Effect of Seed Moisture Content and Temperature on the Seed Coat Durability of Field Pea[1]

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ABSTRACT

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The Tangential Abrasive Dehulling Device (TADD) was modified and used to evaluate the effects of seed moisture content (6–20%) and temperature (from −40 to 40° C) on seed coat breakage of two cultivars of field pea. Seed coat breakage of peas at 24° C and 14–15% seed moisture content (approximating harvest conditions) was comparable to seed coat breakage of commercially harvested farmers' samples. Analysis of variance showed that seed coat breakage was affected mostly by seed moisture content, followed by temperature and cultivar. At all temperature levels seed coat breakage increased linearly ($r = -0.92$ to -0.999, $P < 0.01$ or 0.05) with decreasing moisture content for both cultivars. Generally, seed coat breakage increased with decreases in seed temperature, particularly at −40° C. To avoid excessive seed coat breakage, it is recommended that peas not be handled at moisture contents less than 14% or at temperatures below −25° C and that they be handled with care at temperatures between −10 and −25° C. The effect of low temperature (−40° C) on seed coat durability was completely reversible.

Considerable potential for seed coat breakage exists during mechanical harvesting and handling of grain subject to damage. Consequently, seed coat durability is an important quality criterion for such grains. Seed coat durability refers to the resistance of the seed coat to breakage when the grain is subjected to various stresses. Damaged grains are downgraded by grain grading procedures and are consequently of less economic value on both the domestic and export markets. Seed coat breakage of field pea (*Pisum sativum* L.) has recently been a significant concern in the prairie provinces of Canada. This problem seems to be accentuated in dry years and in the winter months when temperatures may be as low as −40° C.

Seed coat durability in field pea has not been studied. In other crops, however, seed coat durability is commonly measured by assessing mechanically induced damage to the seed; a variety of apparatuses has been used to induce such damage (Watson and Herum 1986). The more common devices such as the Stein breakage tester and rotating impactor techniques require a large quantity (100–400 g) of sample and often long testing times. In this investigation the Tangential Abrasive Dehulling Device (TADD, Reichert et al 1986) was modified to provide a rapid, small-sample method of inducing damage in field pea. The method was used to assess the effect of seed moisture content and temperature on field pea seed coat durability.

MATERIALS AND METHODS

Samples

Samples (Canada grade no. 1) of commercial field pea cultivars were purchased at Early's Farm and Garden Centre Inc., Saskatoon, Saskatchewan, in May 1984. Values for 1,000-seed weight of Trapper and Tara field pea were 110 ± 2.0 g SD, and 218 ± 8.4 g, respectively; the seed shapes of these cultivars were round and flattened, respectively. The samples were equilibrated at 52% relative humidity to approximately 11% seed moisture with saturated $Ca(NO_3)_2$ solution. The temperature was maintained at 23 ± 1° C.

Trapper and Tara pea samples (75 and 8 samples, respectively) were collected from individual farmers in the fall of 1983. The percentage of split seeds (w/w) in each sample was determined, and the mean for each cultivar was calculated.

Measurement of Seed Coat Durability

A rubberized aluminum disk was used in place of the standard grinding wheel in the TADD (Reichert et al 1986). To fabricate the disk, a smooth rubber mat (3.2-mm neoprene/nylon rubber, Continental Petroleum Rubber Company, Saskatoon, Saskatchewan) was glued to an aluminum disk (25.4 cm diameter, 7.9 mm thick, and 2.5 cm arbor) and the edges were trimmed. The pressure cups, used to apply vertical pressure to the seeds, were made from DWV copper pipe (5.2 cm i.d. × 1 mm thick) with a brass plate (2 mm) soldered on one end. The pipe was trimmed until the final weight was 68 g.

To determine seed coat breakage, the rubberized aluminum disk and the 8-cup plate were installed in the TADD. Twenty-five seeds, selected randomly with a seed counter, were placed in the sample cup. A pressure cup was placed on top of the seeds in the sample cup. The disk was rotated at 1,750 rpm for an interval of time. The number of broken seeds was visually assessed and seed coat breakage expressed on a percentage basis:

$$\text{Seed coat breakage} = (\text{number of broken seeds} \times 100)/25$$

Broken seeds were counted as 1) seeds with the seed coat completely removed and with cotyledons intact or separated and 2) seeds without seed coat completely removed but split into two. The average of 15 replicates was recorded.

