AGRONOMY (AGRONOMIA)

Revista Brasileira de Ciências Agrárias
ISSN (on line) 1981-0997
v.13, n.2, e5523, 2018
Recife, PE, UFRPE. www.agraria.pro.br
DOI:10.5039/agraria.v13i2a5523
Protocolo 5523 - 16/02/2017 • Aprovado em 28/02/2018

Drum priming in snap bean (*Phaseolus vulgaris* L.) seed

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ABSTRACT: Priming is a treatment that improves the seed lot performance of several species, particularly the speed of germination. Drum priming (DP) is a low-cost process that promotes a slow water uptake by the seeds. The purpose of this study was to assess the efficiency of DP on the performance of large and small seeds of six snap bean cultivars. The curves of seed imbibition and the seed water content at the time of radicle protrusion were evaluated. In addition, the influence of DP on seed performance was examined based on vigour index using the Seedling Vigor Image System software (SVIS®), electrical conductivity and percentage of germination. The results showed that the seed water content at the time of radicle protrusion ranged between 33.8 and 51.5%. The DP technique improved snap bean seed performance in a cultivar-specific pattern. Snap bean seed vigour was efficiently evaluated through SVIS®, which was used for determination of the vigour index and seedling length.

Key words: cultivars; germination; hydropriming; seed size; vigour

Condicionamento fisiológico em sementes de feijão de vagem (*Phaseolus vulgaris* L.) pelo método do tambor

RESUMO: A técnica de condicionamento fisiológico tem demonstrado a possibilidade de aprimorar o desempenho de lotes de sementes de várias espécies. O método do tambor é um processo de baixo custo que permite a absorção controlada de água pelas sementes. O objetivo deste estudo foi avaliar os efeitos do condicionamento fisiológico pelo método do tambor em sementes pequenas e grandes de seis cultivares de feijão de vagem. As avaliações foram realizadas por meio de curvas de absorção de água, germinação, primeira contagem do teste de germinação, índices de vigor e comprimento de plântulas por meio de software Seedling Vigor Image System (SVIS®) e condutividade elétrica. Os resultados mostraram que o teor de água necessário para iniciar a protrusão da radícula variou entre 33,8 e 51,5%. O condicionamento fisiológico pelo método de tambor aumentou o desempenho das sementes feijão de vagem e os efeitos foram dependentes da cultivar. O índice de vigor obtido no SVIS® software na avaliação do desenvolvimento e comprimento de plântulas mostrou diferenças de vigor em função do tamanho das sementes e do condicionamento fisiológico.

Palavras-chave: cultivares; germinação; hidrocondicionamento; tamanho de semente; vigor

Introduction

Imbibition damage is a phenomenon that influences germination performance and seed vigour of numerous seed legumes. Injury is caused by rapid entry of water into the cotyledons during imbibition, leading to high solute leakage from the seed and eventually cell death. In seed legumes of *Phaseolus vulgaris* L., a genotypic trait of susceptibility to imbibition damage is to be considered. More specifically, seeds whose testa is partially or completely unpigmented imbibe water more rapidly and exhibit more considerable levels of imbibition damage than those of cultivars with pigmented testa. Importantly, imbibition damage can be prevented by slowing down the rate of water uptake under low temperatures (Powell et al., 1986).

Seed size is another characteristic that influences water uptake and vigour. Pereira et al. (2013) concluded that under ideal moisture conditions, larger seeds have better physiological qualities, producing more vigorous seedlings. However, under water potential of −0.2 MPa, smaller seeds produce larger seedlings. They found that, compared with the radicle growth, the hypocotyl growth was influenced to a greater extent by water stress. The association between pigmentation and slower rates of imbibition has been demonstrated in earlier studies on seed development (Legesse & Powell, 1996). Adherence of the pigmented testa to the cotyledons was found to limit the rate of water movement within the seed of *P. vulgaris* L. (Powell et al., 1986) and chickpea (Legesse & Powell, 1996).

Seed priming is a technique that involves uptake of water by the seed (by soaking) and is followed by drying to initiate early events of germination up to the point of radicle emergence. Benefits of seed priming include speeding up of seed germination, achieving increased and uniform germination of seeds and enhancing seedling vigour and growth under a broad range of environmental conditions that result in the establishment of an improved stand (Aboutalbian et al., 2012; Ghassemi-Golezani et al., 2014).

