

J. Range Manage.
45:175-179, March 1992

Germination of prechilled mechanically scarified and unscarified Indian ricegrass seed

T.A. JONES AND D.C. NIELSON

Authors are research geneticist and entomologist, USDA-ARS, Forage and Range Research Laboratory, Logan, Utah 84322-6300.

Abstract

Seed dormancy typically limits stand establishment of Indian ricegrass [*Oryzopsis hymenoides* (Roem. and Schult.) Ricker]. The mechanical and physiological mechanisms that contribute to dormancy must both be overcome before germination. Our objective was to study potential interactions between the breaking of mechanical dormancy and breaking of physiological dormancy. Germination of 13 seedlots of 'Nezpar', 'Paloma', and PI 478833, ranging in age from 4 to 19 years and in viability from 67 to 96%, was tested. Seed was scarified with an air-gun scarifier to reduce mechanical dormancy approximately 2 1/2 years before testing, or left unscarified. Over 77% of seeds remained intact following scarification. Seed was moved from 5° C to room temperature 1 year before testing to reduce physiological dormancy, or left refrigerated. Seed was also prechilled for 3 weeks at 5° C to reduce physiological dormancy, or left nonprechilled. Germination was determined after 2-week and 3-week 15° C germination periods for prechilled and nonprechilled treatments, respectively. Scarification improved germination of undamaged seed in 12 of the 13 seedlots from 9.5 to 29.7%. Prechilling improved germination of 10 of the 13 seedlots from 8.0 to 22.8%. Room-temperature storage improved germination of 5 seedlots from 4.9 to 12.8%. In 9 seedlots prechilling improved germination of scarified seed 13.1% less than unscarified seed. In 4 seedlots room-temperature storage improved germination of scarified seed 6.5% less than unscarified seed. Depending on the vigor of the seedlot, such effects may be related to a greater reduction of either physiological dormancy or viability in scarified seed than in unscarified seed.

Key Words: embryo dormancy, mechanical dormancy, Nezpar, Paloma, physiological dormancy, seed coat dormancy

Contribution of Utah Agr. Exp. Sta., Journal Paper 4060, and USDA-ARS, Forage and Range Research Laboratory.

Appreciation is extended to L. W. Griffith and D. T. Booth of the USDA-ARS High Plains Grassland Research Station, Cheyenne, Wyo. for scarifying the seed. We also wish to thank Rhonda Pace, who planted most of the 44,000 seeds for this study. Thanks also to Ray Brown of the USDA-FS Intermountain Research Station, Logan, Utah, for determining soil matric potentials.

Manuscript accepted 11 May 1991.

Indian ricegrass [*Oryzopsis hymenoides* (Roem. and Schult.) Ricker], an important species for revegetation of western USA rangelands, typically exhibits high levels of seed dormancy. Early research (Huntamer 1934) indicated that mechanical and physiological mechanisms are involved. Seed dormancy is an important cause of the poor stand establishment that has limited use of this species. Mechanical dormancy, resulting from the exclusion of O₂ by the indurate lemma and palea (Toole 1940), is more persistent than physiological dormancy (McDonald 1976). Physiological dormancy decreases over time, but storage at low humidity and temperature slows the process (Robertson 1976, McDonald and Khan 1977). Physiological dormancy is of less concern when fall seeding is practiced, as is common in the Intermountain region, because it can be broken by cool, moist field conditions (Stevens and Meyer 1990). A better understanding of the relationship between mechanical and physiological mechanisms may lead to improved procedures for breaking seed dormancy.

Physiological dormancy has been reduced by aging seed (Rogler 1960), fall planting (Fendall 1966), prechilling (Huntamer 1934, Toole 1940, Clark and Bass 1970), and application of growth regulators such as kinetin and gibberellic acid (Clark and Bass 1970, McDonald 1976, Young et al. 1985). Mechanical dormancy has been reduced by mechanical and acid scarification, but scarification increases germination at the expense of seed quality. Early workers (Huntamer 1934, Stoddart and Wilkinson 1938) eliminated mechanical dormancy by manually dissecting the lemma and palea, but more recently mechanical scarification has been employed. Zemetra et al. (1983) treated 3 seedlots with a tumbler scarifier, a Forsberg Line scarifier, and a rubbing machine and evaluated field emergence in a November-planted trial in western Colorado. The rubbing machine increased emergence of 1 seedlot from 15.0 to 23.7%, but otherwise scarification did not improve emergence. Scarification with an air-gun scarifier gave better germination with less seed damage than a Forsberg Model 2 Hüller/Scarifier or Quaker Oats Experimental Impact Dehuller (Griffith and Booth 1988). Adjustment of combine harvesters to crack the lemma and palea has also been used to mechanically scarify

