Reduction of Hardseededness in Crownvetch (*Coronilla Varia* L.) Seed Lots [1]

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ABSTRACT

The use of crownvetch (*Coronilla varia* L.) as a forage crop might be increased considerably if seed with low hard seed content could be made available at reasonable cost. Since mechanical scarification damages a large percentage of crownvetch seeds, this study was initiated to find other ways of reducing hardseededness. Two approaches to the problem were studied: (a) separation of hard and soft seeds on the basis of differences in physical properties, and (b) boiling water scarification followed by separation of soft seeds after soaking in water.

Attempts to separate hard and soft seeds on the basis of length and width were only partially successful. Long-narrow seeds contained up to 33% less hard seeds than short-wide seeds in some lots, but this relationship did not exist in other lots.

Immersion for 5 seconds in boiling water reduced hardseededness without lowering the viability of soft seeds. The percentage of hard seeds remaining after a 5-second treatment was further lowered by a second treatment, again without reducing viability. It appears that the abrupt change in temperature, rather than long exposure to high temperature, is important in breaking hardseededness. The viability of hard seeds averaged 24% higher than that of naturally soft seeds.

Soft seeds were successfully separated from hard seeds, after soaking in tap water, by removing the swollen soft seeds with round-hole screens. After separation, swollen soft seeds can be air-dried to their initial moisture content without apparent damage. Soaked and dried seeds showed reduced dormancy, good storability, and good emergence from soil in greenhouse studies.

Techniques for boiling water scarification and separation of hard and soft seeds are suggested.

Additional index words: scarification, seed size, seed conditioning, dormancy.

INTRODUCTION

Crownvetch (*Coronilla varia* L.) is a perennial leguminous plant used for erosion control and beautification, but which has a limited use as a forage crop. High percentages of hardseededness necessitate high seeding rates which lead to excessive costs of stand establishment. Use as a forage crop might be increased considerably if seed lots with low hard seed content could be made available at reasonable cost. Most crownvetch seed lots are mechanically scarified to lower the hard seed content, but this practice damages a large percentage of the seed because of their narrow oblong shape. (Peiffer, McKee and Ditmer, 1972)

Hard seed content of crownvetch seed lots could conceivably be reduced by development of a technique for removal of hard seeds with conventional conditioning equipment. This would require a physical difference between hard and soft seeds that could be sensed by the equipment. Such differences exist to some extent in several small-seeded legumes. Vaughan (1962) demonstrated that hardseededness was associated with small seed size in white clover (*Trifolium repens*), red clover (*T. pratense*) and crimson clover (*T. incarnatum*), while Middleton (1933) found the same to be true for Korean lespedeza (*Lespedeza stipulata*).

Another approach is to develop an improved scarification technique that will not lower seed viability. Brant (1968) was successful in lowering hard seed content in crownvetch by soaking seeds in concentrated sulfuric acid for 15 minutes, immersing in boiling water for 15 seconds, or dipping in liquid nitrogen for 1 minute. Casey (1939) increased germination of bur clover (*Medicago arabica* and *M. maculata*) by immersing the seed in boiling water for 1 minute.

The primary objectives of this study were: (a) to determine the degree of association between hardseededness of crownvetch seeds and certain physical characteristics (length and width) that can be used as the basis for upgrading the germinability of seed lots and (b) to determine the feasibility of mechanically separating hard and non-hard seeds by soaking them to artificially create size differences that would allow them to be separated by seed sizing equipment.

MATERIALS AND METHODS

Seed Lots

Two lots each of three commonly grown cultivars of crownvetch (*Coronilla varia* L.) were obtained from commercial seed sources. The characteristics of these lots were as follows: 'Chemung' Lot A — Idaho origin, commercial class; Chemung Lot B — Idaho origin, commerical class; 'Emerald' Lot A — Iowa origin, Certified class; Emerald Lot B — Iowa origin, Certified class; 'Penngift' Lot A — Pennsylvania origin, Foundation class; Penngift Lot B — Pennsylvania origin, Foundation class.