Hydropriming is a technique that uses only water to facilitate seed imbibition. This method has contributed to significant improvement in broad bean seed vigour (Yazdani, et al., 2011). However, hydropriming may not be suitable for application on legumes seeds because of their sensitivity to leakage of solutes, which is associated with cracking of the cotyledon. Furthermore, after complete immersion in water, large-seeded bean cultivars are more sensitive to cotyledon cracking than small-seeded ones. After the priming process, the larger seeded cultivars lost their desiccation tolerance (Abebe & Modi, 2009).

Researchers at the Ohio State University developed an equipment for application of hydration cycles called 'drum priming' (DP). This technique has proved to be suitable for numerous crop seeds that can benefit from controlled hydration. The water uptake by a seed is restricted by limiting water availability which is distributed evenly and slowly over the seed mass to the desired seed water content, typically 25-30% on a fresh weight basis (Warren & Bennett, 1997).

In a previous study, hydropriming of mung-bean seeds resulted in the highest seedling emergence in the field and improved the resistance of the crop to water restriction (Ghassemi-Golezani et al., 2014). The application of this procedure also increased the germination percentage, particularly under drought stress (Aboutalbian et al., 2012). However, to the best of our knowledge, the effect of DP on the seed performance in snap dry bean seeds remains unknown. Therefore, the objective of this investigation was to evaluate the effect of hydration intervals followed by dehydration, using DP, on germination and vigour of small and large seeds of six snap bean cultivars.

Materials and Methods

Experiments of the current study were conducted from October 2012 to June 2013 at the Seed Laboratory of the Ohio State University. We used organic seeds of six snap bean cultivars 'Tavera', 'Provider', 'Fresh Pick', 'Rocdor', 'Royal Burgundy' and 'EZ-Pick', which were purchased from Johnny's Selected Seeds Company.

Seeds were classified by size into two categories 'large' and 'small', obtained after using sieves with oblong screens ranging from 3.25 to 5.5 mm in width and from 12.0 to 22.0 mm in length. After sieving, X-Ray images of samples of 50 seeds were obtained utilising the Faxitron X-Ray Model MX-20 equipment, followed by seeds analysis using the Tomato Analyser software. This software automatically determined seed parameters, including length (mm), width (mm) and thickness (mm).

The 1000-seed weight was obtained from the average of eight replicates of 100 seeds multiplied by 10 (ISTA, 2006). The seed coat colour was defined as described according to the instructions of the Johnny's Selected Seeds Company: The small and large seed size ranges and main seed physical characteristics of the snap bean cultivars are presented in Table 1.

A seed hydration curve was constructed using 50 seeds from each cultivar and their seed size. Seeds were placed between six sheets of filter paper moistened with water equivalent to 2.5 times the dry mass of the paper sheets in mL. Sheets were placed inside an acrylic box (11.0 × 11.0 × 3.5 cm) in a chamber at 25°C, checking from hourly, during the first ten hours, then every two hours until the twenty-fourth hour and then every four hours, until the start of radicle protrusion. The seed water content value for each period of the hydration interval was obtained from the difference between the weight of the hydrated seed and that of the seed with baseline moisture content (Table 2). On radicle protrusion, the seed water content was determined by the oven method at 105°C for 24 h (ISTA, 2006).

Table 1. Coat colour; mean values of length, width, thickness and 1,000-seed weight of the small and large seeds of the six snap bean cultivars.

Cultivar	Coat colour	Type	Seed size	Length	Width (mm)	Thickness	P 1,000 (g)
'Tavera'	White	Bush	Small	9.13	2.78	3.43	103.39
			Large	10.89	3.56	4.21	164.42
'Provider'	Purple	Bush	Small	11.01	4.62	4.93	241.35
			Large	13.01	4.96	6.01	345.18
'Fresh Pick'	Palegreen	Bush	Small	12.65	4.56	6.01	212.38
			Large	13.91	5.87	6.67	283.05
'Rocdor'	Black	Yellowwax	Small	12.12	4.55	5.81	205.13
			Large	14.12	5.92	6.81	314.50
'Royal Burgundy'	Brown	Bush	Small	11.32	4.93	5.34	259.96
			Large	13.73	5.66	6.42	363.04
'EZ-Pick'	White	Bush	Small	13.34	5.44	6.05	271.53
			Large	15.46	6.66	7.25	374.74