seed (Robertson 1976). Extensive research has been conducted on acid scarification (Stoddard and Wilkinson 1938, Plummer and Frischknecht 1952, McDonald 1976, Young et al. 1985). Seed damage during acid scarification can probably be reduced by adjusting length of treatment to seed size (Stoddard and Wilkinson 1938) or to lemma thickness (Zemetra and Cuany 1984).

While germination of naked seed is considerably higher than seed with lemma and palea intact (Young and Evans 1984, Jones et al. 1988), naked seed are susceptible to fungal and bacterial disease. The disease resistance conferred by the lemma and palea has been attributed to phenolic compounds (M.B. McDonald, Jr., pers. comm.). McDonald (1976) successfully controlled disease in the laboratory with 40% maneb (manganese ethylenebisdithiocarbamate) applied as a dust or slurry. Poor field establishment of acid-scarified seed despite dusting was attributed to deterioration of the lemma and palea over winter (Zemetra et al. 1983). Lemmas and paleas of intact mechanically scarified seed may be more persistent over winter than those of acid-scarified seed. This suggests a possible advantage of mechanical over acid scarification for field establishment.

Toole (1940) concluded acid scarification reduced physiological dormancy as well as mechanical dormancy because some scarified seedlots exhibited enhanced germination despite persistent lemmas and paleas. Griffith and Booth (1988) suggested loss of dormancy in recently harvested seed could be accelerated by scarification before storage. Shaw (1976) found that prechilling more effectively broke dormancy of naked seed than intact seed. These results suggest that breaking mechanical dormancy may accelerate the loss of physiological dormancy. To understand the impact of scarification on subsequent levels of physiological dormancy we measured germination response in 13 seedlots to mechanical scarification, prechilling, and room-temperature storage.

Materials and Methods

Seedlots of Nezpar (4), Paloma (5), and PI 478833 (4) were obtained spring 1987 from USDA-SCS Plant Materials Centers in Aberdeen, Ida.; Los Lunas, N.M.; and Bridger, Mont., respectively. All 3 genotypes are increases of populations collected from

native sites. Nezpar (White Bird, Ida.) seedlots, designated 'NZ', were produced in 1980, 1983, 1985, and 1986 at Aberdeen and stored at 20° C and 40% relative humidity. Paloma (Florence, Colo.) seedlots, designated 'PA', were produced in 1971, 1973, 1980/1981 (bulk), 1982, and 1984 and stored at Los Lunas at 15° C and 30% relative humidity. PI 478833 (Yellowstone Co., Mont.) lots, designated 'PI', were produced in 1977/1978 (bulk), 1980, 1981, and 1982 and stored at Bridger in a barn without temperature or humidity control.

After seed was obtained, it was cleaned with a South Dakota seed blower, alcohol-separated (Stoddard and Wilkinson 1938), and refrigerated at 5° C until scarification. Each seedlot was divided into 4 equal samples. Two samples were scarified with an air-gun scarifier (Booth and Griffith 1984) on 17 July 1987 and 2 others were left unscarified. The scarifier was lined with 24-grade sanding cloth and operated at an air pressure of 345 kPa (50 psi) for 15 s per sample. After scarification samples were recleaned with the seed blower. To assess seed damage from scarification, the cleaned sample was subsampled and approximately 3 g was separated into components of intact, naked, and damaged seed. The terms "intact" and "naked" refer to the presence and absence of the lemma and palea, respectively. Damaged seeds were split or chipped in addition to being naked.

After post-scarification cleaning, the seed was refrigerated until 28 March 1989 when 2 of the 4 samples of each seedlot, 1 scarified and 1 unscarified, were placed at room temperature for approximately 1 year until germination testing began. The 2 remaining samples were kept refrigerated. Thus for each of 13 seedlots we generated 4 sublots: unscarified/refrigerated storage, unscarified/room-temperature storage, scarified/refrigerated storage, and scarified/room-temperature storage. In addition, sublots were nonprechilled or prechilled before germination as described below. Thus 8 treatments were applied in a 2 × 2 × 2 factorial (2 levels each of scarification, prechilling, and storage temperature) to the 13 seedlots.