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General Procedures for Germination Tests

The effects of sizing, boiling water, and soaking treatments were evaluated by germinating the seeds according to the methods prescribed in the Rules for Testing Seeds (Association of Official Seed Analysts, 1978). For each test, four samples of 100 seeds each were obtained with a pneumatic seed counter and planted between moist 11.5 x 11.5 cm germination blotters in 12 by 12 by 3 cm plastic boxes. Seeds were incubated in germinators without light at 20 C for 14 days. Germination boxes were placed in a completely randomized design in the germinators and results were analyzed as a factorial arrangement of treatments. Preliminary germination counts were made after 7 days, at which time the germinated and dead seeds were removed. At the 14-day count, total germination, hard seeds, dormant seeds and dead seeds were evaluated.

Relationship of Seed Length and Width to Hardseededness

Samples of the six lots were first sized into three length classes, and each length class was further sized into three width classes, yielding nine size groups from each seed lot.

Length separations were made with a laboratory model disc separator with R type disc pockets. Seeds that could be lifted with an R4 disc were first removed and designated as the "Short" category. Then the seeds that could be lifted with an R5 disc were removed and designated as the "Medium" category. The remaining seeds not lifted by the R5 disc were designated as "Long."

Each length group was further divided into three different widths using perforated round-hole hand screens of 1.41 and 1.27 mm (1/18 and 1/20 inch) diameter. "Wide" seeds were those held on the 1.41 screen; "Intermediate" seeds were those passing through the 1.41 and held on the 1.27; and "Narrow" seeds were those passing through the 1.27 mm screen.

Scarification of Hard Seeds by Boiling Water

The boiling water scarification methods of Brant (1968), Gray (1962) and Wilson (1937; 1944) were refined to eliminate hard seeds from a seed lot without lowering the viability of the non-hard seeds. The technique involved submerging the seeds briefly in boiling water, then soaking in tap water at 30 C to allow swelling of permeable seeds, followed by separation of hard seeds from swollen seeds with a round-hole screen. This treatment was then repeated with the hard seeds that remained.

To determine the optimum period of treatment in boiling water, seeds of Chemung (Lot B) and Emerald (Lot B) were placed in wire mesh containers and submerged in boiling water. Seeds were removed at 5-second intervals for 60 seconds. Four samples of 100 seeds were subjected to each treatment period.

After the safe treatment period was determined, a similar experiment was conducted to determine the optimum heat treatment period for a second cycle of treatment on the seeds that remained hard after the first cycle of treatment. To obtain hard seeds for the second cycle, samples of the same two lots were submerged in boiling water for 5 seconds, then placed in plastic boxes containing water at 30 C for 24 hours to allow swelling of the permeable seeds. Following the soaking period and surface drying, the hard seeds were removed with a round-hole screen. Eighteen 50-seed samples of the hard seeds were placed in wire mesh containers and again placed in boiling water. Three samples were removed after 10 and 30 seconds and 1, 2, 3, and 4 minutes.

Mechanical Separation of Hard and Soft Seeds

Samples of Chemung (Lot A), Emerald (Lot A) and Penngift (Lot B), were separated into six width groups with round-hole screens. These width groups were: over 1.49 mm (1/17 inch) (widest seeds), 1.49-1.41, 1.41-1.34 (1/18-1/19), 1.34-1.27, 1.27-1.21 (1/20-1/21), and through 1/21 (narrowest seeds).

Four samples of 200 seeds were obtained from each width group and submerged in boiling water for 5 seconds. After this treatment, seeds were placed in plastic boxes containing tap water at 30 C for 24 hours to allow swelling of the permeable seeds.

Swollen seeds were considerably larger than hard seeds, suggesting that they could be separated readily with hand screens. To facilitate screening, the wet seeds were first surface dried by spreading them on absorbant blotters near a forced air heater. The six width groups within each lot were then passed over the same screens used to form the six groups originally. The efficiency (percent recovery of swollen seeds) of each screen was then determined.

Viability of Naturally Soft and Hard Seeds

The viability of naturally soft seeds and hard seeds in all six lots was determined. "Naturally Soft Seeds" were obtained by soaking samples in tap water at 30 C for 24 hours and discarding the remaining hard seeds.

Hard seeds of these same lots were recovered after the 14-day germination count of several experiments and scarified by submerging in boiling water for 5 seconds, then placed in tap water at 30 C to allow swelling of permeable seeds. The swollen seeds obtained by this method were termed "Boiling Water Soft Seeds."

