Variability in Dehulling Quality of Cowpea, Pigeon Pea, and Mung Bean Cultivars Determined with the Tangential Abrasive Dehulling Device[1]

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ABSTRACT

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The Tangential Abrasive Dehulling Device was used to investigate the dehulling quality of 11 cowpea (*Vigna unguiculata* L. Walp.), 23 pigeon pea (*Cajanus cajan* L. Millsp.), and 24 mung bean (*Vigna radiata* L. Wilczek) cultivars. Differences ($P<0.05$) in dehulling quality of cultivars within each species were observed. The yield (47.8–90.2%) and dehulling time (0.08–6.18 min) of cowpea varied widely suggesting that it may be desirable to monitor these characteristics in a cowpea breeding program. Some cultivars of cowpea, including 1836-013J, 2724-01F, and 3871-02F, exhibited very good dehulling quality (high yield and short dehulling time). The yield (79.0–83.8%) and dehulling time (0.48–1.78 min) of pigeon pea did not vary as widely as cowpea, and most cultivars exhibited good dehulling quality. The dehulling quality of the mung bean cultivars was generally poor because of low yields (58.2–73.8%) and long dehulling times (2.00–3.50 min). The major seed factors responsible for good dehulling quality of these legumes included resistance to seed splitting during dehulling and a seed coat loosely bound to the cotyledon.

There is increasing emphasis on the utilization of legume grains in formulated foods, particularly in relation to relieving protein shortages in developing countries. As a result, the processing of legumes has become more attractive, and there are continuing efforts to improve the yield of edible grain either through better processing techniques or plant breeding, or both. In many countries of the world, grain legumes are initially processed by hull (seed coat) removal and splitting (Siegel and Fawcett 1976). Removal of the hull (dehulling) facilitates a reduction of fiber and tannin contents, and improvement in the appearance, texture, cooking quality, palatability, and digestibility of the grain (Deshpande et al 1982, Kon et al 1973).

Dehulling of legume grains is accomplished traditionally with a mortar and pestle (Dovlo et al 1976) or mechanically with attrition-type dehullers (DeMan et al 1973), roller mills (Singh and Sokhansanj 1984, Shyeh et al 1980, Kurien and Parpia 1968), or abrasive-type dehullers (Reichert et al 1984). Dehulling grain legumes by the traditional method is laborious and time-consuming, hence the trend towards more modern mechanical processing methods. Attrition-type dehullers and roller mills are particularly suitable for dehulling and splitting legume grains with loose seed coats, whereas abrasive-type dehullers are suitable for dehulling grains with more tightly adhering seed coats (Kurien 1984).

Dehulling quality describes both the rate of hull removal from the cotyledon and the yield of dehulled grain obtained. High throughput and a high yield of dehulled grain are desirable in commercial practice. In a recent study, Reichert et al (1984), using a PRL (Prairie Regional Laboratory) mini dehuller (6.8 kg capacity), demonstrated marked differences in the dehulling quality of eight legume species. Soybean (*Glycine max*), faba bean (*Vicia faba equina* L.), and field pea (*Pisum sativum* L.) had particularly good dehulling quality, whereas cowpea (*Vigna unguiculata* L. Walp.) and mung bean (*Vigna radiata* L. Wilczek) exhibited very poor dehulling quality. One objective of the present study was to determine the variability in dehulling quality among cowpea and mung bean cultivars so that cultivars with acceptable dehulling characteristics can be identified. Pigeon pea (*Cajanus cajan* L. Millsp.) was also evaluated since it is generally dehulled prior to consumption (Singh and Jambunathan 1981). The relationship between dehulling and seed characteristics was also investigated to provide information on how the dehulling quality of each species can be improved in a plant breeding program.

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MATERIALS AND METHODS

Grain Samples

Cowpea cultivars (11) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Pigeon pea cultivars (23) were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. Mung bean cultivars (24) were obtained from the Asian Vegetable Research and Development Center (AVRDC), Tainan, Taiwan, R.O.C. All samples were equilibrated to approximately 10% moisture at 52% relative humidity over saturated $Ca(NO_3)_2$ solution. The temperature was maintained at $23 \pm 1°C$.

