Seed Dormancy and Germination of Switchgrass from Different Row Spacings and Nitrogen Levels[1]

R.E. Mullen, P.C. Kassel, T.B. Bailey, and A.D. Knapp[2]

ABSTRACT

Various levels of seed dormancy in switchgrass (*Panicum virgatum* L.) influence germination results. However, most germination data in switchgrass seed production management studies have not considered seed dormancy. The purpose of this study was to determine whether seed dormancy varies with management practices. Seed dormancy and germination response of three switchgrass cultivars to different row spacing and nitrogen (N) treatments on 2- and 3-year-old stands were examined. Field experiments were conducted in 1979 and 1980 on a predominantly Webster loam (Typic Haplaquoll) soil near Ames, Iowa. Blackwell, Cave-in-Rock, and Pathfinder cultivars were seeded in a clean-tilled seedbed on 18 May 1978 at a rate of 230 seeds m^{1} of row in 20-, 60-, and 100-cm rows and fertilized with 0, 90, and 180 kg ha^{-1} of N. Prechill germination (PG), short-term dormancy (STD), long-term dormancy (LTD), and viable seed did not appreciably differ among cultivars at different row spacings. Prechill germination and STD values increased with additions of N fertilizer to 180 kg ha^{-1} for Cave-in-Rock, but N fertilizer decreased these values for Blackwell and Pathfinder. Seed dormancy and germination among cultivars significantly varied between years. Prechill germination values averaged 37, 48, and 44% in 1979 and 16, 40, and 38% in 1980 for Cave-in-Rock, Blackwell, and Pathfinder, respectively. Short-term dormancy among cultivars was greatest for Cave-in-Rock in 1979 but least in 1980. Long-term dormancy was greater for all cultivars in 1980 than in 1979 and influenced pure live-seed yields. Results indicated that for 2- and 3-year-old stands of cultivated switchgrass, germination and seed dormancy can vary among cultivars, years, and N-levels. The 2-week prechilling treatment commonly used in standard switchgrass germination procedures may not uniformly break seed dormancy for different cultivars.

Additional index words: **native grasses *Panicum vergatum* L., prechill germination, pure live-seed yield, seed quality, tetrazolium test, viable seed, warm germination test, warm-season grasses.**

[1]Journal Paper No. J-11996 of the Iowa Agric. and Home Econ. Exp. Stn., Ames, IA 50011. Project 2470. Received for publication 30 September 1985.

[2]Associate professor, Dept. of Agronomy; extension crop production specialist, Spencer, IA (formerly graduate research assistant); professor, Dept. of Statistics, and associate professor, Dept. of Plant Pathology, Seed and Weed Sciences, Iowa State Univ., Ames, IA 50011, respectively.

INTRODUCTION

Seed dormancy frequently has been observed in switchgrass (*Panicum virgatum* L.) and other warm-season grasses (Blake, 1935; Robocker et al., 1953; Sautter, 1962; Shaidaee et al., 1969). The degree and length of dormancy and treatments necessary to overcome seed dormancy in native grasses vary with species and locations of production. Variable seed dormancy and the resultant variable germination have complicated results of seed-quality experiments in switchgrass.

Switchgrass germination has been improved by exposing seeds to freezing (Blake, 1935) or to a chilling temperature of 10 C (Sautter, 1962; Norris and Decker, 1943). Norris and Decker (1943) suggested that switchgrass germinates best at 17/30 C, or 20/30 C for 16/8 h cycles. Seedlings can be counted at 7, 14, 21, and if needed, 28 days after planting. New seed should be prechilled for 2 weeks at 10 C. This germination procedure was similar to the procedure of the Association of Official Seed Analysts (A.O.S.A.) (Anon., 1978). Combine-harvested and recleaned switchgrass, cv. Pathfinder, seed germinated 84 and 94%, respectively, when a 30-day prechill period at 5 C was used (T.N. Shiflet, 1970). Unpublished studies of germination and seedling growth of switchgrass. Dept. of Agronomy, Univ. of Nebraska, Lincoln NE). Germination values were 30 and 35% less, respectively, when prechilling was not used. Shiflet concluded that prechilling increased the germination percentage of switchgrass seed that was less than 1 year old and increased the germination rate of switchgrass seed stored over 1 year.