Relative Storability of Soft Seeds

Small samples of air-dried Boiling Water Soft Seeds, Naturally Soft Seeds and untreated seeds were placed in sealed glass containers at 10 and 30 C to determine their storability. Germination tests were conducted after 1, 4 and 10 months.

Effect of Selected Seed Treatments on Emergence From Soil

The emergence-survival of selected seed categories in Chemung (Lot B), Emerald (Lot A) and Penngift (Lot B) were studied in greenhouse plantings. Within each lot, the following seven categories of seed were selected: (1) untreated, (2) naturally soft, (3) boiling water soft, (4) long-narrow, (5) short-wide, (6) 5-second scarification in boiling water, and (7) hand scarified between sand paper.

Fifty seeds from each category were planted 1 cm deep in

gallon cans filled with unfertilized river alluvial soil. Temperature in the greenhouse ranged from 22 to 25 C. The experiment was set up in a completely randomized design with each treatment repeated four times. Seedlings were counted daily for 15 days. Since a number of the seedlings died during the period, the figures represent only the number of seedlings that survived. Data were analyzed as a factorial arrangement of treatments.

RESULTS

Relationship of Seed Length and Width to Hardseededness

The relationship of seed length and width to hardseededness is shown in Table 1. When the hard seed percentages were averaged over the three widths, short seeds contained more hard seeds than the medium and long seeds. Since short seeds of crownvetch are the smaller seeds, the results are in agreement with data presented by Middleton (1933) and Vaughan (1962) which showed that smaller seeds of Korean lespedeza and clovers were also higher in hard seed content. When hard seed percentages were averaged over lengths, wide seeds (which could be considered larger seeds) contained more hard seeds than intermediate or narrow seeds. This suggests that in this species, hardseededness is associated with shape of the seed rather than size itself, with long-narrow seeds containing the lowest hard seed content and the short-wide seeds the highest amount.

Table 1. Relation of length and width to percent hard seed in crownvetch. Average of two lots each of three cultivars.

	Width			
Length	Wide	Intermediate	Narrow	Average
		%		
Long	47.33	46.50	43.70	45.85
Medium	51.91	51.37	46.00	49.76
Short	56.70	51.83	51.91	53.48
Average	51.98	49.90	47.20	

$LSD_{.01}$ for all 9 length-width combinations: 3.58
$LSD_{.05}$ for all 9 length-width combinations: 2.72

Variation in hard seed content for the nine length-width groups within each seed lot and cultivar is shown in Table 2. In Chemung Lot A and B, Emerald Lot A and Penngift Lot B, the wide seed group contained more hard seeds than the narrow groups; but in Emerald Lot B and Penngift Lot A, this tendency was not present. In every cultivar and lot there was a definite association between length and hardseededness, short seeds being more hard-seeded than long seeds in each width group.

Table 2. Relation of length and width to percent hard seed in six lots of crownvetch.

			Width		
Cultivar	Lot	Length	Wide	Intermediate	Narrow
				%	
		Long	48.25	44.25	36.00
Chemung	A	Medium	57.50	53.25	38.50
		Short	68.50	54.00	50.76
		Long	87.75	82.75	80.75
Chemung	B	Medium	88.00	83.75	85.00
		Short	91.25	89.75	84.50
		Long	25.75	22.75	20.00
Emerald	A	Medium	33.25	28.50	22.25
		Short	38.00	32.25	30.50
		Long	46.50	55.00	55.75
Emerald	B	Medium	53.75	62.00	55.75
		Short	54.50	62.00	68.50
		Long	35.75	36.00	39.00
Penngift	A	Medium	36.00	40.50	34.75
		Short	38.00	37.50	40.50
		Long	41.00	38.25	30.75
Penngift	B	Medium	45.00	40.25	39.75
		Short	50.00	41.50	42.75

Scarification of Hard Seeds by Boiling Water

Effect of a Single Boiling Water Treatment

The effects of a single boiling water treatment on hardseededness are shown in Figure 1. After 5 seconds of treatment, hard seed content decreased about 25% in Chemung Lot B and 40% in Emerald Lot B. The decline in hardseededness with longer periods of soaking was negligible. Soaking longer than 10 seconds increased the number of dead seeds in both seed lots and also decreased the speed of germination (as indicated by the first count germination) in Chemung Lot B. These results indicate that 5 seconds would be the optimum period of treatment to render the most hard seeds permeable without killing any soft seeds.