Effect of Seed Moisture Content and Temperature

To adjust the moisture content of the grains, saturated salt solutions—analytical grades of LiCl, $MgCl_2$, $Ca(NO_3)_2$, NaCl, and $BaCl_2$—were used to obtain relative humidities of 11, 33, 52, 75, and 90%, respectively (Hutchison and Otten 1984, Brooker et al 1974, Rockland 1960, O'Brien 1948). Grain samples were placed in cloth bags and stored (25 ± 1° C) over the saturated solution in a desiccator. Samples were taken periodically for moisture determination (method 44-15A, AACC 1983), and equilibration was continued until samples had attained a constant moisture content (30–45 days).

The effect of temperature on seed coat breakage of field peas varying in moisture content was investigated by storing samples (previously equilibrated at the aforementioned relative humidities) in double, tightly sealed plastic bags at 40, 24, 6, −10, −25, and −40° C for two days. Samples were removed from storage and immediately tested using the TADD method with a testing time of 20 sec.

Statistical Evaluation

The effect of moisture, cultivar, and temperature on seed coat breakage was analyzed by a three-way analysis of variance. Within

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each cultivar the effect of seed moisture content at constant temperature on seed coat breakage was analyzed by Duncan's multiple range test ($P < 0.05$). A least significant difference value ($P < 0.05$) was calculated to evaluate the effect of seed temperature at a constant moisture content on seed coat breakage.

RESULTS AND DISCUSSION

To determine seed coat durability of field peas, the TADD system described by Reichert et al (1986) was modified to allow small samples of peas to be simultaneously subjected to a tangential force provided by the rotation of a rubberized aluminum disk and a vertical force provided by a pressure cup (Fig. 1). Without vertical force the seeds bounced freely in the sample cups and the rate of seed coat breakage was negligible. Preliminary experiments showed that the rate of seed coat breakage increased with an increase in vertical force (weight of pressure cup) or an increase in the tangential force (speed of disk). Using standardized conditions (1,750 rpm, 68 g pressure cup, 25 seeds per test, mean of 15 tests), it was observed that seed coat breakage increased linearly with testing time in the TADD for two commercial cultivars of pea (Fig. 2).

Effect of Seed Moisture and Temperature on Seed Coat Breakage

Analysis of variance revealed that seed coat breakage was most affected by seed moisture content, followed by seed temperature

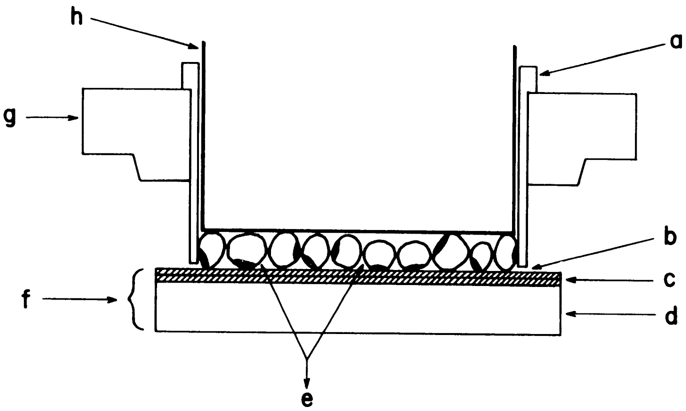

Fig. 1. Diagram of the system used for assessing seed coat breakage of field peas with the TADD: (**a**) sample cup (i.d. 5.6 cm), (**b**) gap, (**c**) rubber pad, (**d**) aluminum disk, (**e**) field pea seeds, (**f**) rubberized aluminum disk, (**g**) sample plate, and (**h**) pressure cup (30–90 g).