Improved germination has been observed for native grass seed stored after harvest. Robocker et al. (1953) reported that germination percentages were greatest 2 years after seed harvest for big bluestem (*Andropogon gerardi* Vitman) and switchgrass and 1 year after seed harvest for indiangrass (*Sorghastrum nutans* (L.) Nash). Hoover et al. (1947) and Wheeler and Hill (1957) reported that switchgrass had 30% germination the year after seed harvest and that germination percentage may double if seeds are stored more than 1 year. Shaidaee et al. (1969) found that 'Grenville' switchgrass seed, 7 years after harvest, had greater field emergence than younger seed. It seems that seed of switchgrass in dry storage for several years may exhibit less dormancy and may be capable of producing better stands in the field.

Cultural practices and other factors have influenced seed quality of switchgrass and other native grasses. Smika and Newell (1968) found that side-oats grama (*Bouteloua curtipendula* Michx.) produced heavier caryopsis weight when grown in 101-cm rows than in solid stands. Kneebone and

Cremer (1955) studied the relationship of seed size to seedling vigor in several native grasses, including buffalograss (*Buchloe dactyloides* Nutt.), indiangrass, side-oats grama, and switchgrass. Switchgrass showed pronounced differences in germination percentages in response to seed size, but other species showed no response. 'Blackwell' switchgrass seed sized on 1.27-, 1.15-, and 1.06-mm screens emerged 82, 64, and 31% respectively, in sphagnum moss. Smaller switchgrass seed also required 7 days longer to germinate than larger seed.

The effect of nitrogen management on seed quality varies with species of native grasses. Austenson and Peabody (1964) found no differences in seed germination tests or purity tests among row spacing or N level treatments in several cool-season species grown for seed. Cosper et al. (1967) that germination of western wheatgrass (*Agropyron smithii* Rydb.) slightly increased as N level increased up to 88 kg ha^{-1}, although the trend was not statistically significant. Smika and Newell (1966) found that seed weight of western wheatgrass was not influenced by N level but that seed weight was increased by irrigation at growth initiation and heading stages of growth. Smika and Newell (1965) also showed that seed weight of side-oats grama was increased by N applications up to 88 kg ha^{-1}.

It is evident from the literature that seed dormancy associated with native grasses can influence germination response and complicate interpretations of treatment effects on seed quality. Primary emphasis of experiments measuring effects of cultural management on seed quality of switchgrass have centered on germination without regard to seed dormancy. Row spacing and nitrogen fertilization are important management considerations for seed production of switchgrass, but little or no information is available on row-spacing or nitrogen-level effects on switchgrass seed dormancy and subsequent germination capability. This study was conducted to compare seed dormancy and germination response of three switchgrass cultivars to three N levels and three row spacings on 2-, and 3-year-old stands.

MATERIALS AND METHODS

Field experiments were conducted in 1979 and 1980 on a predominately Webster Loam (Typic Haplaquoll) soil at the Agronomy and Agricultural Engineering Research Center located near Ames, Iowa. The study site contained some Nicollet loam (Aquic Hapludoll) soil and was blocked accordingly in experimental layout. Blackwell (B), Cave-in-Rock (C), and Pathfinder (P) cultivars of switchgrass were used in the experiment. Cave-in-Rock switchgrass is a bottomland ecotype and was developed by the Soil Conservation Service in Elsberry, Missouri. Selections were initially from southern Illinois. Cave-in-Rock was the tallest cultivar studied, having coarse stems and leaves. Pathfinder switchgrass, a synthetic cultivar and upland ecotype, was developed in Nebraska. It has fine leaves and stems. Blackwell switchgrass is an upland ecotype and was collected in northern Oklahoma on fine-textured soils. It was further developed in Kansas and has vegetative characteristics similar to those of Pathfinder.