Effect of a Second Boiling Water Treatment on Remaining Hard Seeds

The hard seeds remaining after a 5-second treatment in boiling water were subjected to a second boiling water treatment of 10 to 180 seconds (Figure 2).

The hard seed content of these seeds decreased with treatments up to 30 seconds after which no further reduction of hardseededness occurred. Dead seed content was not increased until the 2-minute period in this second cycle, but the speed of germination was decreased with periods longer than 30 seconds. Thus, periods of soaking longer than 30 seconds should be avoided in the second cycle of boiling water scarification.

The cumulative changes in amount of hard seeds and germination after each of the two optimum treatment periods are shown in Figure 3. The initial 82% hard seed content of Chemung was reduced to 55% with a 5-second treatment in boiling water. Since the remaining hard seeds were lowered to 52% with 10 seconds in the second cycle, only 28% (52% x 55%) hard seed would be left in this lot.

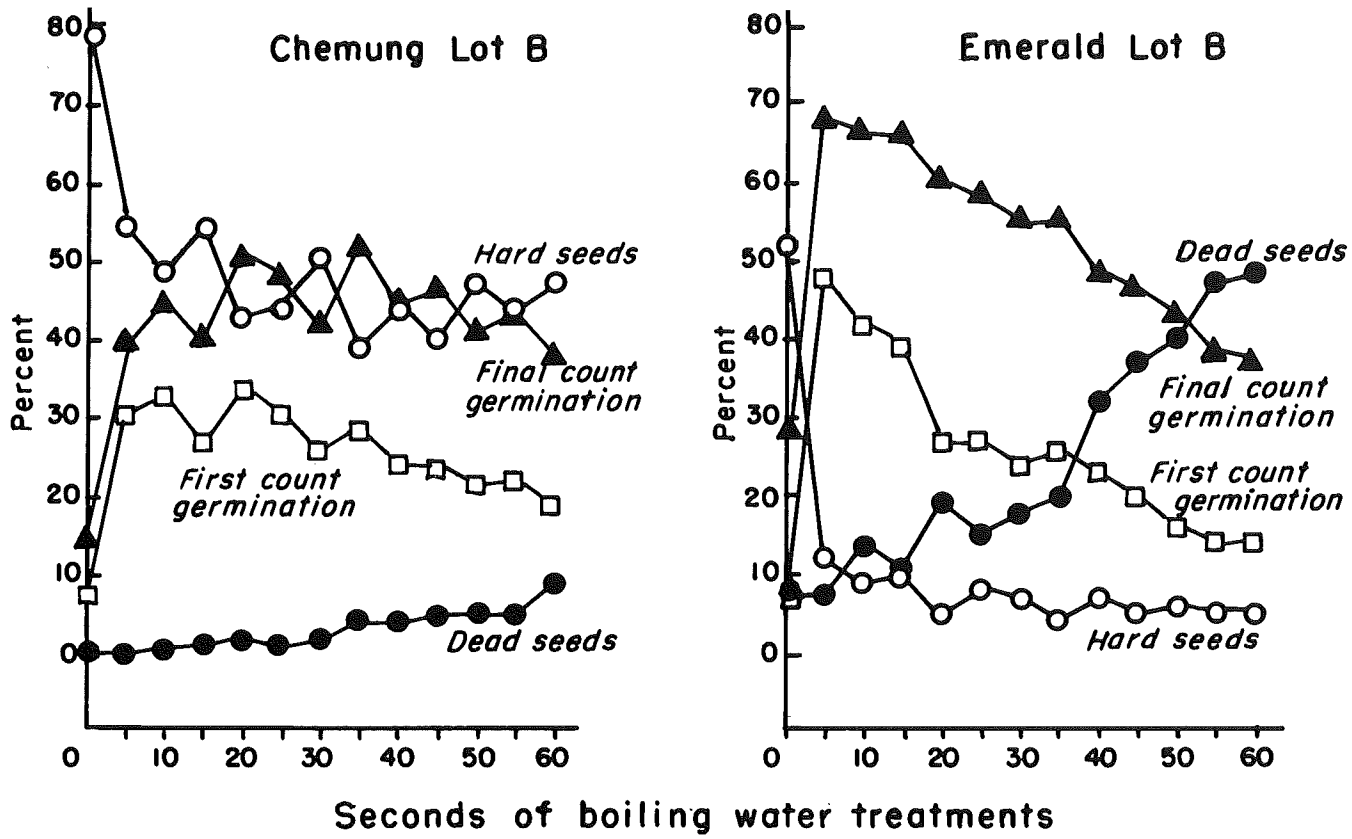


Fig. 1. Effects of a single boiling water treatment on crownvetch seeds.