Dehulling Characteristics and Calculations

Dehulling characteristics were investigated with the Tangential Abrasive Dehulling Device (TADD), which was recently developed to simulate large-scale abrasive dehulling equipment (Reichert et al 1986). Replicate 5-g samples (initial weight) were dehulled with an A46L5VBE grinding wheel (V-sided) at various time intervals (20 sec to 4 min) in the TADD. Material was collected from the sample cups with a vacuum aspirating device described by Oomah et al (1981). The partially dehulled grain was hand sorted from the fines, weighed (final weight), and soaked in distilled water until the residual seed coat was loosened sufficiently to permit manual removal. The residual seed coat was collected and dried in an air oven (100° C) to constant weight. The following parameters were calculated:

$$\% \text{ Kernel removed} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

$$\% \text{ Seed coat removed} = 100 - \left(\frac{\% \text{ Seed coat in partially dehulled grain}}{\% \text{ Seed coat in whole grain}} \times 100\right)$$

Yield = 100 − % Kernel removed in removing 90% of the seed coat from the grain by dehulling (determined by plotting % kernel removed against % seed coat removed).

$$\text{Dehulling efficiency (DE)} = \frac{\text{Seed coat removed (g/100 g seed)}}{100 - \text{Yield (g/100 g seed)}}$$

The DE gives the proportion of the fines fraction comprised by seed coat, greater values indicating greater dehulling efficiency (Reichert et al 1984).

Seed Characteristics

Seed coat adhesion was determined by nicking the seed coat with a knife and subjectively evaluating the degree to which the seed coat was attached to the cotyledon, where: 1) indicated loose adhesion, the seed coat could be squeezed off by hand rubbing; 2) indicated intermediate adhesion, large pieces could be peeled off with a knife; and 3) indicated tight adhesion, only very small pieces could be peeled off with a knife.

The abrasive hardness index was determined according to Reichert et al (1984), greater abrasive hardness values indicating harder seeds.

The percent seed coat in whole grain (seed coat content) was determined by soaking approximately 2 g of seed in distilled water (2 hr at 50° C). The seed coats were separated manually from the cotyledons, dried in an air oven (100° C), and weighed.

The 1,000-seed weight was based on the average (× 10) of four replicates of 100 seeds.

RESULTS AND DISCUSSION

The percent kernel removed as fines increased linearly with dehulling time for cowpea, pigeon pea, or mung bean cultivars as illustrated in Figure 1. The slopes of the lines in Figure 1 were used to estimate the abrasive hardness index of the grain.

Cowpea

A wide range of dehulling and seed characteristics existed among cowpea cultivars (Table I). The wide range in the yield and dehulling time, which reflect product yield and throughput, respectively, in a commercial plant, suggest that it will be useful to monitor these characteristics in a cowpea breeding program. Dehulling efficiency, which reflects the proportion of the abraded fines comprised by seed coat, varied by a factor of approximately 14. Some cowpea cultivars including 1836-013J, 2724-01F, and 3871-02F had very good dehulling qualities because of high yield, short dehulling time, and high dehulling efficiency. In contrast, based on dehulling criteria, cultivars 3629, 4577-02D, and 3671-14C-01D exhibited very poor quality. The wide variation in the percent intact seeds, which indicates the proportion of the dehulled grains that did not split into cotyledons, may be related to seed morphology and shape as suggested for kidney beans (Bourne 1967). For example, the susceptibility of some of the cowpea cultivars to seed splitting may result from the presence of a large cavity between the cotyledons or from the wide variation in seed

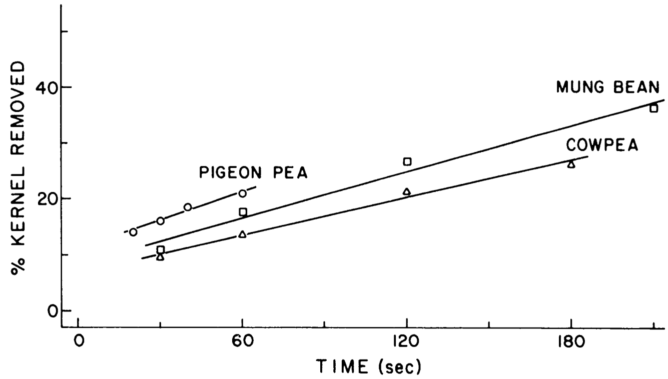

Fig. 1. Effect of dehulling time on percent kernel removed from cowpea (4262-09D), pigeon pea (HY-4), and mung bean (NGG45) samples. The percent kernel removed is equal to 100 minus yield. Slopes of regression lines for each are as follows. Pigeon pea: $Y = 11.0 + 0.170X$, $r = 0.986$** (** = significant at the 1% probability level), standard error of the mean (SE) = 0.603. Mung bean: $Y = 8.44 + 0.137X$, $r = 0.989$**, SE = 1.97. Cowpea: $Y = 6.67 + 0.112X$, $r = 0.994$**, SE = 1.00.