Cultivars were seeded in a clean-tilled seedbed on 18 May 1978 at a rate of 230 seeds m^{-1} of row in 20-, 60-, and 100-cm rows, which corresponds to seedling rates of 13.5, 4.5, and 2.7 kg ha^{-1}, respectively. Four-row plots were used in the 20-cm row seedings, and 3-row plots were used in the 60- and 100-cm row seedings. Each plot was 3.7 m in length. After seeding, the soil was firmed with a roller packer, and no fertilizer was applied. Atrazine (2 chloro-4-ethylamino-6-isopropyl amino-1, 3-5-triazine) was applied to plots at a rate of 3.36 kg ha^{-1} active ingredient was a preemergence treatment in 1978 and as a postemergence treatment during spring growth initiation in subsequent years. Hand hoeing was used each year as an additional weed control measure and to maintain row-spacing treatments. Plots were fertilized with urea in May 1979 and 1980 at rates of 0, 90, and 180 kg ha^{-1} of N.

The experimental design consisted of three whole plots replicated three times. Row spacing treatments were randomly assigned to each of the whole plots. Nitrogen treatments were applied in random strips across each whole plot, and cultivars were assigned in random strips perpendicular to N treatments for each whole plot.

Seeds were hand-harvested during 22 to 29 September 1979 and 20 to 27 September 1980. Cave-in-Rock matured approximately 1 week later than Blackwell and Pathfinder cultivars. Harvest was initiated when seed from the top of the panicle had begun to shatter and the seed from lower panicle branches was hard and brown. Seed was harvested from a 3.2 m length of one row in the center of each plot. Harvested inflorescences were dried in a 38 C heated-air oven for 7 days and stored at 10 C until threshed. Inflorescences were threshed with a hammer mill at 850 rpm with a 4.8-mm screen. Seed was cleaned with a Clipper bench-type seed cleaner with a No. 8 (3.0 mm) screen for preliminary cleaning and a No. 6 (2.3 mm) screen for additional cleaning. A 1-mm screen was used as a lower screen in all cleanings. Unthreshed seeds were separated from remaining trash with a 1.8-mm screen, hand threshed, cleaned, and returned to the sample. Seed subsamples were threshed by hand rubbing to remove glumes, sifted in a 1.8-mm screen, and cleaned in an air-column separator.

Standard germination tests, with prechill (PG) and without (WG) prechill, were conducted on units of 100 seeds (A.O.S.A. Anon., 1978). Seeds were planted on blotter paper moistened with 0.2% KNO_3. Seeds were prechilled at 5 C for 2 weeks. The germination test was conducted in growth chambers set at 15/30 C temperatures for 16/8 h cycles for 28 days with light during the warm cycle, according to A.O.S.A. (Anon., 1978) specifications. Germination was counted at 7, 14, 21, and 28 days after planting. Seed germination was defined according to A.O.S.A. (Anon., 1978). Ungerminated firm seeds from the prechill test were cut in half and stained with 0.1% tetrazolium to determine viability. Seed viability (V) was expressed by the equation, $V = c + t$, in which c = germinated seeds (prechill test) per 100 seeds, and t = ungerminated firm seeds per 100 seeds that were alive based on the tetrazolium test. Seed dormancy was divided into short-term (STD) and long-term (LTD) dormancy in which STD = prechill test % - warm test % and

Table 1. Mean squares for seed quality measurements.