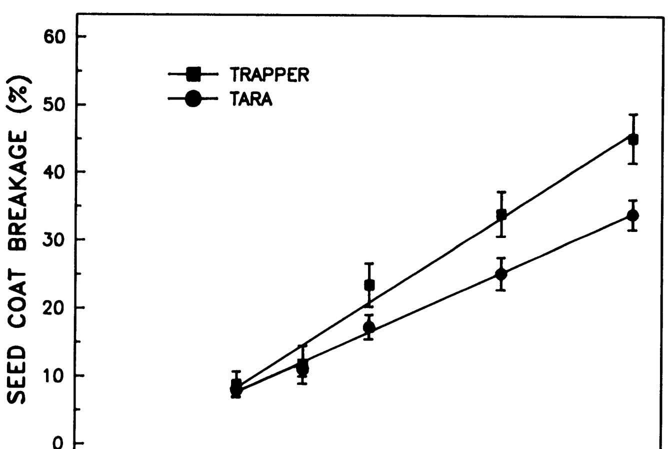

Fig. 2. Effect of testing time in the TADD on seed coat breakage (%) of field peas. Bars indicate standard error. The regression equations were, for Trapper, $Y = 1.18X - 2.03$, $r = 0.991$ (significant at the 0.01 level), and for Tara, $Y = 0.86X - 0.52$, $r = 0.999$ (significant at the 0.01 level).

and cultivar (Table I). The seed coat breakage values at various moisture contents (6–20%) and temperatures (from 40 to −40° C) for Trapper and Tara peas are compared in Table II. The effects of cultivar, location, and year of growth on seed coat durability and its physiochemical basis were extensively investigated and reported elsewhere (Reichert and Ehiwe 1987).

Effect of moisture. At 24° C and 14–15% seed moisture content (approximating harvest conditions), a value of 9.6% seed coat breakage was recorded for both Trapper and Tara peas (Table II). This value was within the range obtained for split pea content of farmers' samples for Trapper (5.6 ± 5.1%, $n = 75$) and Tara (6.4 ± 3.4%, $n = 8$) field peas harvested in 1983 in Saskatchewan.

At all temperature levels, seed coat breakage increased linearly ($r = -0.92$ to -0.999, $P < 0.01$ or 0.05) with decreasing moisture content for both cultivars. To avoid excessive damage during the harvesting operation, and for safe storage of field pea, peas should be harvested at 14–16% moisture content. This range falls within the "straight grade" category of the Canadian Grain Act (Schedule 1), which considers field pea harvested at less than 16% moisture content acceptable for safe storage and sale. Similar trends for the effect of seed moisture content on seed coat breakage were reported by Siddique and Goodwin (1980) for snap bean, Miller et al (1979) for soybean, Stephens and Foster (1976) for corn, and Dorrell (1968) and Barriga (1961) for navy bean.

The reasons for the increased seed coat breakage at lower moisture contents may result from changes in either tissue elasticity (Dorrell 1968) or the binding between the inner seed coat surface and the cotyledon (Sefa-Dedeh and Stanley 1979). According to Dorrell (1968), when the tissues begin to lose moisture, there is an increase in brittleness caused by either an increase in crystallization or a change in cellulosic orientation. The

TABLE I
Analysis of Variance: Effect of Seed Moisture Content and Temperature on Seed Coat Breakage of Two Cultivars of Field Pea

Source of Variation[a]	Degrees of Freedom	Mean Square	*F* Value[b]
M	4	2,809.3	525.1**
T	5	368.4	68.9**
C	1	271.0	50.7**
M × C	4	111.8	20.9**
C × T	5	28.0	5.2**
M × T	20	17.9	3.4**
M × C × T	20	5.4	ns[c]

[a] M = Moisture, T = temperature, and C = cultivar.
[b] ** = Significant at the 1% probability level.
[c] ns = Not significant.

TABLE II
Effect of Seed Moisture Content and Temperature on Seed Coat Breakage (%) of Field Pea Cultivars

	Relative Humidity (%)/Average Moisture (%)				
Temperature (° C)	11/6.3	33/9.1	52/11.3	75/14.8	90/18.3
Trapper					
40	59.2 a[a]	34.7 b	24.3 c	4.8 d	5.1 d
24	65.1 a	41.9 b	27.5 c	9.6 d	6.1 d
6	70.1 a	48.5 b	25.6 c	12.0 d	3.2 e
−10	72.5 a	52.3 b	29.6 c	8.5 d	3.7 d
−25	71.7 a	50.4 b	36.3 c	10.9 d	5.9 d
−40	84.0 a	74.1 b	49.9 c	19.2 d	5.9 e
LSD[b]	8.3	8.1	9.4	5.9	3.6
Tara					
40	27.7 a	18.7 b	16.5 b	6.7 c	3.5 c
24	32.8 a	25.1 b	17.9 c	9.6 d	3.5 e
6	43.7 a	26.9 b	17.3 c	9.3 d	4.8 d
−10	61.9 a	36.8 b	25.9 c	9.3 d	10.7 d
−25	60.3 a	45.9 b	25.6 c	14.7 d	7.7 e
−40	79.7 a	62.4 b	49.3 c	21.1 d	16.3 d
LSD[b]	7.3	7.0	6.4	5.2	4.4

[a] Seed coat breakage values bearing different letters in a row (constant temperature) are significantly different ($P < 0.05$).
[b] Least significant difference ($P < 0.05$) between seed coat breakage values within one cultivar at constant moisture content.