TABLE I
Dehulling and Seed Characteristics of 11 Cowpea Cultivars[a]

	Dehulling Characteristics			Seed Characteristics				
Cultivar	Yield[b] (%)	Dehulling Time[c] (min)	Dehulling Efficiency[b]	Intact Seeds[d] (%)	Seed Coat Adhesion[e]	Abrasive Hardness Index (sec)	Seed Coat Content (%)	1,000-Seed Weight (g)
1836-013J	90.2	0.08	0.84	63.2	1	4.9	9.1	194.3
3236-019	90.0	0.52	0.31	26.4	1	5.3	3.5	108.1
2724-01F	88.1	0.24	0.66	60.4	2	6.2	8.8	132.7
3871-02F	85.5	0.30	0.68	35.8	1	4.6	10.9	139.5
1948-01F	84.0	0.29	0.56	30.7	1	1.4	10.0	118.6
VITA-7	82.0	0.31	0.56	12.8	1	1.3	11.2	126.8
4262-09D	79.2	2.14	0.32	5.9	3	9.0	7.5	181.1
Senegal Specked	73.8	3.46	0.16	14.7	3	7.4	4.7	215.4
3671-14C-01D	58.0	5.81	0.13	6.0	3	8.4	6.1	130.1
4577-02D	57.8	4.06	0.14	1.4	3	7.4	6.5	136.4
3629	47.8	6.18	0.06	6.7	3	7.2	3.9	124.2
LSD ($P<0.05$)	2.9	0.34	0.06	9.5	···	1.3	0.6	3.0
Range	47.8–90.2	0.08–6.18	0.06–0.84	1.4–63.2	1–3	1.3–9.0	3.5–11.2	108.1–194.3

[a] 10.1 ± 0.1% moisture.
[b] Yield and dehulling efficiency when 90% of the seed coat had been removed from the grain.
[c] Dehulling time required to remove 90% of the seed coat.
[d] Percent by weight of seeds that did not split into their dicotyledenous components after dehulling to remove 90% of the seed coat.
[e] The designation 1, 2, and 3 indicates loose, intermediate, and tight adhesion, respectively, between the seed coat and cotyledons.

TABLE II
Matrix of Correlation Coefficients (*r*) of Cowpea (11 cultivars) Dehulling and Seed Characteristics

Characteristic	Yield	Dehulling Time	Dehulling Efficiency	Intact Seeds	Seed Coat Adhesion	Abrasive Hardness Index	Seed Coat Content	1,000-Seed Weight
Yield	···	−0.96**[a]	0.82**	0.72*	−0.78**	−0.52	0.51	0.12
Dehulling time		···	−0.87**	−0.70*	0.85**	0.67*	−0.65*	0.01
Dehulling efficiency			···	0.85**	−0.80**	−0.61*	0.80**	0.07
Intact seeds				···	−0.62*	−0.35	0.42	0.12
Seed coat adhesion					···	0.85**	−0.58	0.29
Abrasive hardness index						···	−0.64*	0.36
Seed coat content							···	−0.04

[a] * and **, Significant at the 5% and 1% levels, respectively.

coat adhesion among the cultivars, which is likely due to differences in the quantity of a cementing layer of gum/lignin between the seed coat and cotyledon (Kurien 1984). Seed hardness, seed coat content, and 1,000-seed weight varied by factors of approximately 7, 3, and 2, respectively.

A correlation matrix of all cowpea dehulling and seed characteristics showed that 16 of the 28 possible correlations were significant (Table II). A large proportion of the variability in yield could be explained by variation in the percent intact seeds ($r^2 = 0.52$, $P<0.05$) and seed coat adhesion ($r^2 = 0.61$, $P<0.01$), which suggests that greater yields resulted from cultivars with tight cotyledon/cotyledon adhesion and loose seed coat adhesion. Cultivars with a high yield generally showed a short dehulling time ($r^2 = 0.92$, $P<0.01$). In addition to the percent intact seeds and seed coat adhesion, dehulling time was also related to seed hardness and seed coat content. Unfortunately, hard seeds tended to have more tightly adhering seed coats ($r^2 = 0.72$, $P<0.01$). Hard seeds with loosely adhering seed coats are desirable. Seed size was not related to any of the other seed or dehulling characteristics.