Source	Degree of Freedom	Prechill germination 1979	Prechill germination 1980	Short-term dormancy 1979	Short-term dormancy 1980	Long-term dormancy 1979	Long-term dormancy 1980	Total seed viability 1979	Total seed viability 1980
Replication	2	286	759	28	534	20	282	286	116
Row Spacing (S)	2	236	39	100	13	16	12	118	47
Error A	4	113	147	95	128	7	90	147	84
Cultivar (V)	2	896**	4788**	714**	3714**	1353**	9607**	217*	895*
CvsPB†	(1)	1513*	9491*	1300*	7428*	2705*	18517*	172*	1494*
PvsB	(1)	280*	86	128	0	0	697*	262*	294*
V x S	4	63	75	82	75	14	39	37	68
CvsPB x S-linear	(1)	78	3	1	1	49*	118*	3	84
Error B	12	43	79	69	83	8	37	43	58
Nitrogen (N)	2	137	136	49	66	1	15	156	241
N x S	4	30	41	144	78	2	42	23	20
Error C	12	125	152	50	118	24	67	92	69
V x N	4	132*	123	139**	89	7	80	102	62
CvsPB x N-Linear	(1)	184*	352*	247*	290*	2	30	149	176
V x N x S	8	42	14	56	33	7	55	19	56
Error D	24	46	48	25	54	12	46	45	66

*, ** Significant at .05 and .01 levels, respectively.

† C, P, and B represent Cave-in-Rock, Pathfinder and Blackwell cultivars, respectively.

LTD = V - prechill test %. Pure live-seed yields were calculated by multiplying the percentage germination (prechill test) by the amount of pure seed harvest per plot.

The effects of cultivars, row spacing and nitrogen, and their interactions were tested by using analysis of variance (ANOVA) F-tests. Treatment and interaction effects were tested at $P \leq 0.05$ except where noted. Whenever cultivar by row spacing, or cultivar by nitrogen, interaction effects were significant, they were interpreted by partitioning the degrees of freedom and sums of squares into meaningful comparisons.

RESULTS AND DISCUSSION

Prechill germination (PG), short-term dormancy (STD) and viable seed (V) means did not differ among cultivars at

Table 2. Long-term seed dormancy of switchgrass cultivars grown in three row spacings.

Cultivar	Year	Row spacing (cm) 20	60	100
		(%)		
Cave-in-Rock	1979	11.2	14.7	14.9
	1980	54.4	52.1	51.4
Blackwell	1979	1.6	1.4	0.8
	1980	16.0	17.4	17.6
Pathfinder	1979	1.0	2.2	1.0
	1980	22.1	23.3	27.1

Table 3. Prechill test and short-term seed dormancy values for switchgrass cultivars fertilized at three N levels.

Test	N-level	Cave-in-Rock 1979	Cave-in-Rock 1980	Blackwell 1979	Blackwell 1980	Pathfinder 1979	Pathfinder 1980
	(kg ha $^{-1}$)	(%)					
Prechill test	0	35.3	14.5	53.1	44.5	48.7	43.4
	90	38.9	16.2	43.6	37.1	42.7	37.0
	180	36.8	18.1	48.7	39.8	40.3	33.5
Short-term dormancy	0	26.3	12.8	23.0	38.3	26.4	39.5
	90	31.8	15.0	15.8	33.0	22.3	33.9
	180	30.1	16.9	19.3	34.3	18.6	32.1

different row spacings in either year of the experiment. Long-term dormancy (LTD) varied among cultivars at different row spacings (Table 1). The orthogonal contrast of Cave-in-Rock versus Blackwell and Pathfinder at different row spacings was significant for 1979 and 1980, but the maximum range of differences in LTD was within 5 percentage points and was not considered to be of practical significance (Table 2). The results show that row spacing treatments in this study had little or no influence on seed germination and dormancy of switchgrass.

Cultivar values for PG and STD were influenced by N level (Table 1). Prechill test and STD values for Cave-in-Rock increased with added N, but these values decreased for Blackwell and Pathfinder with additions of N fertilizer (Table 3). Cave-in-Rock was lodging resistant, but Blackwell and Pathfinder lodged throughout the study regardless of row spacing or N level. Possibly, N additions accentuated lodging effects for Blackwell and Pathfinder, resulting in poor seed fill and decreases in seed quality; however, this seems unlikely because cultivar values for 100-seed-weight were not influenced by N level (Kassel et al., 1985).