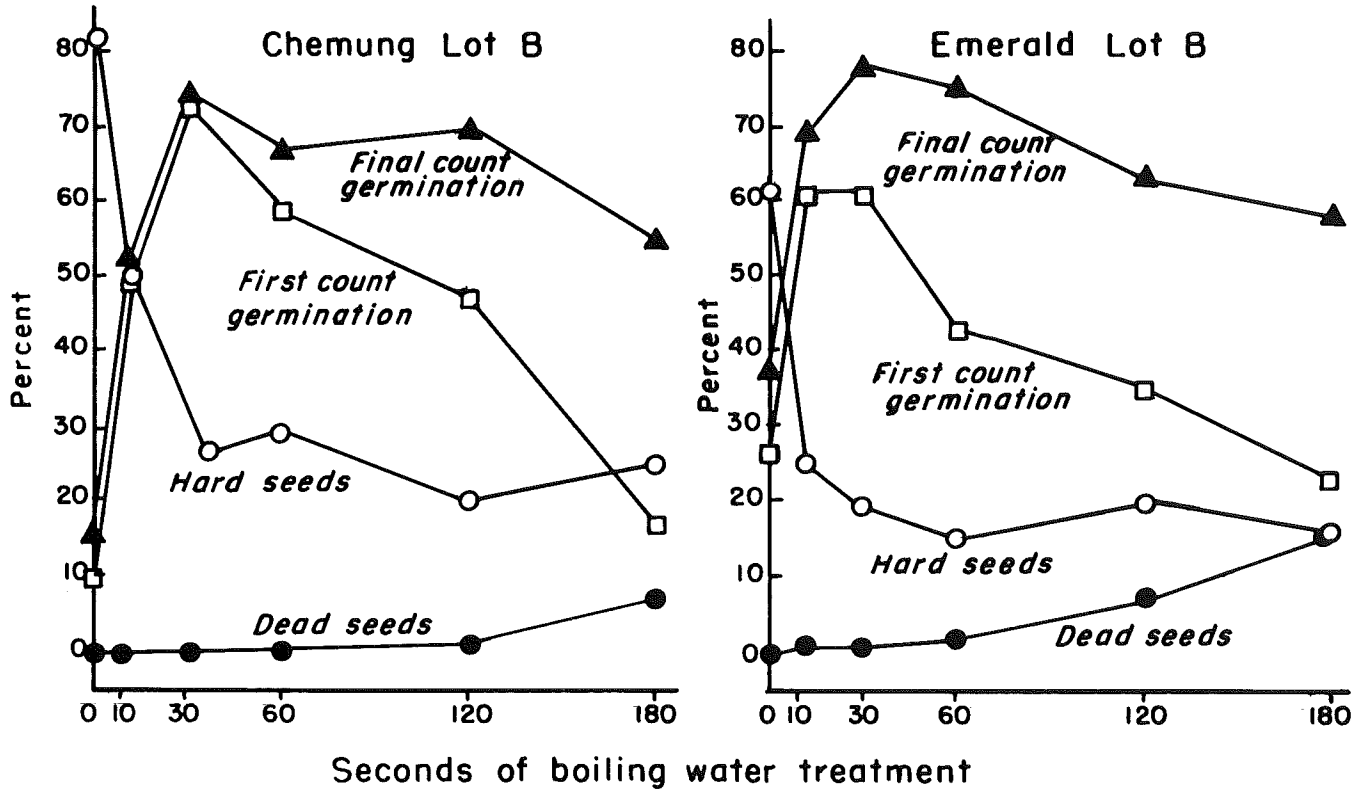


Fig. 2. Effect of a second cycle of boiling water treatments on crownvetch seeds.