TABLE III

Effect of Storage of Field Peas (6–20% moisture content) at −40 or 24° C for 48 hr on Seed Coat Breakage Measured at −40 or 24° C

Moisture (%)	Stored at −40° C Tested at +24° C	Stored at +24° C Tested at +24° C	Stored at −40° C Tested at −40° C
Trapper			
6.3	65.1 a[a]	60.8 a	84.0 b
9.1	41.9 a	35.2 a	74.1 b
11.4	27.5 a	20.8 a	49.9 b
15.1	9.6 a	7.2 a	19.2 b
19.8	6.1 a	4.5 a	5.9 a
Tara			
6.3	32.8 a	40.8 a	79.7 b
9.1	25.1 a	25.6 a	62.4 b
11.2	17.9 a	14.1 a	49.3 b
14.5	9.6 a	7.7 a	21.1 b
16.8	3.5 a	5.9 a	16.3 b

[a] Seed coat breakage values in a row (constant moisture content) bearing different letters are significantly different ($P<0.05$).

resultant loss of elasticity at lower moisture contents may result in increased susceptibility to seed coat breakage. According to Sefa-Dedeh and Stanley (1979), the adhesion between the inner seed coat surface and the cotyledons is influenced by the hydration level of these seed components. At higher moisture levels the tissues expand, resulting in a tighter cotyledon/seed coat binding. The tighter the cotyledon/seed coat adhesion, the greater the tolerance to seed coat breakage (Dorrell 1968).

Effect of temperature. With only one exception (Trapper peas at 19.8% moisture content), seed coat breakage increased significantly ($P< 0.05$) with decreases in seed temperature for both cultivars at all moisture contents (Table II). However, a decrease in seed temperature from 24 to 6° C did not significantly increase seed coat breakage for either cultivar at all moisture contents with the exception of Tara at 6.3% moisture. Similarly, an increase in seed temperature from 24 to 40°C did not significantly decrease seed coat breakage. However, seed coat breakage was significantly ($P< 0.05$) lower at 40°C than at 6°C for 5 of the 10 possible moisture/cultivar combinations. These findings were generally comparable to the observations of Miller and co-workers (1979) for two (breakage prone and sound) soybean samples (12% moisture content) studied at temperatures between 4 and 39°C. Within the temperature range of 1 to 40 °C, Mazza and Campbell (1985) found that dehulling properties of buckwheat were essentially similar. Table II also shows that at −10 and −25° C, seed coat breakage was significantly ($P< 0.05$) greater than at 24° C for five and four of the 10 possible moisture-cultivar combinations, respectively, suggesting that peas should be handled more carefully at these temperatures. A decrease in seed temperature from −25 to −40° C resulted in a significant ($P< 0.05$) increase in seed coat breakage for both cultivars at all moisture levels, with the exception of Trapper at 19.8% moisture. This dramatic increase in seed coat breakage at −40° C was not expected and suggests that handling of peas below −25° C should be avoided if possible.

The reversibility of the temperature effect on seed coat durability was investigated for Trapper and Tara peas equilibrated at moisture contents from 6 to 20% (Table III). Peas stored at −40° C for two days, warmed to 24°C, and tested at this temperature showed similar ($P< 0.05$) seed coat breakage to peas that were both stored and tested at 24° C. Peas stored at −40° C and tested at −40° C generally showed a dramatic increase in seed coat breakage. These results showed that storage of peas at temperatures as low as −40° C did not cause a permanent change in the susceptibility of the seed coat to breakage.

Biological materials show a net contraction effect (a property related to thermal expansion coefficients) with decreasing temperatures, and materials containing less water show a greater contraction, resulting in reduced elastic properties when the material is cooled to subfreezing temperatures (Fennema and Powrie 1964). This reduction in elastic properties at low temperatures may be responsible for the consequent decrease in seed coat durability that we observed.

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