A significant year X variety interaction was obtained in a combined-year ANOVA (data not shown). The greatest variation obtained in means of seed quality measurements in both years was due to cultivars, and most of the variation was accounted for in the orthogonal comparison of Cave-in-Rock versus Blackwell and Pathfinder (Table 1). Prechill germination values averaged 37, 48, and 44% in 1979 and 16, 40, and 38% in 1980 for Cave-in-Rock, Blackwell and Pathfinder, respectively (Fig. 1). Blackwell differed from Pathfinder in PG in 1979 but not in 1980 (Table 1).

Germination values were appreciably less than those reported in the literature and those advertised for switchgrass in industry. Environmental factors, cultivar, age of seed, or different germination testing procedures may have contributed to the higher germination values reported elsewhere for switchgrass. The majority of switchgrass seed is produced in states receiving less rainfall than Iowa. Possibly, less rainfall and humidity increases subsequent germination values of switchgrass. Sautter (1962) reported 84% germination for scarified seeds of switchgrass and Shaidaee et al. (1969) reported 90% germination of Greenville switchgrass in 2 out of 3 years using alternating temperatures of 30 C for 16 h and 20 C for 8 h. Low prechill test germination values may also be related to seed size of switchgrass. Kneebone and Cremer (1955) observed slower emergence and reduced germination percentages with smaller seed. Possibly, decreased seed weights of switchgrass seed in this experiment contributed to reduced PG values. Seed weights in this experiment ranged from 110 to 130 mg for 100 seeds. Expected 100-seed-weights of switchgrass range from 120 mg per 100 seeds (Atkins and Smith, 1967) to 180 mg per 100 seeds (A.O.S.A., Anon., 1978). Seed weights of switchgrass may have been below the critical level necessary for high germination in this experiment.

The large difference in PG values observed between Cave-in-Rock and the other two cultivars support conclusions by Shaidaee et al. (1969) that differences in germination ability exist among cultivars. Cultivar differences in PG were related to seed dormancy. Although PG values in both years were lowest for Cave-in-Rock, this cultivar had the highest percentage of viable seed (Fig. 1). These results indicate that the greatest amount of seed dormancy was associated with Cave-in-Rock. Cave-in-Rock is a lowland ecotype, and Blackwell and Pathfinder are upland ecotypes. Possibly, seed dormancy was associated with differences in growth characteristics or adaptation between lowland and upland ecotypes.

Short-term dormancy in our study was the total amount of seed dormancy that was broken with a 2-week prechilling treatment conducted in accordance with A.O.S.A. (Anon., 1978) standards. Long-term dormancy was the remaining viable, but nongerminated seeds after the conclusion of the prechill germination test. In 1979, STD accounted for 86% of the total seed dormancy of Cave-in-Rock and was significantly greater than the STD for Blackwell and Pathfinder. For Cave-in-Rock in 1980, however, STD accounted for only 25% of the total seed dormancy and was significantly lower that STD for Blackwell and Pathfinder. Long-term dormancy was greater for all cultivars in 1980 than in 1979

Table 4. Prechill test germination values and calculated pure live seed yields of three switchgrass cultivars for different testing dates.

Date of harvest	Cultivar	Pure seed yield	Germination	PLS yield[b/]	Germination	PLS yield
			Tested: 4-1-80[a/]		Tested: 5-1-81	
		(kg ha^{-1})	(%)	(kg ha^{-1})	(%)	(kg ha^{-1})
22-29 Sept. 1979	Cave-in-Rock	1002	37	371	75	752
	Blackwell	289	48	139	58	168
	Pathfinder	287	44	126	67	192
			Tested: 2-1-81		Tested: 5-1-81	
			(%)	(kg ha^{-1})	(%)	(kg ha^{-1})
20-27 Sept. 1980	Cave-in-Rock	813	16	130	31	252
	Blackwell	349	40	140	60	209
	Pathfinder	491	38	187	56	275