Germination boxes were filled with 250 g sand, planted with 100 intact seed of a subplot using a vacuum seed head, covered with a blue blotter, and watered with 60 ml tapwater. This created a soil

Table 1. Germination of 8 scarification (SC), prechill (PC), and room-temperature storage (RTS) treatments, contrasts between treatments, and viability of 4 Nezpar seedlots.

1980			1983			1985			1986		
Treatment	---%---		Treatment	---%---		Treatment	---%---		Treatment	---%---	
SC PC RTS			SC PC RTS			SC PC RTS			SC PC RTS		
SC PC RTS	44		SC RTS	24		SC PC RTS	52		SC RTS	34	
SC PC	40		SC PC	24		SC PC	48		SC PC	29	
SC	37		SC PC RTS	21		SC RTS	41		SC PC RTS	27	
SC RTS	36		SC	17		SC	30		SC	25	
PC RTS	21		PC	7		PC RTS	28		PC RTS	6	
PC	21		PC RTS	6		RTS	18		PC	5	
RTS	17		RTS	3		PC	14		RTS	4	
	5			1			4			2	
Contrast ¹											
SC	32**			16**			26**			23**	
PC	15**			6**			11**			ns	
RTS	12**			ns			14**			ns	
SC × PC	13**			ns			ns			ns	
SC × RTS	13**			ns			3+			ns	
PC/SC	ns			6+			19**			ns	
RTS/SC	ns			7+			11*			9+	
Tz ²	91			91			96			93	

*, **, ***Significant at $P < 0.10$, 0.05 , and 0.01 , respectively.

¹Contrasts describing the increase (+) or decrease (-) of germination by SC, PC, and RTS relative to unscarified, nonprechilled, refrigerated seed, by PC (SC × PC) or RTS (SC × RTS) of scarified seed relative to unscarified seed, and PC (PC/SC) or RTS (RTS/SC) of scarified seed relative to scarified, nonprechilled, refrigerated seed.

²Tetrazolium viability.

matric potential of approximately -0.17 MPa (R. W. Brown, pers. comm.), which is in the desirable range for field-collected soil (Blank and Young 1990). Four boxes (replications) were planted for each treatment for each seedlot. Nonprechilled treatments were germinated at 15° C with a 9-hour photoperiod and germination was recorded after 3 weeks. Prechilled treatments were placed in a dark 5° C refrigerator for 3 weeks and then transferred to a 15° C germination chamber with a 9-hour photoperiod. Counts were made 2 weeks later, instead of 3 weeks, as for the nonprechilled treatments, because water imbibition was previously accomplished during prechilling. Testing of Nezpar, PI 478833, and Paloma lots began 12 Feb., 15 Feb., and 30 Mar. 1990, respectively. Tetrazolium viability was determined by the Utah state seed laboratory, Salt Lake City, on 200-seed samples of unscarified, nonprechilled, refrigerated seed.

Seed of Nezpar, Paloma, and PI 478833 was produced at Providence, Utah, to compare seed dormancy of these 3 genotypes when produced in a common environment. Seed was harvested from replicated plots 15 Sep. 1989 and stored at room temperature until germination tests began 26 Feb. 1990. Prechill and nonprechill treatments were applied to 4 boxes (replications) as above for each genotype. Counts for nonprechilled boxes were made at 5 weeks. Counts for prechilled boxes were also made at 5 weeks (2 weeks after a 3-week prechill).

All data were transformed with an arcsine transformation prior to analysis, but reported means were calculated for untransformed data. Responses to scarification, prechilling, and room-temperature storage relative to the unscarified, nonprechilled, refrigerated control were evaluated with single degree-of-freedom contrasts. Contrasts were also used to evaluate the relative impact of prechilling and room-temperature storage on scarified vs. unscarified seed and on scarified seed alone. Means were separated in both experiments with the Bayes L.S.D. at *k* ratio = 100 (Smith 1978).

Results and Discussion

Mechanical damage by the air-gun scarifier was similar to that of Griffith and Booth's (1988) once-treated seed. Approximately 78% (SD = 10%) of the seed remained intact and approximately 7% (SD

= 4%) were damaged. The remaining 16% (SD = 7%) were naked.