Pigeon Pea

Pigeon pea cultivars exhibited less variation in dehulling characteristics than cowpea cultivars (Table III). The range in yield (79.0–83.8%) was narrower than that (72.3–82.0%) obtained by Ramakrishnaiah and Kurien (1983) in dehulling 200 g each of 18 pigeon pea cultivars for 45 sec in a "Karkoran" barley debranning machine. Given the relatively narrow range in yield and efficiency, improvement of dehulling characteristics by plant breeding will be difficult. The range in dehulling time suggested that throughput could vary by a factor of nearly four depending on the cultivar; it may, therefore, be desirable to develop cultivars with improved throughputs by reducing the dehulling times. The percent intact seeds was generally great in comparison to cowpea cultivars. The seed coat adhesion of most pigeon pea cultivars was rated intermediate. The range in the abrasive hardness index was slightly wider than that obtained for the cowpea cultivars. Ranges in seed coat content and 1,000-seed weight were similar to those reported by Ramakrishnaiah and Kurien (1983) (10.5–15.5% and 70.9–191.6 g, respectively). Using the same criteria as for cowpea,

TABLE III
Dehulling and Seed Characteristics of 23 Pigeon Pea Cultivars[a]

Cultivar	Dehulling Characteristics: Yield[b] (%)	Dehulling Time[c] (min)	Dehulling Efficiency[b]	Seed Characteristics: Intact Seeds[d] (%)	Seed Coat Adhesion[e]	Abrasive Hardness Index (sec)	Seed Coat Content (%)	1,000-Seed Weight (g)
HY-2	83.8	1.09	0.70	76.7	2	7.3	12.6	104.7
ICPL-87	83.8	0.74	0.74	55.1	2	7.5	13.3	105.2
UPAS-120	83.1	0.66	0.78	78.0	2	7.6	14.5	73.5
BDN-1	83.1	0.48	0.74	57.1	1	2.2	13.8	82.9
ICPL-270	83.1	0.68	0.71	55.7	2	5.9	13.3	107.1
Gwalior-3	83.0	1.08	0.65	54.6	2	7.7	12.3	90.8
T-21	82.8	0.49	0.77	69.9	2	1.9	14.7	69.2
ICPL-1	82.7	0.64	0.74	74.5	1	2.6	14.4	77.1
T-7	82.5	1.23	0.58	67.4	2	8.6	11.2	121.8
T-17	82.4	0.99	0.69	52.2	2	8.2	13.4	82.0
C-11	82.3	1.00	0.66	68.4	2	11.0	13.0	98.9
Pusa Ageti	82.2	0.82	0.68	68.5	2	3.6	13.5	104.8
ICPL-6	82.0	1.15	0.69	64.8	2	8.8	13.7	79.5
ICPL-295	82.0	0.67	0.66	90.4	2	6.6	13.2	90.9
ICPH-6	81.5	1.70	0.68	81.2	2	6.4	13.8	85.6
No. 148	81.4	0.63	0.69	61.7	2	3.4	14.2	84.7
IE #4916	81.2	0.74	0.64	61.1	2	3.9	13.2	92.1
HY-1	80.2	1.40	0.56	54.4	2	3.9	12.3	101.6
HY-3C	80.2	1.40	0.50	26.0	2	6.3	11.1	187.6
NP(WR)-15	79.8	1.16	0.59	47.8	2	5.2	13.3	78.5
ICPH-2	79.2	1.22	0.62	53.4	2	5.7	14.4	74.4
LRG-30	79.2	1.78	0.66	71.3	3	7.0	15.3	65.2
HY-4	79.0	1.05	0.66	62.4	2	5.9	15.3	91.3
LSD ($P<0.05$)	1.4	0.24	0.05	8.2	...	2.4	0.7	2.3
Range	79.0–83.8	0.48–1.78	0.50–0.78	26.0–81.2	1–3	1.9–11.0	11.1–15.3	65.2–187.6

[a] 10.2 ± 0.1% moisture.
[b] Yield and dehulling efficiency when 90% of the seed coat had been removed from the grain.
[c] Dehulling time required to remove 90% of the seed coat.
[d] Percent by weight of seeds that did not split into their dicotyledenous components after dehulling to remove 90% of the seed coat.
[e] The designation 1, 2, and 3 indicates loose, intermediate, and tight adhesion, respectively, between the seed coat and cotyledons.