Drum priming

Small and large seed samples of each seed cultivar were subjected to DP using a priming method, referred to as DP, following the procedure described by Warren and Bennett (1997). The experiments were executed defining the initial seed weight for each seed size and cultivar as equivalent to the weight of approximately 1,000 seeds. During each cycle, the seed samples were exposed to a predetermined volume of distilled water, followed by rotation in the drum for varying periods at 25°C to ensure uniform absorption until the seed water content reached the radicle protrusion point as indicated by the hydration curve (Figure 1). Based on these results, we determined the number of cycles, volume of water per cycle and the total water volume added during the DP treatment applied to each cultivar (Table 2). These values depended on the previous hydration curve for each cultivar and the settings of the equipment (Figure 1 and Table 2). After each period of hydration, seeds were initially dried in a controlled chamber at 20°C for 6 h and then the temperature was increased to 25°C. Next, final seed drying was completed inside an oven at 35°C. The seed water content was reduced until the level approximated the equivalent of the initial or non-hydrated seed. The seed water content was determined before and after final DP treatments using the oven method of 105°C/24 h (ISTA, 2006).

Seed performance before and after DP was assessed based on a germination test for each cultivar and the seed size, according to the germination method described by ISTA (2006). Four replicates of 50 seeds, placed equidistant apart on moist germination paper towels, were evaluated (Anchor Paper Co., St. Paul, MN, USA). The test was performed under a constant temperature of 25°C, and normal seedling evaluations were performed 5 and 9 days later to establish the percentage of germination. Data from the first analysis constituted the first germination count lasting for 5 days.

Electrical conductivity (EC), representing leaching of solutes from the seeds, was assessed following the method suggested by AOSA (2009). Four sub-samples of 50 seeds were accurately weighed to the nearest 0,001 g and soaked in Erlenmeyer flasks containing 250 mL of distilled water. Samples were retained at 25°C for 24 h. Subsequently, EC of the solutions was determined using a conductivity meter model YSI 3100; mean values were recorded as μS cm^{-1} g^{-1} $seed^{-1}$.

Table 2. Drum priming (DP) settings used in small and large seeds of six snap bean cultivars.

Cultivar	Seed size	Initial weight* (g)	SWC initial** (%)	Number of cycles***	Volume/Cycle (mL)	Total water (mL)	SWC after DP (%)
'Tavera'	Small	105.04	7.3	6	14	84	43.4
	Large	165.04	7.4	6	20	120	43.1
'Provider'	Small	242.28	7.5	6	20	120	36.2
	Large	346.15	7.6	6	24	144	34.7
'Fresh Pick'	Small	213.12	7.5	6	23	138	43.4
	Large	284.00	7.3	9	24	216	40.2
'Rocdor'	Small	206.19	7.6	6	20	120	29.4
	Large	315.10	7.6	8	24	192	36.7
'Royal Burgundy'	Small	260.08	9.3	8	22	176	40.6
	Large	364.10	9.2	10	24	240	39.6
'EZ-Pick'	Small	212.19	7.9	6	20	120	43.5
	Large	385.10	8.0	9.5	23	207	48.6

* 1,000 seeds approximated
** SWC: seed water content
*** Cycle: Number of times that seeds were hydrated