[a/] Germination was tested in accordance with Association of official Seed Analysts (1978) standards.
[b/] PLS = Pure live seed
PLS yield = (kg of pure seed harvested) x (% prechill test germination ÷ 100)

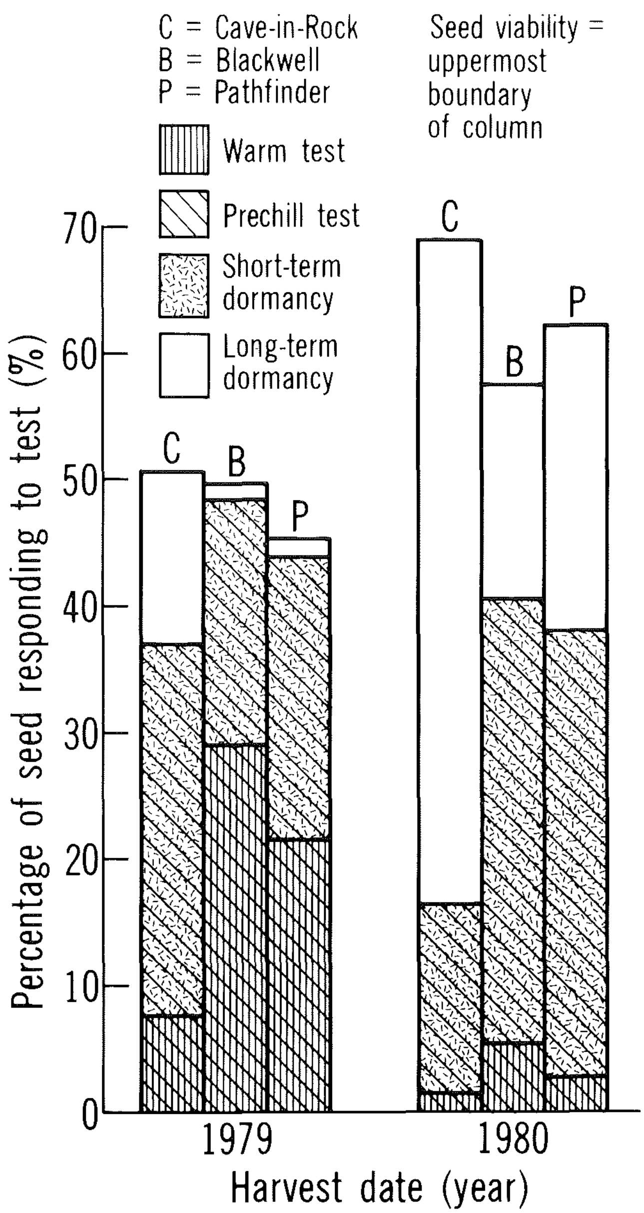

Figure 1. Seed quality of three switchgrass cultivars harvested in 1979 and 1980 and tested in April, 1980 and in February, 1981. Values are averaged over row spacings and nitrogen levels.

(Table 1 and Figure 1). Results indicate that STD and LTD for switchgrass can vary among cultivars and years. It also appears that the 2- week prechilling treatment recommended for switchgrass germination by A.O.S.A. may not uniformly break seed dormancy of seed from different cultivars. Rules by the A.O.S.A. acknowledge that dormant seeds may remain at the end of the germination test for switchgrass.