TABLE IV
Matrix of Correlation Coefficients (*r*) of Pigeon Pea (23 cultivars) Dehulling and Seed Characteristics

Characteristic	Yield	Dehulling Time	Dehulling Efficiency	Intact Seeds	Seed Coat Adhesion	Abrasive Hardness Index	Seed Coat Content	1,000-Seed Weight
Yield	...	−0.58**[a]	0.62**	0.29	−0.40	0.10	−0.23	0.00
Dehulling time		...	−0.62**	0.00	0.57**	0.40	−0.19	0.19
Dehulling efficiency			...	0.59**	−0.28	−0.17	0.62**	−0.61**
Intact seeds				...	0.01	0.01	0.45*	−0.54**
Seed coat adhesion					...	0.43*	0.06	−0.01
Abrasive hardness index						...	−0.30	0.17
Seed coat content							...	−0.77**

[a] * and **, Significant at the 5% and 1% levels, respectively.

most of the pigeon pea cultivars exhibited good dehulling qualities.

A correlation matrix of all pigeon pea dehulling and seed characteristics showed that 11 of the 28 possible correlations were significant (Table IV). No seed characteristics were correlated with yield. As in cowpea, yield and dehulling time were negatively correlated. Seed coat adhesion accounted for 32.5% ($r^2 = 0.325$, $P < 0.01$) of the variability in dehulling time, suggesting that cultivars with a loosely bound seed coat have a shorter dehulling time. The seed factors affecting dehulling efficiency were percent intact seeds, seed coat content, and 1,000-seed weight.

Mung Bean

The yield, dehulling efficiency, and percent intact seeds of mung bean cultivars were generally low (Table V). The range in dehulling time, abrasive hardness index and seed coat content was narrower than that observed for the cowpea and pigeon pea cultivars. The range in the seed coat adhesion was very narrow; 16 of 24 cultivars had a tightly bound seed coat and no cultivar was rated 1. The 1,000-seed weight varied by a factor of approximately three.

A correlation matrix of all mung bean dehulling and seed characteristics showed that 17 of the 28 possible correlations were significant (Table VI). As with the cowpea and pigeon pea cultivars, increased dehulling times reduced the yield of dehulled grains ($r^2 = 0.64$, $P < 0.01$). The seed factors affecting the variability in the yield were percent intact seeds ($r^2 = 0.29$, $P < 0.01$), abrasive hardness index ($r^2 = 0.52$, $P < 0.01$), and seed coat content ($r^2 = 0.18$, $P < 0.05$). This suggested that greater yields resulted from cultivars with greater cotyledon/cotyledon adhesion and seed hardness, and more seed coat. Seed coat content was negatively correlated ($r^2 = 0.81$, $P < 0.01$) with 1,000-seed weight, suggesting that smaller seeds contained a larger amount of seed coat; pigeon pea was observed to have a similar relationship ($r^2 = 0.59$, $P < 0.01$). The dehulling characteristics of the 24 cultivars of mung bean were generally poor, and improvement in dehulling quality is warranted. The poor dehulling characteristics probably resulted from high susceptibility to seed splitting during dehulling and tight seed coat adhesion.

Further investigations to screen collections of mung beans to identify cultivars with poor seed coat adhesion and resistance to seed splitting are necessary.