Tetrazolium viability ranged from 67 to 96%, with only PA 1980/81, PA 1982, and PI 1977/78 less than 85%. Germination of seedlots by treatment ranged from 1 to 52% for Nezpar (Table 1), 5 to 44% for Paloma (Table 2), and 4 to 38% for PI 478833 (Table 3). When seed was unscarified and nonprechilled, older seedlots generally germinated best (Table 5). Rogler (1960) found that germination increased through 6 years of storage across 50 strains of Indian ricegrass, then declined as decreases in viability exceeded decreases in dormancy. The difference between germination and viability is considered to be dormancy remaining after any particular seed treatment plus seed mortality resulting from the germination test itself (Ebener 1988). The former should be more important in newer seedlots than older seedlots and the latter more important in older seedlots than newer seedlots of Indian ricegrass.

For valid comparison of seed dormancy among genotypes, seed must be produced in a common environment. In the Providence experiment, germination of prechilled seed was 39, 25, and 14% for Paloma, Nezpar, and PI 478833, respectively, each significantly different (*k* ratio = 100). Germination without prechill was less than 1% for all 3 genotypes, demonstrating the high physiological dormancy typical of new seed.

Scarification (SC contrast) significantly increased germination of 12 of the 13 seedlots from an average of 9.5 to 29.7%, indicating that mechanical dormancy was inhibiting germination of those seedlots. The oldest seedlots, e.g., PA 1971, PA 1973, and PI 1977/78, showed the least response to scarification. McDonald and Khan (1977) and Young et al. (1985) also found that old seed required less acid scarification than new seed.

Either prechilling (PC contrast) or room-temperature storage (RTS contrast), practices which reduce physiological dormancy, effectively increased germination of 10 seedlots. The importance of physiological dormancy in these 10 lots, ranging from 5 to 12 years old when tested, seems to contradict McDonald's (1987) assertion that physiological dormancy does not persist in seed older than 1 year. All seedlots responsive to room-temperature storage were also responsive to prechilling, but 5 seedlots responsive to prechilling were nonresponsive to room-temperature storage. Physiologi-

Table 2. Germination of 8 scarification (SC), prechill (PC), and room-temperature storage (RTS) treatments, contrasts between treatments, and viability of 5 Paloma seedlots.

Treatment	1971			1973			1980/81			1982			1984		
	SC	PC	RTS	SC	PC	RTS	SC	PC	RTS	SC	PC	RTS	SC	PC	RTS
SC	44			39			36			33			44		
SC	41			34			35			32			43		
PC		40			34			34			31			34	
PC		39			33			32			27			34	
PC		37			32			30			25			33	
PC		35			32			30			23			28	
PC		32			29			17			13			11	
PC		31			28			16			11			5	
Contrast ¹															
SC	9+			ns			13**			16**			28**		
PC	ns			ns			17**			14**			23**		
RTS	ns			ns			ns			ns			6**		
SC × PC	17*			ns			11*			10*			14**		
SC × RTS	ns			ns			ns			ns			6*		
PC/SC	-10+			ns			7+			ns			9*		
RTS/SC	ns			ns			ns			ns			ns		
Tz ²	90			85			80			67			92		

*,**,***Significant at *P* < 0.10, 0.05, and 0.01, respectively.

¹Contrasts describing the increase (+) or decrease (-) of germination by SC, PC, and RTS relative to unscarified, nonprechilled, refrigerated seed, by PC (SC × PC) or RTS (SC × RTS) of scarified seed relative to unscarified seed, and PC (PC/SC) or RTS (RTS/SC) of scarified seed relative to scarified, nonprechilled, refrigerated seed.

²Tetrazolium viability.

Table 3. Germination of 8 scarification (SC), prechill (PC), and room-temperature storage (RTS) treatments, contrasts between treatments, and viability of 4 PI 478833 seedlots.

