, there was a wide range of significantly different responses to this treatment. The stand of PI 278703 from Canada was reduced only 7%, whereas that of PI 230240 from Iran was reduced 45%.

None of the spring treatments completely desiccated the foliage of any entry. Necrosis of foliage ranged from 10 to 50 and from 60 to 90% 2 months after treatment at 1.1 and

TABLE 2. SPRING DORMANCY, LEAF LENGTH AND BASAL WIDTH OF UNTREATED RED FESCUE ENTRIES GROWN AT PROSSER, WASHINGTON.[1]

Country or state of origin	P.I. No.[2]	Dormancy[3] 2-23-78	Dormancy[3] 4-5-78	Leaf length[4] 9-26-78 (cm)	Basal width[4] 9-26-78 (cm)
Alaska	349062*	2.3 e-i	4.3 a-c	43 c-n	50 b-l
Alaska	349068*	1.8 g-j	2.8 e-h	34 k-n	46 e-n
Alaska	349072*	1.0 j	2.5 f-h	33 l-n	42 i-n
Alaska	349077*	1.3 ij	2.3 gh	30 mn	38 k-n
Alaska	349081*	1.3 ij	2.8 e-h	29 n	45 e-n
Alaska	349082*	1.5 h-j	3.3 c-g	34 k-n	43 h-n
Alaska	349089*	1.8 g-j	3.3 c-g	37 h-n	45 f-n
Alaska	349090*	2.0 f-j	3.5 b-f	44-b-m	48 c-m
Alaska	349091*	2.0 f-j	3.0 d-h	35 j-n	40 j-n
Alaska	349092*	1.3 ij	3.3 c-g	35 j-n	40 j-n
Alaska	349096*	1.0 j	2.3 g-h	42 d-n	34 mn
Alaska	349097*	2.3 e-i	2.5 f-h	35 j-n	42 i-n
Alaska	349099*	3.0 c-f	3.3 c-g	33 l-n	43 h-n
Alaska	349100*	1.8 g-j	3.5 b-f	37 h-n	43 h-n
Alaska	349101*	2.0 f-j	4.0 a-d	35 j-n	48 c-m
Alaska	349102*	1.5 h-j	3.3 c-g	35 j-n	46 d-n
Alaska	349103*	1.8 g-j	3.3 c-g	37 h-n	44 g-n
Alaska	349107*	1.8 g-j	3.5 b-f	38 h-n	54 a-j
Canada	236839	3.0 c-f	4.0 a-d	54 a-g	65 ab
Canada	236841*	2.0 f-j	3.3 c-g	46 a-l	42 i-n
Canada	236843*	1.3 ij	2.0 h	29 n	33 n
Canada	236844*	1.3 ij	2.8 e-h	36 i-n	37 l-n
Canada	236845	3.3 b-e	4.3 a-c	54 a-g	66 a
Canada	278703	3.3 b-e	4.5 ab	54 a-g	63 ab
Canada	303005	2.5 d-h	4.0 a-d	49 a-k	62 a-c
Canada	303006	3.3 b-e	4.0 a-d	55 a-f	63 ab
Czechoslovakia	182856	2.5 d-h	3.8 a-e	55 a-c	57 a-h
Denmark	217418	2.5 d-h	4.5 ab	49 a-k	67 a
Finland	189285	3.8 a-d	4.3 a-c	49 a-k	57 a-h
Germany	234778	3.5 a-d	4.5 ab	60 a	65 ab
Germany	235087*	2.0 f-j	3.3 c-g	41 e-n	43 h-n
Germany	235088*	4.3 ab	4.8 a	53 a-g	63 ab
Iran	230240	3.5 a-d	4.5 ab	58 a-c	53 a-k
Netherlands	237181	2.3 e-i	4.0 a-d	57 a-d	59 a-f
Netherlands	266208	3.5 a-d	4.8 a	54 a-g	54 a-j
Netherlands	302999	3.5 a-d	4.5 ab	51 a-i	60 a-e
Poland	255171	3.8 a-c	4.8 a	52 a-h	62 a-c
Poland	255880	3.3 b-e	3.8 a-e	45 a-k	60 a-e
Poland	267056	3.5 a-d	4.5 ab	57 a-d	63 ab
Poland	287543	3.3 b-e	4.5 ab	58 a-c	56 a-i
Poland	287546	3.5 a-d	3.8 a-e	51 a-i	61 a-d
Poland	287547	3.5 a-d	4.5 ab	56 a-e	57 a-h
Poland	287548	3.3 b-e	4.5 ab	59 ab	60 a-e
Poland	287550	2.5 d-h	4.0 a-d	54 a-g	63 ab
Poland	287552	2.8 c-g	4.3 a-c	57 a-d	59-a-f
Spain	234755*	4.5 a	4.8 a	47 a-l	56 a-i
Spain	234757*	2.0 f-j	2.8 e-h	39 g-n	42 i-n
Spain	237802	3.0 c-f	4.0 a-d	49 a-k	54 a-j
Spain	237803	3.5 a-d	4.8 a	59 ab	64 ab
Spain	302895	3.3 b-e	4.5 ab	47 a-l	54 a-j
Sweden	302998*	3.0 c-f	4.3 a-c	58 a-c	58 a-g
Switzerland	234901*	1.0 j	3.3 c-g	40 f-n	43 h-n
Switzerland	234902*	2.3 e-i	2.5 f-h	37 h-n	36-l-n
U.S.A.	300968	3.8 a-c	4.5 ab	54 a-g	62 a-c
U.S.A.	300969	3.5 a-d	4.0 a-d	50 a-j	62 a-c
U.S.S.R.	251687	2.5 d-h	3.8 a-e	48 a-l	55 a-i
U.S.S.R.	295672*	2.5 d-h	3.8 a-e	48 a-l	57 a-h
Yugoslavia	251133*	1.8 g-j	2.5 f-h	37 h-n	46 d-n
Yugoslavia	255422	2.5 d-h	4.5 ab	56 a-d	59 a-f
Yugoslavia	255424	3.5 a-d	4.8 a	49 a-k	60 a-e
Yugoslavia	255428	3.3 b-e	4.5 ab	52 a-h	55 a-i
Yugoslavia	255469	3.3 b-e	4.5 ab	58 a-c	62 a-c
Cultivar					
Boreal		3.5 a-d	4.5 ab	57 a-d	61 a-d
Fortress		3.5 a-d	4.8 a	52 a-h	61 a-d
Novaruba		3.8 a-c	4.8 a	60 a	62 a-c