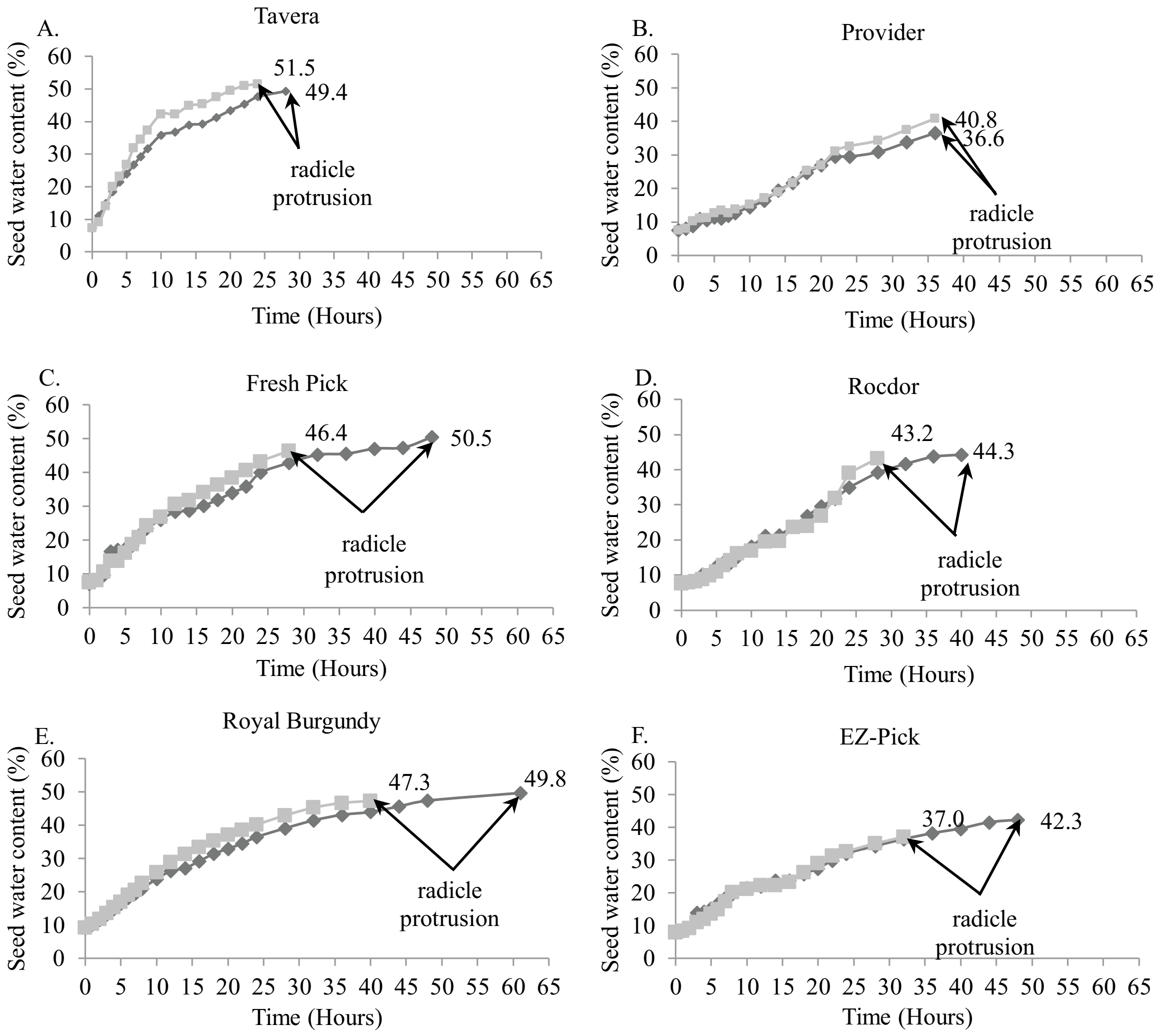

Figure 1. Time course of water absorption by six snap bean seeds cultivars during hydration and radicle protrusion (■ – small seed; ♦ – large seed).

The Seedling Vigor Image System (SVIS)® software procedure comprised evaluating the scanned image of seedlings taken 4 days after germination. Four replications of 25 seeds each per treatment were analysed using procedures described by Hoffmaster et al. (2005) and SVIS® was employed according to the methodology reported by Sako et al. (2001), facilitating automatic processing of seedling images. This software automatically measures growth of all seedlings. Results of each replicate were combined following processing of data of each individual seedling and automatic-manual measurements to obtain a growth and uniformity index, both ranging from zero (no germination) to 1,000 (maximum germination). The software was set to overall vigour index, which consisted of 70% of the sum of the growth index and 30% of the uniformity index. Seedling length in mm was recorded using the same software that measures individual seedlings, and results were presented as deviation from the mean of the normal seedlings.

Statistical analysis was conducted using analysis of variance in a completely randomised design experiment with a factorial arrangement of six varieties *vs*. two seed sizes *vs*. 'with' or 'without DP treatment' with four replications. Percentage of germination and the percentage of first count germination data were transformed to arc sin $\sqrt{100/x}$. The original percentage values are presented in the tables. Mean comparisons were performed using Tukey's test ($P < 0.05$).

Results and Discussion

As can be observed in Figure 1, hydration of the large and small seed of each cultivar increased the seed water content, the degree of which depended on the imbibition time. Small seeds of all cultivars evaluated reached the seed water content necessary for radicle protrusion faster than large seeds. Percentages of the seed water content and the corresponding time required to the start of radicle protrusion for small and large seeds were as follows: 'Tavera', 51.5% (24 h) and 49.4% (28 h); 'Provider', 40.8% (36 h) and 33.6% (32 h); 'Fresh Pick', 46.4% (28 h) and 50.5% (48 h); 'Rocdor' 43.2% (28 h) and 44.3% (40 h); 'Royal Burgundy', 47.3% (40 h) and 49.8% (61 h); 'EZ-Pick', 37.0% (32 h) and 42.3% (48 h), respectively (Figure 1).