The increased amounts of LTD obtained in all cultivars in 1980, compared with 1979, may be related to seed storage time. Seed harvested in 1980 was in dry storage approximately 8 weeks less than seed harvested in 1979 before initial germination testing. Germination tests conducted on 1 May 1981 resulted in increased PG values for all cultivars, with increases ranging from 20 to 100% (Table 4). The improved PG observed for older seed would lower LTD and suggests that a period of storage is needed for maximum germination. Blake (1935), Robocker et al. (1953), and 1 Coukos (1944) have also shown increased germination values of switchgrass with increased time in dry storage. The failure of the 2-week prechilling treatment to adequately break switchgrass seed dormancy in this study indicates that pure live seed (PLS) yields of freshly harvested seed would increase with additional storage time. PLS yields obtained in 1979 increased for all cultivars and more than doubled for Cave-in-Rock when PLS yield was calculated from the higher germination values obtained from the later testing date (Table 4). Frequently, switchgrass seed is marked on a PLS basis, and the reduced dormancy and resulting improvement in germination with additional storage time observed in this study would be of obvious importance to firms or buying and selling seed. The greater initial seed dormancy and greater rate of improvement in germination with additional storage time for Cave-in-Rock compared with Blackwell or Pathfinder (Table 4) also indicates that time between harvest and maximum germination of seed in storage will vary among cultivars.

In our study, seed viability was determined by tetrazolium staining of ungerminated seeds remaining from the PG test. Viability of switchgrass seed harvested in 1979 and measured on 1 April 1980 was 51% or less for all cultivars (Fig. 1), but when PG tests were conducted on the same seedlots on 1 May 1981, PG values ranged from 58% for Blackwell to 75% for Cave-in-Rock (Table 4). The method of determining viability in our study underestimated the germination of seeds after a storage period. Recent rule changes for germination procedures (Anon., 1985) require that the viabiity of ungerminated seed remaining at the end of the germination test be evaluated. For switchgrass, a tetrazolium test on "fresh" seed before germination may be a better indication of potential viability than a tetrazolium test on the ungerminated seed remaining after the germination test. Additional work would be necessary to identify the best method of tetrazolium testing for determining viability of switchgrass seedlots.

Results of this study indicated that row spacing was not an important factor influencing germination and seed dormancy. Nitrogen fertilizer did influence germination and STD, but the N response varied among cultivars. Nitrogen fertilizer improved germination and decreased dormancy of recently harvested seed of the lowland ecotype, Cave-in-Rock, but not of the upland ecotypes, Blackwell and Pathfinder. Row spacing and nitrogen treatments in this study were imposed on 2- and 3-year-old cultivated stands, and results may differ for older or noncultivated stands of switchgrass. Long-term seed dormancy was greatest for Cave-in-Rock in both years, and subsequent improvement in germination of Cave-in-Rock during storage was greater than for Blackwell and Pathfinder. The amount of short-term dormancy and the effectiveness of a 2-week prechilling treatment in breaking seed dormancy will vary with cultivars and years. Tetrazolium staining of ungerminated seeds remaining after the conclusion of the prechill germination test may underestimate germination potential of switchgrass seeds after a period of storage.