[1]Means followed by the same letter within each column are not significantly different at the 1% level according to Duncan's Multiple Range Test.

2.2 kg/ha, respectively. The percentage of necrotic foliage was not highly correlated with the stand that remained 1 year after application (r = −.693).

Although foliage of surviving plants appeared normal at the time of the second application (May 17, 1978), many of the entries apparently had not completely recovered from the initial treatment. With few exceptions, the second annual application reduced the stands considerably more than did the first application. This effect was especially pronounced at 2.2 kg/ha and is best demonstrated by PI 278703 from Canada where the first application reduced the stand only 7%, but the second application reduced it an additional 82%. The PI 787552 from Poland was affected least by 2.2 kg/ha; stand was reduced 12% by the first application and an additional 25% by the second application.

One application of glyphosate at 2.2 kg/ha in the fall killed most plants of each entry, and the second annual application killed any survivors (data not presented). This is in sharp contrast to the 2.2 kg/ha rate applied in May when stands were reduced 7 to 45% by one application and 37 to 92% by two annual applications. Ivany (9) found that glyphosate at 1.1 kg/ha or less controlled quackgrass [*Agropyron repens* (L.) Beauv.] more effectively when applied in the fall than in the spring. However, a rate of 2.2 kg/ha was equally effective at both dates of application. Red fescue is more tolerant of glyphosate than many other grasses, and some rate higher than 2.2 kg/ha probably would reduce stands of red fescue similarly when treated at different seasons (stages of growth). However, 2.2 kg/ha or less of glyphosate controls most of the troublesome monocots on ditchbanks in the Pacific Northwest.

The three commercial cultivars of red fescue were intermediate in their tolerance to glyphosate, compared to the PI's as a group (Table 1). Glyphosate injured all of the entries, but there were substantial differences in the degree of recovery among them. Plants used on ditchbanks to suppress weeds do not need to tolerate herbicides to the degree required of crop plants. Chlorosis, necrosis and stunting, which could not be tolerated in turf and crop plants, are quite acceptable on ditchbank plants if the unwanted vegetation is controlled and the desirable species recover and occupy the site.

There were widespread differences in the time that the entries produced new foliage in the spring (broke dormancy) (Table 2). On February 23, 1978, dormancy ratings ranged from 1 (no green foliage) to 4.5 (75% green foliage). In general, the PI's from Alaska and Switzerland had the least new growth in late February. Of the 20 entries from these two areas, only PI 349099 from Alaska rated as high as 3 (25 to 50% green). An entry from Spain, PI 234755, was least dormant on February 23 (rated 4.5), but it was not significantly different from some entries from Finland,

[2]Abbreviation for plant introduction number; numbers are those designated by the Western Regional Plant Introduction Station, Pullman, Washington. Those with an asterisk did not sustain a full stand and were considered to be nonadapted.
[3]Dormancy rating for foliage where 1 equals no green, 2 equals < 25% green, 3 equals 25 to 50% green, 4 equals 50 to 75% green, and 5 equals > 75% green.
[4]Measured in cm.

Germany, Iran, The Netherlands, Poland, Yugoslavia, USA, USSR, and the three cultivars. Seven weeks later (April 5) there were still highly significant differences in dormancy among entries, but at least one entry from each country, except Switzerland, did not differ from the highest ranking entry (Table 2). Entires from Alaska and Switzerland also were first to go dormant in the fall (data not presented). The altitude and latitude at which the PI's were collected are not known to the authors, but it is evident that red fescue has adapted itself to complete its life cycle and seasonal growth in different periods of time, which is probably related to the environment whence they originated.

The length of leaves and lateral spread of rhizomes (basal width) also differed significantly among selections in September 1978 (Table 2). In general, those selections that broke dormancy late in the spring and went dormant first in the fall had the shortest leaves and the least basal width. There were no significant differences in the leaf length or basal width of the 35 selections that sustained more than a 90% stand for 3 years at Prosser; those selections given in Table 1.

Our results show that there is a wide range of tolerance to glyphosate applied in the spring within the red fescue population. Because there were no significant differences in the leaf length or lateral spread of rhizomes between the selections that were adapted to growing conditions at Prosser, it appears that all would be agronomically suitable for use on ditchbanks of the region. Since one or more of the PI's was more tolerant of two annual spring applications of glyphosate at 1.1 or 2.2 kg than any of the cultivars evaluated, seed of these tolerant PI's should be increased for additional field plantings on ditchbanks.

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