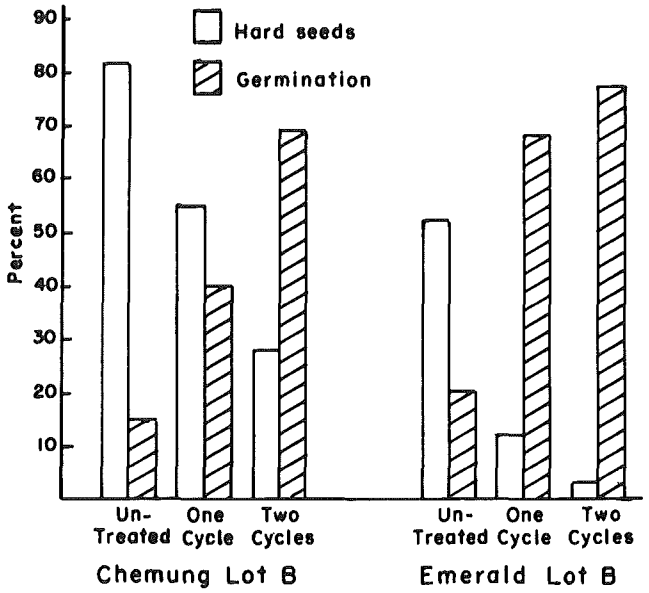


Fig. 3. Effects of one and two cycles of boiling water treatment on hard seed content and germination of Chemung Lot B and Emerald Lot B.

In Emerald Lot B, the initial 52% was lowered to 12% with the first cycle and to 3% (12% x 25%) after the second cycle. Germination increased in proportion to the reduction in hardseededness.

The sudden reduction in hardseededness following the two short (10 and 30 seconds) soaking periods compared to a single 40 second treatment indicates that it is the abrupt change in temperature rather than long exposure to high temperature that is important in breaking hardseededness. This further emphasizes that rather than trying to break most hardseededness with a single deleteriously long treatment in boiling water, more beneficial effects could be achieved with two or more short cycles. If this approach was to be tried on a practical basis, the seed lot should first be subjected to a 5-second treatment in boiling water. If this treatment does not reduce hardseededness to an acceptable level, the seeds that become soft by this treatment should be separated. Only the remaining hard seeds should be subjected to a second treatment of 10 to 30 seconds in boiling water.

Mechanical Separation of Hard and Soft Seeds

Several techniques or methods were tried with the aim of separating hard seeds from swollen soft seeds. The most successful approach was to use round-hole screens which separate on the basis of seed width and do not cause damage to the seed.

In a mixture of swollen seeds and hard seeds there is considerable overlapping in width between wide hard seeds and narrow soft seeds after they have swollen. This overlapping can be avoided by dividing the seed lot into several width groups before scarification treatment. Soft seeds will increase in width while hard seeds will not, creating a definite width difference between soft and hard seeds. Separation can then be made with the same screens originally used to divide the seed lot into width groups.

Using this approach, all hard seeds passed through the screen and the soft seeds remained on the screen, when the screens used were as follows (Table 3): 1.49 diameter screen for seeds that were 1.49-1.41 width before soaking, 1.41 screen for seeds that were 1.41-1.34 width before soaking, 1.34 screen for seeds that were 1.34-1.27 width before soaking, and 1.27 screen for seeds that were 1.27-1.21 width before soaking.

Table 3. Percent separation of soft seeds obtained with round-hole screens from each initial width class in crownvetch lots.

Cultivar	Lot	Seed width class	Diameter of screen in mm					
			1.81	1.49	1.41	1.34	1.27	1.21
		(mm)	---------- % ----------					
Chemung	B	Over 1.49	100					
Chemung	B	1.49-1.41	92	100				
Chemung	B	1.41-1.34	64	100	100			
Chemung	B	1.34-1.27		100	100	100		
Chemung	B	1.27-1.21		90	100	98	100	
Chemung	B	Thru 1.21			60	78	85	100
Emerald	A	Over 1.49	90					
Emerald	A	1.49-1.41	72	100				
Emerald	A	1.41-1.34	57	98	100			
Emerald	A	1.34-1.27		97	100	100		
Emerald	A	1.27-1.21		82	99	100	100	
Emerald	A	Thru 1.21			72	80	86	100
Penngift	B	Over 1.49	90					
Penngift	B	1.49-1.41	70	100				
Penngift	B	1.41-1.34	58	88	100			
Penngift	B	1.34-1.27		46	100	100		
Penngift	B	1.27-1.21			82	93	100	
Penngift	B	Thru 1.21				56	72	96

A good but not perfect separation was obtained from the widest groups of Emerald Lot A and Penngift Lot B. These wide groups included seeds ranging from 1.81 to 1.49 mm (1/14 to 1/17 inch) in diameter. These extreme width classes represented a very small proportion of the seed lots.