According to Esteves et al. (2002), differences in water uptake among cultivars of bean seeds may be associated with stiffness of the coat and smaller intracellular spaces. In addition, the grip of cotyledons of different cultivars varies depending on the calcium pectate deposition in the middle lamela and colloidal porosity properties. Some cultivars may additionally have higher levels of pigmented testa with lignins and tannins, which are waterproofing substances that can influence water uptake. Powell et al. (1986) observed that cultivars without coat pigmentation subjected to soaking showed little adherence to water by the cotyledons and thus allowed more rapid movement of water than that in pigmented coat seeds treated in an identical way. In the latter case, coat adherence of the cotyledons impeded water movement, resulting in slower soaking. In the current study, seeds of the cultivars with a white coat had faster average water absorption rates than those of the cultivars with a pigmented coat, except for large seeds of 'EZ-Pick'.

Radicle protrusion in the seeds of 'Rocdor', which have a black coat, started at a seed water content of 43.2% for small and 44.3% for large seeds. Water uptake occurred rapidly in the cultivar 'Tavera' and the uptake of water by the smaller seeds was faster than that in the large seeds, regardless of the cultivar. Correlation between seed imbibition speed and seed size was observed because small seeds had a lower volume to surface area ratio than large seeds, except for seeds of cultivar 'Provider'.

The initial seed weight and the initial and final seed water content reached by seeds during DP treatment can be seen in Table 2. A higher number of cycles (8–10) and a greater volume of water were required for application in large seeds of cultivars 'Ez-Pick', 'Royal Burgundy', 'Rocdor' and 'Fresh Pick' because of the higher weight of their seed. Treatments divided into six cycles were implemented for other cultivars and seed sizes. The seed water content percentage obtained at the final DP treatment for each cultivar and seed size ranged from 29.4% to 48.6% (Table 2).

Potential uneven hydration of seeds is one of the major disadvantages of the hydropriming method; this results in failure of uniform activation of the physiological processes, necessary for synchronising and improving seed performance. Mazibuko & Modi (2005) found that different bean cultivars and seed sizes responded differently to seed priming treatment, and dehydration and larger-seeded varieties were more sensitive to desiccation. After priming, seeds of some black bean cultivars investigated by these authors reached seed water content values ranging from 48% to 50%. It is noteworthy that seed drying after priming led to the worst physiological seed performance. In the current study, DP ensured seed imbibing that was slow and constant over time, which probably decreased seed imbibition damage. Slower drying after DP treatment, starting at 20°C and subsequently continuing further at 25°C and 35°C, decreased tegument cracking and the risk of seed damage.

In our examination, the bean seed absorbed a larger volume of water compared with that in experiments conducted by Warren & Bennett (1997). They used DP in several lots of sweet corn seeds at 25°C for 6 h, and all seed lots gradually achieved the desired water content from 25% to 30%. They established that seed hydration was an effective treatment resulting in high, medium and low vigour within three sweet corn seed cultivars.

Our analysis of variance indicated significant interaction between cultivars and seed size for the first count, percentage of germination, EC, vigour index and seedling length.

After DP treatment, the percentage of germination varied among the different cultivars and seed sizes and (Table 3). Variations in the percentages of germination in the no priming treatment group were cultivar-specific and reached values of above 80%, except that for the large seed of 'Royal Burgundy' which had a germination rate of 75%. Large seeds of cultivar 'Tavera' had a higher germination percentage than the small seeds; moreover, DP treatment decreased germination in 'Tavera' and 'Fresh Pick', regardless of their seed size.

Abebe & Modi (2009) observed failure of seed germination after complete immersion of bean seeds in a water-filled flask. They concluded that not the hydration method used, but the dehydration treatment, in which concentrated lithium chloride solution was applied after hydration, was the cause for these negative results. Slower hydration achieved by DP reduces deleterious effects associated with faster seed hydration. Furthermore, slow drying after seed priming is required for avoiding high cotyledonal and coat cracking in the seeds and for maintaining integrity of the seeds. The time of treatment influences the results of germination. For

Table 3. Germination of large and small seeds of six snap bean cultivars in the no priming treatment and after drum priming and drying groups.