1977/78		1980		1981		1982	
Treatment	---	Treatment	---	Treatment	---	Treatment	---
SC PC RTS	%	SC PC RTS	%	SC PC RTS	%	SC PC RTS	%
PC	34	SC PC	38	SC PC	32	SC PC RTS	31
SC	32	SC PC RTS	33	SC PC RTS	31	SC PC	27
SC RTS	29	SC	32	SC	26	PC RTS	25
PC RTS	28	SC RTS	28	SC RTS	25	SC RTS	24
RTS	24	PC RTS	21	PC RTS	23	SC	23
SC PC	23	PC	21	PC	19	PC	22
SC PC RTS	22	RTS	7	RTS	4	RTS	8
	20		7		7		4
Contrast ¹							
SC	13**		25**		22**		20**
PC	14**		14**		15**		19**
RTS	ns		ns		3*		5*
SC × PC	23**		8*		9*		15**
SC × RTS	ns		ns		4+		ns
PC/SC	-9*		ns		7*		ns
RTS/SC	ns		ns		ns		ns
T ₂ ²	71		96		92		85

*, **, ***Significant at P<0.10, 0.05, and 0.01, respectively.

¹Contrasts describing the increase (+) or decrease (-) of germination by SC, PC, and RTS relative to unscarified, nonprechilled, refrigerated seed, by PC (SC × PC) or RTS (SC × RTS) of scarified seed relative to unscarified seed, and PC (PC/SC) or RTS (RTS/SC) of scarified seed relative to scarified, nonprechilled, refrigerated seed.

²Tetrazolium viability.

cal dormancy was broken more effectively by prechilling than by 1 year of room-temperature storage.

We included storage temperature as a variable based on results of Griffith and Booth (1988). They found that germination at 20° C of a newly harvested seedlot scarified with the Quaker Oats Impact Dehuller increased from 10.4 to 20.7% after 2 years storage at 5° C. However, germination of their unscarified control did not increase after storage. In contrast, germination of a 6-year-old seedlot increased more after storage when unscarified, from 4.8 to 23.7%, than when scarified, from 29.6 to 42.0%. The difference between the response of the 2 seedlots to scarification over time was attributed to "differential aging" in storage, i.e., aging reduced primarily viability in the older seedlot but primarily dormancy in the newer seedlot. Regardless of whether this interpretation is correct, both seedlots germinated best when scarified prior to storage. Additionally, both seedlots increased germination following the 2-year 5° C storage period more when scarified than unscarified. On the basis of their results, Griffith and Booth (1988) suggested scarification of new seed before storage to increase germination. Although they

did not interpret their results in terms of mechanical and physiological dormancy, their results suggest that disruption of mechanical dormancy in new seed facilitates loss of physiological dormancy. If so, scarification followed by storage would probably be most effective in new seedlots because both physiological dormancy and viability are high.

Prechilling improved germination significantly less for scarified seed than unscarified seed (SC × PC contrast) in 9 seedlots by 13.1%, while the contrast in the remaining 4 seedlots was nonsignificant. The effect of room-temperature storage was lower for scarified seed (SC × RTS contrast) for 4 seedlots, while not significantly different for the remaining 9 seedlots. Again, prechilling had a greater impact than 1 year of room-temperature storage.

Two alternative hypotheses can explain these interactions (SC × PC, SC × RTS contrasts) between the breaking of mechanical dormancy and the breaking of physiological dormancy, expressed here as a smaller response of scarified seed to prechilling and room-temperature storage. First, the smaller response of scarified seed could be a result of a greater loss of physiological dormancy in

Table 4. Effect of scarification and prechilling on germination of 13 seedlots of Nezpar (NZ), Paloma (PA), and PI 478833 (PI). Means are calculated over refrigerated and room-temperature storage treatments.

----- Unscarified -----				----- Scarified -----			
----- Nonprechilled -----		----- Prechilled -----		----- Nonprechilled -----		----- Prechilled -----	
Seedlot	---	Seedlot	---	Seedlot	---	Seedlot	---
	%		%		%		%
PA 1971	34 a	PA 1971	39 a	PA 1971	43 a	NZ 1985	50 a
PA 1973	31 a	PA 1973	37 ab	NZ 1980	37 b	PA 1984	43 b
PI 1977/78	22 b	PA 1980/81	34 abc	NZ 1985	35 bc	NZ 1980	42 b
PA 1980/81	16 c	PI 1977/78	31 bc	PA 1984	33 bc	PI 1980	35 c
PA 1982	12 d	PA 1984	31 c	PA 1973	33 bc	PA 1971	34 c
NZ 1980	11 de	PA 1982	24 d	PI 1977/78	30 cd	PA 1980/81	34 cd
NZ 1985	11 de	PI 1982	23 d	PI 1980	30 cd	PI 1981	32 cde
PA 1984	8 def	PI 1981	21 d	PA 1980/81	30 cd	PA 1982	32 cde
PI 1980	7 ef	NZ 1985	21 d	PA 1982	30 cd	PA 1973	30 cde
PI 1982	6 fg	PI 1980	21 d	NZ 1986	30 cd	PI 1982	29 de
PI 1981	5 fg	NZ 1980	21 d	PI 1982	24 e	NZ 1986	28 e
NZ 1986	3 gh	NZ 1983	6 e	PI 1981	23 de	PI 1977/78	23 f
NZ 1983	2 h	NZ 1986	6 e	NZ 1983	21 e	NZ 1983	22 f