Viability of Naturally Soft and Hard Seeds

The germination percentage of the "Naturally Soft Seeds" (seeds that do not require scarification to become permeable to water) and scarified hard seeds of six seed lots is presented in Table 4. Hard seeds averaged 92% germination after boiling water scarification with a range of 85% to 100%. Naturally soft seeds averaged 68% germination with a range of 46% to 88%.

Relative Storability of Soft Seeds

Although hardseededness can be broken effectively and soft seeds can be mechanically separated from the hard seeds, the practicability of the technique is also dependent on the storability of the treated seeds. When stored in sealed

Table 4. Percent germination of "naturally soft seeds" and hard seeds in crownvetch cultivars and lots.

Cultivar	Lot	Naturally soft seeds	Hard seeds
		%	
Chemung	A	65	100
Chemung	B	78	92
Emerald	A	78	93
Emerald	B	53	85
Penngift	A	88	97
Penngift	B	46	88
Average		68	92

glass containers, both "Naturally Soft Seeds" and "Boiling Water Soft Seeds" (hard seeds made permeable by boiling water), showed a slight decline in germination after 10 months of storage at 30 C (Table 5). Neither seed category showed a decline in germination after 10 months at 10 C. The increased germination of the untreated seeds after 10 months is attributed to some hard seeds becoming permeable during this period.

Table 5. Percent germination of air-dried soft seeds of crownvetch lots stored at 30 and 10 C. Average of Chemung Lot B, Emerald Lot A, and Penngift Lot A.

Seed category	Storage temperature	Months of storage 0	1	4	10
	°C	%			
Untreated	30	32	32	32	38
Naturally Soft	30	92	89	87	85
Untreated	10	32	30	32	43
Naturally Soft	10	84	85	82	86
Boiling Water Soft	10	92	90	91	91

Effect of Selected Seed Treatments on Emergence From Soil

The average daily emergence-survival of selected seed classes from three seed lots when planted in the greenhouse is presented in Figure 4.

Emergence-survival of every seed category was lower than germination in the laboratory, but in general, seed categories that showed higher germination in the laboratory studies also showed higher emergence-survival in the greenhouse. The "Boiling Water Soft Seeds and "Naturally Soft Seeds" showed faster emergence and about 40 and 30% higher final emergence-survival than the untreated seeds. The lower emergence of "Naturally Soft Seeds" can be attributed to the higher dead seed content of this seed category.

On the average, the long-narrow seeds (which showed highest germination in the length-width studies) emerged as well as the seeds scarified in boiling water for 5 seconds and better than the short-wide seeds (which showed the lowest germination in the length-width studies). Untreated seeds,