Germination (%)						
Priming	No priming			Drum priming and drying		
Cultivar/seed size	Large	Small	Mean	Large	Small	Mean
'Tavera'	83 Ca	77 Ba	80	70 Da	58 Db	64
'Provider'	92 Ba	95 Aa	94	98 Aa	92 Ab	95
'Fresh Pick'	91 Ba	93 Aa	92	70 Db	80 Ca	75
'Rocdor'	99 Aa	97 Aa	98	94 Aa	95 Aa	95
'Royal Burgundy'	75 Cb	83 Ba	79	81 Ca	77 Ca	79
'EZ-Pick'	95 Aa	82 Bb	89	88 Ba	90 Ba	89
Mean	89	88	88	83	82	83
CV (%)	2.87					

Means followed by the same lowercase letter on the lines, and same uppercase letter on the columns do not differ statistically by Tukey's test at 5% probability.

example, hydropriming of sunflower seeds for 24 h increased the germination rate and seed vigour (Moghanibashi et al., 2012). In addition, *Aegle marmelos* seeds were also found to display improved germination and promoted vigour after hydropriming for 48 h (Singh, 2017**)**.

Characteristics of the performance of the seeds of the studied cultivars are presented in Tables 4–7. The percentage of normal seedlings 5 days after germination was cultivar and seed size-dependent. Cultivars 'Rocdor' and 'Provider' had higher percentages of normal seedlings 5 days after the germination, regardless of the seed size and presence or absence of DP treatment. The DP treatment increased the percentage of normal seedlings after 5 days, except for 'Rocdor' and 'Royal Burgundy' cultivar (Table 4).

DP treatment decreased EC values of the seeds of all cultivars, except those of small seeds of cultivar 'Provider'. Electrolyte leakage from seeds during the priming process resulted in reduced EC values after DP treatment, and the lowest values were obtained for small seeds (Table 5). Our values, ranging from 15.8 to 55.2 µS cm^{-1} g^{-1}, were lower than those obtained by Ptasznik & Khan (1993) which ranged from 34.3 µS cm^{-1} g^{-1} under seed matriconditioning treatment to 94.7 µS cm^{-1} g^{-1} without the matriconditioning treatment. These differences could be due to direct contact between seeds and water during the DP process, which promoted a greater loss of solutes from the seeds with no matriconditioning than that from seeds after matriconditioning. Abebe & Modi (2009) discovered that EC of a large seed dry bean cultivar was higher

Table 4. First count of germination of large and small seeds of six snap bean cultivars with no priming and after drum priming and drying.

Priming	No priming			Drum priming and drying		
Cultivar/seed size	Large	Small	Mean	Large	Small	Mean
'Tavera'	61 Ca	49 Cb	55	68 Ca	68 Ca	68
'Provider'	81 Ba	84 Aa	83	85 Aa	83 ABa	84
'Fresh Pick'	57 Cb	67 Ba	62	76 BCb	85 ABa	81
'Rocdor'	90 Aa	86 Aa	88	88 Aa	88 Aa	88
'Royal Burgundy'	62 Ca	68 Ba	65	59 Da	63 Ca	61
'EZ-Pick'	61 Ca	62 Ba	62	71 BCb	80 Ba	76
Mean	69	69	69	75	78	77
CV (%)			4.24			

Means followed by the same lowercase letter on the lines, and same uppercase letter on the columns do not differ statistically by Tukey's test at 5% probability.

Table 5. Electrical conductivity test for large and small seeds of six snap bean cultivars with no priming and after drum priming and drying.

Electrical conductivity (µS cm^{-1} g^{-1})						
Priming	No priming			Drum priming and drying		
Cultivar/seed size	Large	Small	Mean	Large	Small	Mean
'Tavera'	62.3Ab	75.7 Aa	69.0	55.2 Aa	28.9 Bb	42.0
'Provider'	23.0 Da	15.8 Db	19.4	16.9 Db	22.9 BCa	19.9
'Fresh Pick'	51.0 Ba	51.7 Ba	51.3	35.3 Bb	37.2 Aa	36.3
'Rocdor'	20.5 Db	23.9 Da	22.2	15.8 Da	17.1 Ca	16.5
'Royal Burgundy'	31.5 Cb	44.9 Ba	38.2	24.6 Cb	29.1 Ba	26.9
'EZ-Pick'	37.5 Ca	33.9 Cb	37.5	31.8 Ba	28.2 Bb	30.0
Mean	49.9	54.8	52.3	43.5	28.6	36.0
CV (%)			3.01			

Means followed by the same lowercase letter on the lines, and same uppercase letter on the columns do not differ statistically by Tukey's test at 5% probability.