REFERENCES

1. Anonymous. 1978. Rules for testing seeds. Association of Official Seed Analysts. J. Seed Technol. 3(3):29-118.
2. Anonymous. 1985. Association of Official Seed Analysts. Newsletter. 59(3):43-50.
3. Atkins, M.D., and J.E. Smith, Jr. 1967. Grass seed production and harvest in the Grain Plains. U.S. Dept. Agric. Farmers Bull. 2226.
4. Austenson, H.M., and D.V. Peabody, Jr. 1964. Effects of row spacing and time of fertilization on grass seed production. Agron. J. 56:461-463.
5. Blake, A.B. 1935. Variability and germination of seeds and early life history of prairie plants. Ecol. Monogr. 5:405-460.
6. Cosper, H.R., J.R. Thomas, and A.Y. Alsayeh. 1967. Fertilization and its effect on range improvement in the Northern Great Plains. J. Range Mange. 20:216-222.
7. Coukos, C.J. 1944. Seed dormancy and germination in some native grasses. J. Am. Soc. Agron. 36:337-345.
8. Hoover, M.M., J.E. Smith, A.L. Ferber, and D.R. Cornelius. 1947. Seed for regrassing Great Plains areas. U.S. Dept. Agric. Farmers Bull. 1985.
9. Kassel, P.C., R.E. Mullen, and T.B. Bailey. 1985. Seed yield response of three switchgrass cultivars for different management practices. Agron. J. 77:214-218.
10. Kneebone, W.R., and C.L. Cremer. 1955. The relationship of seed size to seedling vigor in some native grass species. Agron. J. 47:472-477.
11. Norris, E.L., and A. Decker. 1943. Report of the committee on range grass studies. Proc. Assoc. Off. Seed Anal. 35:63-67.
12. Robocker, W.C., J.T. Curtis, and H.L. Ahlgren. 1953. Some factors affecting emergence and establishment of native grass seedlings in Wisconsin. Ecology 34:194-199.
13. Sautter, E.H. 1962. Germination of switchgrass. J. Range Mange. 15:108-110.
14. Shaidaee, G., B.E. Dahl, and R.M. Hansen. 1969. Germination and emergence of different age seed of six grasses. J. Range Mange. 22:240-243.
15. Smika, D.E., and L.C. Newell. 1965. Irrigation and fertilization practices for seed production from established stands of side-oats grama. Nebr. Agric. Exp. Stn. Res. Bull. 218.
16. Smika, D.E., and L.C. Newell. 1966. Cultural practices for seed production from established stands of western wheatgrass. Nebr. Exp. Stn. Res. Bull. 223.
17. Smika, D.E., and L.C. Newell. 1968. Seed yield and caryopsis weight of side-oats grama as influenced by cultural practices. J. Range Mange. 21:402-404.
18. Wheeler, W.A., and D.D. Hill. 1957. Great Plains Grasses. pp. 591-592. *In* Grassland seeds. D. Van Nostrands Co., Inc., New York.

Effect of Pesticide Residues in Alfalfa Pollen and Nectar on the Foraging and Reproduction Activities of Alfalfa Leafcutting Bees *Megachile rotundata*[1]

C.M. Rincker and D.A. George[2]

ABSTRACT

Foraging and reproduction activities of alfalfa leafcutting bees (*Megachile rotundata* F.) were not affected when alfalfa was treated with various insecticides. Treatments consisted of recommended and 1.5 times recommended rates of demeton, oxydemeton-methyl, aldicarb, trichlorfon, dimethoate and carbofuran applied to alfalfa grown for seed in 1980 and 1981. Exposure of the bee larvae to insecticide residues in the pollen-nectar ball within the reproductive cell did not adversely affect percent live larvae nor emergence and flight of bees in the succeeding year.

***Additional index words: Medicago sativa,* seed production, pollinators, insecticides.**

[1]Contribution of Agricultural Research Service, USDA. Received 19 Sept. 1985.

[2]Research Agronomist, Agricultural Research Service, USDA, Irrig. Agric. Res. & Ext. Center, Prosser, WA 99350, and Research Chemist, Agricultural Research Service, USDA, Yakima Agric. Res. Lab., Yakima, WA 98902.

INTRODUCTION

Alfalfa leafcutting bees *(Megachile rotundata* F.) are one of the most important pollinators of alfalfa grown for seed in the Pacific Northwest (McGregor, 1976). Seed growers, therefore, must use considerable care to protect these bees from toxic insecticides applied to seed fields for control of insects detrimental to seed production. Use of insecticides is even more of concern to seed growers since leafcutting bees are more susceptible to most insecticides than either honey bees (*Apis mellifera* L.) or alkali bees (*Nomia melanderi* Ckll) (Johansen 1983; Capizzi et al., 1982).

George and Rincker (1982) reported residues of demeton (Systox ®), trichlorfon (Dylox®), dimethoate (Cygon®), carbofuran (Furadan®), and/or their respective metabolites were found in the pollen-nectar ball collected by leafcutting bees. Waller (1969) studied the susceptibility of alfalfa leafcutting bees to various insecticides. He found azinphosmethyl (Guthion®) most toxic and carbaryl (Sevin®) least toxic. More recently we found residues of oxydemeton-methyl (Metasystox-R®) and it's metabolite in pollen-nectar balls.

Leafcutting bees collect pollen and nectar from flowering