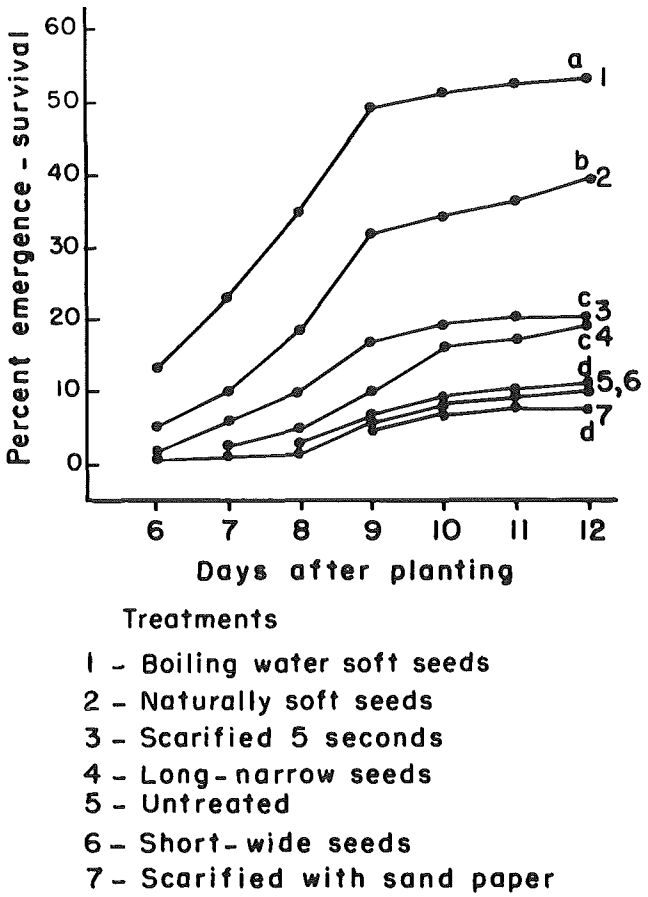


Fig. 4. Average emergence-survival of selected seed classes of crownvetch in the greenhouse. Average of Chemung Lot B, Emerald Lot A, and Penngift Lot B.

seeds hand scarified between sand paper and short-wide seeds showed the lowest emergence-survival.

DISCUSSION

Attempts to separate hard and soft seeds on the basis of length and width conditioning procedures were only partially successful. In some lots, hardseededness tended to be concentrated in certain sizes or shapes, but in other lots, the proportion of hardseededness did not vary much between sizes or shapes. In those lots where hardseededness is associated with shape, a sublot with reduced hardseededness could be created by making the proper length and width separation. The remainder of the seed lot, of course, would have an increased percentage of hardseededness. The sublot with the lowest hard seed content would be the most suitable for planting, while the more hardseeded sublot could remain in storage or be scarified to reduce hardseededness.

In commercial seed conditioning, artificial size differences are sometimes created when they do not exist naturally. An example of this is the addition of sawdust to moistened buckhorn plantain (*Plantago lanceolata* L.) seeds to make them larger so they can be separated from alfalfa (*Medicago*

sativa) seeds. Similarly, soft seeds of crownvetch may be made wider than hard seeds by soaking them in water. With this width difference, hard and soft seeds may be easily separated with round-hole screens.

It is possible to scarify the hard seeds of a crownvetch seed lot without killing the soft seeds, by combining boiling water scarification and separation of soft seeds. A suggested procedure for doing this is as follows:

1. Before scarification, subdivide the seed lot into several width groups (sublots) with a series of round-hole screens.
2. Submerge each sublot in boiling water for 5 seconds.
3. After removal from boiling water, soak the seeds for 16 hours in water at room temperature to allow the soft seeds to swell. Remove from the water and surface-dry the seeds.
4. Pass each sublot over the same screen that was used to make the original width groups. For example, the sublot that passed through a 1.49 mm screen but was held by a 1.41 mm screen, should be passed over a 1.49 mm screen. Hard seeds will fall through as they did before soaking, but the swollen soft seeds will be held.
5. The hard seeds remaining may be put through a second cycle of boiling water scarification, soaking at room temperature and screening.
6. A third cycle may be necessary for lots with an extreme degree of hardseededness. One cycle may be sufficient for other lots.
7. Swollen seeds should be dried to their original moisture content for safe storage and to permit the use of normal seeding equipment.

As a variation of this procedure, sublots with no hard seeds could also be created without boiling water scarification merely by soaking in water and screening off the swollen seeds. The procedure could also be adapted to eliminate fast swelling seeds which are lowest in viability. (Peiffer, McKee and Ditmer, 1972)

Since hard seeds are higher in viability than soft seeds, and constitute a high proportion of the seedlot, there is considerable value in scarifying crownvetch seed before planting. The practicability of the procedure described will be dependent on the size of the seed lot and its intended use, equipment available, need, economics and the extent of hardseededness present. In seed testing, for example, boiling water scarification provides an efficient way of overcoming hardseededness so that viability of hard seeds may be determined in a germination test.

In research, boiling water scarification could be very practical for small lots of seed for experimental plantings. The procedure could likewise be practical for small- to medium-sized lots used for erosion control and ornamental plantings. The feasibility of using these techniques for very large seed lots may be questionable, however.

Additional research may show that the several-cycle approach to boiling water scarification could be applied to other species of legumes as well. Previous workers have frequently concluded that boiling water scarification is impractical because the long treatments required to overcome hardseededness frequently reduced the viability of the soft seeds in the lot. This disadvantage is overcome with the repeated-cycle approach.

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