TABLE V
Dehulling and Seed Characteristics of 24 Mung Bean Cultivars[a]

	Dehulling Characteristics			Seed Characteristics				
Cultivar	Yield[b] (%)	Dehulling Time[c] (min)	Dehulling Efficiency[b]	Intact Seeds[d] (%)	Seed Coat Adhesion[e]	Abrasive Hardness Index (sec)	Seed Coat Content (%)	1,000-Seed Weight (g)
NGG40	73.8	2.00	0.32	5.4	3	8.7	9.4	37.8
CES 44	70.5	2.46	0.24	9.2	3	6.3	8.0	71.7
PH. Coll.02	69.8	2.25	0.26	23.3	3	6.8	8.9	51.3
V1779-1	69.6	2.80	0.34	21.2	2	8.8	11.4	28.7
V2170-1	69.5	3.19	0.30	13.6	2	8.3	9.9	38.9
CES 87-17	67.8	2.78	0.24	20.2	2	6.1	8.3	63.1
CES 55	67.8	2.70	0.24	4.6	3	6.7	8.3	76.6
NGG45	67.0	3.06	0.26	5.7	2	7.3	9.6	37.4
Parunagarh 1-11	66.0	3.40	0.24	12.4	3	6.6	8.8	53.3
S-8	64.5	3.14	0.24	8.9	3	5.6	9.3	38.4
MG-50-10A	64.5	3.13	0.20	6.5	3	6.4	8.0	77.0
LM 144	64.2	2.80	0.20	3.7	3	6.4	7.7	65.4
LM 088	64.0	2.90	0.25	12.2	3	6.7	9.9	34.8
LM 196	63.6	3.32	0.25	5.4	3	6.5	10.2	29.5
M 1963	63.5	2.80	0.20	3.5	2	5.9	8.4	61.3
MG50-10A	63.5	3.14	0.20	3.5	3	6.4	8.1	69.3
M 1878	63.0	3.04	0.23	9.2	2	5.7	9.5	35.7
MD15-2	63.0	3.27	0.18	4.8	3	6.1	7.5	70.1
P. T. 18	62.9	3.32	0.22	7.5	2	6.4	9.3	43.8
MG-MD-6D	62.5	3.44	0.20	0.0	3	6.8	8.2	74.1
BPI GLAB=3	62.0	3.20	0.20	7.4	2	6.1	8.8	72.8
MD-15-2	61.8	3.21	0.18	4.1	3	5.9	7.8	76.2
CES 28	61.5	3.50	0.18	4.3	3	6.2	7.8	69.3
CES 140	58.2	3.50	0.16	3.1	3	5.7	7.4	77.1
LSD ($P < 0.05$)	2.3	0.28	0.02	4.4	...	0.7	1.7	1.5
Range	58.2–73.8	2.00–3.50	0.16–0.34	0.0–23.3	2–3	5.6–8.8	7.4–11.4	28.7–77.1

[a] 9.2 ± 0.2% moisture.
[b] Yield and dehulling efficiency when 90% of the seed coat had been removed from the grain.
[c] Dehulling time required to remove 90% of the seed coat.
[d] Percent by weight of seeds that did not split into their dicotyledenous components after dehulling to remove 90% of the seed coat.
[e] The designation 1, 2, and 3 indicates loose, intermediate, and tight adhesion, respectively, between the seed coat and cotyledons.

TABLE VI
Matrix of Correlation Coefficients (*r*) of Mung Bean (24 cultivars) Dehulling and Seed Characteristics

Characteristic	Yield	Dehulling Time	Dehulling Efficiency	Intact Seeds	Seed Coat Adhesion	Abrasive Hardness Index	Seed Coat Content	1,000-Seed Weight
Yield	...	−0.80**[a]	0.84**	0.54**	−0.10	0.72**	0.42*	−0.38
Dehulling time		...	−0.56**	−0.39	−0.02	−0.41*	−0.18	0.19
Dehulling efficiency			...	0.60**	−0.30	0.84**	0.83**	−0.75**
Intact seeds				...	−0.32	0.33	0.50*	−0.43*
Seed coat adhesion					...	−0.19	−0.46*	0.36
Abrasive hardness index						...	0.62**	−0.49*
Seed coat content							...	−0.90**

[a] * and **, Significant at the 5% and 1% levels, respectively.

CONCLUSIONS

Significant differences ($P < 0.05$) in dehulling characteristics existed among 11 cowpea, 23 pigeon pea, and 24 mung bean cultivars. Three of the cowpea cultivars exhibited good dehulling quality because of a high yield, short dehulling time, and high dehulling efficiency. Most of the pigeon pea cultivars were dehulled successfully by abrasive dehulling. Mung bean dehulling quality, which was generally poor, could be improved by identifying cultivars that are increased in seed hardness, adhesion between the cotyledons, and seed coat content. The TADD method for assessing dehulling quality is simple, rapid, requires a small sample size, and is suitable for routine testing in a breeding program.

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