Table 6. Seed Vigour Index of large and small seeds of six snap bean cultivars with no priming and after drum priming and drying*.

Priming	No priming			Drum priming and drying		
Cultivar/seed size	Large	Small	Mean	Large	Small	Mean
'Tavera'	648.0 Ca	620.3 Da	634.1	646.3 Ca	673.0 Ea	659.7
'Provider'	707.8 Ba	655.3 CDa	681.6	913.0 Aa	898.8 Ba	905.9
'Fresh Pick'	607.8 Cb	712.8 Ba	660.3	752.0 Ba	803.5 Ca	777.8
'Rocdor'	878.8 Aa	883.5 Aa	881.2	961.0 Aa	969.5 Aa	965.3
'Royal Burgundy'	712.5 Ba	706.5 BCa	709.5	645.0 Cb	747.3 Da	696.2
'EZ-Pick'	229.3 Da	262.5 Ea	245.9	685.8 Cb	808.0 Ca	746.9
Mean	438.7	441.4	440.0	666.0	740.5	703.3
CV (%)			5.98			

Means followed by the same lowercase letter on the lines, and same uppercase letter on the columns do not differ statistically by Tukey's test at 5% probability.
*zero (low vigour)–1,000 (high vigour).

Table 7. Average seedling length (mm) of large and small seeds of six snap bean cultivars with no priming and after drum priming and drying.

Priming	No priming			Drum priming and drying		
Cultivar/seed size	Large	Small	Mean	Large	Small	Mean
'Tavera'	68 BCa	66 Ca	67	91 BCa	75 Cb	83
'Provider'	81 BCa	70 BCb	76	113 Aba	112 Ba	113
'Fresh Pick'	58 Cb	102 Aa	80	92 BCa	76 Cb	84
'Rocdor'	102 Aa	101 Aa	102	138 Ab	156 Aa	147
'Royal Burgundy'	79 BCa	81 BCa	82	74 Cb	89 BCa	82
'EZ-Pick'	18 Db	32 Da	25	77 Cb	96 BCa	87
Mean	43	49	46	84	86	85
CV (%)			8.58			

Means followed by the same lowercase letter on the lines, and same uppercase letter on the columns do not differ statistically by Tukey's test at 5% probability.

than that of a small-seed cultivar, which showed the lowest level of conductivity. Lower conductivity of the large-seeded bean cultivars indicates that their seeds are more liable to leakage than the small-seeded cultivars.

SVIS® software was efficient for evaluating the vigour index and length of the seedlings in this experiment. In general, DP treatment increased the vigour index of all cultivars, as indicated by assessment by SVIS® for both large and small seeds, except for the large seeds of cv. 'Royal Burgundy' (Table 6). Increase in the seed vigour index of cv. 'EZ-Pick', caused by DP, was the highest among all values of the other cultivars, for either seed size category.

DP treatment promoted faster seed germination, culminating in larger seedlings and thus, resulting in higher seed vigour. The length of the seedlings increased after DP treatment, and small seeds of cultivars 'Rocdor', 'Royal Burgundy' and 'Ez-Pick' produced seedlings with a greater length, whereas large seeds of 'Tavera' and 'Fresh Pick' produced seedlings with a greater length (Table 7). These results are similar to the ones reported for hydropriming of seeds of sorghum and a double-cross maize hybrid (Afzal et al., 2015). Hydropriming of sunflower seeds was also found to be an effective method for improvement of seed vigour and establishment in salty soil and a dry area (Moghanibashi et al., 2012).

Conclusions

The DP technique has a beneficial effect on the performance of snap bean seed lots, and this effect depends on the cultivars and seed size.

Acknowledgements

To the CAPES - Brazilian Coordination for the Improvement of Higher Education Personnel, for financial support, and scholarship for Post-Doctoral Research;

To the Department of Horticulture and Crop Science. The Ohio State University. Columbus, OH 43210 USA, for the availability of Seed Laboratory and staff;

To the Professor Pablo Jourdan. Ornamental Plant Germplasm Center, Department of Horticulture and Crop Science, The Ohio State University, for the English review.

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