¹Means within a column followed by different letters significantly different by Bayes L.S.D. at k ratio = 100.

scarified seed during storage as suggested by Griffith and Booth (1988) for their newly harvested seedlot. If scarification facilitated loss of physiological dormancy during storage, this should be reflected in a lessened response of scarified seed to prechilling as we observed. This may explain why Shaw (1976) found that a 2-week prechill increased germination of naked seed from 50.7 to 80.7% after 14 days, while intact seeds did not germinate with or without prechilling. Prechilling overcame dormancy in recently dehulled naked seed but not in intact seed.

An alternative hypothesis for these interactions (SC × PC, SC × RTS contrasts) is the possibility of higher relative mortality of scarified prechilled seeds during testing. This would be of importance with seedlots of low vigor. Similarly, Griffith and Booth (1988) suspected that their 6-year-old seedlot showed less response to a 2-year storage period after scarification than their newly harvested seedlot because of greater mortality in the 6-year-old seedlot. Ebener (1988) suggested that mortality is reflective of seedlot vigor. Although Zemetra et al. (1983) found no mortality resulting specifically from mechanical or acid scarification in 3 seedlots up to 2 years old, this was certainly a factor with 2 of our older seedlots, PA 1971 and PI 1977/78. Prechilling of these 2 seedlots significantly reduced germination of scarified seed, i.e., the PC/SC contrast was significantly less than zero. Such differential mortality by prechilling is also possible in any of the other seedlots but perhaps was more than compensated for by reductions in dormancy during prechilling. However, such differential seed mortality can less easily explain the striking results of Shaw (1976) or those of Griffith and Booth (1988), where tests were conducted without prechilling. An analogous contrast for room-temperature storage (RTS/SC) does not indicate mortality from room-temperature storage of scarified seed.

Despite uncertainty about the relative importance of these 2 explanations, these data support the practice of scarifying new Indian ricegrass seedlots even if cool, moist field conditions following fall seeding are anticipated. For new seedlots of high vigor, loss of physiological dormancy over winter in the field should generally be greater for scarified seed than unscarified seed. Older seedlots of low vigor, however, even if responsive to either scarification or prechilling alone, may respond negatively when these treatments are combined. Percentage germination of unscarified nonprechilled (control), unscarified prechilled, scarified nonprechilled, and scarified prechilled averaged 9.3, 25.0, 29.4, and 34.7%, respectively, across the 7 responsive seedlots (the 9 seedlots with a significantly positive SC × PC contrast less the 2 seedlots with a significantly negative PC/SC contrast). This represents an increase in germination from the control of 169, 217, and 274% for prechilling alone, scarification alone, and scarification plus prechilling, respectively.

Indian ricegrass seed is characterized by physiological and mechanical dormancy, but their relative importance is a characteristic of the seedlot rather than of the species as a whole. Seed age, genotype, and seed production and storage environments are important factors that affect dormancy among seedlots. If seed growers are to sell mechanically scarified seed they must be compensated for seed damage and additional seed cleaning costs. Additionally, consumers must recognize the importance of purchasing seed on the basis of germination as well as viability (Roundy and Call 1988). Seed law in states such as Utah allows labels to substitute tetrazolium viability for germination, which provides no incentive for sale of low-dormancy seedlots. In the case of fall planting of Indian ricegrass, which is generally more desirable than

spring planting because of improved moisture conditions, germination following prechilling is probably the most critical information for the buyer. Unfortunately, until the problems of monetary compensation, consumer demand, and appropriate labeling are corrected, commercial seed will not be scarified and the success of Indian ricegrass revegetation efforts will remain low.

Literature Cited

- Blank, R.R., and J.A. Young. 1990. The effect of soil matric potential and particle size on the germination of Indian ricegrass (*Oryzopsis hymenoides* cultivar Nezpar). Abstr. 356, Soc. Range Manage.
- Booth, D.T., and L.W. Griffith. 1984. Evaluation of air threshing for small lots of winterfat fruits. J. Range Manage. 37:286-287.
- Clark, D.C., and L.N. Bass. 1970. Germination experiments with seeds of Indian ricegrass, *Oryzopsis hymenoides* (Roem. and Schult.) Ricker. Proc. Assoc. Offic. Seed Anal. 60:226-239.
- Ebener, W.C. 1988. Comparison of viability estimators on Indian ricegrass *Oryzopsis hymenoides*, seeds. M.S. Thesis. Colorado State Univ., Fort Collins.
- Fendall, R.K. 1966. An investigation into the site and cause of seed dormancy of *Stipa viridula* and *Oryzopsis hymenoides*. Ph.D. Diss. North Dakota State Univ., Fargo. (Diss. Abstr. 26:3569-3570).
- Griffith, L.W., and D.T. Booth. 1988. Indian ricegrass seed damage and germination responses to mechanical treatments. J. Range Manage. 41:335-337.
- Huntamer, M.Z. 1934. Dormancy and delayed germination of *Oryzopsis hymenoides*. M.S. Thesis. State College of Washington, Pullman.
- Jones, T.A., R. Hill, and D.C. Nielson. 1988. Germination of intact and naked seed of Indian ricegrass. J. Seed Technol. 12:114-119.
- McDonald, M.B., Jr. 1976. Improving the germination of Indian ricegrass seeds. J. Seed Technol. 1:44-54.
- McDonald, M.B., Jr. 1987. The release of multiple dormancy and metabolic responses to scarification in Indian ricegrass seeds. p. 21-33. In: G.W. Frasier and R.A. Evans (ed.) Seed and Seedbed Ecology of Rangeland Plants. Tucson, Ariz. 21-23 Apr. 1987.
- McDonald, M.B., Jr., and A.A. Khan. 1977. Factors determining germination of Indian ricegrass seeds. Agron. J. 69:558-563.
- Plummer, A.P., and N.E. Frischknecht. 1952. Increasing field stands of Indian ricegrass. Agron. J. 44:285-289.
- Robertson, J.H. 1976. The autecology of *Oryzopsis hymenoides*. *Mentzelia* 2:18-21, 25-27.
- Rogler, G.A. 1960. Relation of seed dormancy of Indian ricegrass (*Oryzopsis hymenoides* (Roem. & Schult.) Ricker) to age and treatment. Agron. J. 52:470-473.
- Roundy, B.A., and C.A. Call. 1988. Revegetation of arid and semiarid rangelands. ch. 24 In: P.T. Tueller (ed.) Vegetation Science Application for Rangeland Analysis and Management. Kluwer Academic Publishers, Dordrecht, Netherlands.
- Shaw, N.L. 1976. An investigation of factors affecting the germination of *Oryzopsis hymenoides* (Roem. and Schult.) Ricker, accession P-2575. M.S. Thesis. Idaho State Univ., Pocatello.
- Smith, C.W. 1978. Bayes least significant difference: a review and comparison. Agron. J. 70:123-127.
- Stevens, R., and S.E. Meyer. 1990. Seed quality testing for range and wildland species. Rangelands 12:341-346.
- Stoddart, L.A., and J.J. Wilkinson. 1938. Inducing germination in *Oryzopsis hymenoides* for range reseeding. J. Amer. Soc. Agron. 30:763-768.
- Toole, V.K. 1940. The germination of seed of *Oryzopsis hymenoides*. J. Amer. Soc. Agron. 32:33-41.
- Young, J.A., and R.A. Evans. 1984. Germination of seeds of 'Paloma' and 'Nezpar' Indian ricegrass. J. Range Manage. 37:19-21.
- Young, J.A., R.A. Evans, and D.A. Easi. 1985. Enhancing germination of Indian ricegrass seeds with sulfuric acid. J. Range Manage. 77:203-206.
- Zemetra, R.S., and R.L. Cuany. 1984. Variation in lemma thickness in Indian ricegrass: implications for dormancy, scarification, and breeding. Crop Sci. 24:1082-1084.
- Zemetra, R.S., C. Havstad, and R.L. Cuany. 1983. Reducing seed dormancy in Indian ricegrass (*Oryzopsis hymenoides*). J. Range Manage. 36:239-241.