Germination and Seedling Vigor of Jack Bean (*Canavalia ensiformis*) as Affected by Seed Size

A Krisnawati, Nuryati[11] *and MM* Adie[1]

[1]Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Republic of Indonesia

Abstract. Seed size is one of a quantitative indicator of seed quality that influences the plant performance and is often associated with yield. The present study was designed to investigate the effect of seed size on germination and seedling vigor in jack beans. The research was carried out in Malang, Indonesia, using local jack bean cultivars from Tanggamus (Lampung, Indonesia). The study was arranged in a completely randomized design with seed size as treatment. The effect of seed size on germination percentage, seed vigor, and seedling morphology was studied. The classification for the seed size in this study was the large seed (1.81 g/seed), medium seed (1.40 g/seed), and small seed (0.95 g/seed). Small and medium seeds have the speed and simultaneity of emerging cotyledons on the fifth day. Small seeds had the highest germination percentage than medium and large seeds on the sixth day. The relationship between GP and seed vigor variables was not significant, however, GP and seed vigor features are determined by emerging cotyledon, germination, and some seedling morphological characters. The vigor parameters (MDG, PV, GV, and GI) of small seed sizes were higher than those of medium and large seed sizes. The medium seed size of jack beans produces a better seedling morphology than other seed sizes. It was concluded that although medium seeds produce a better seedling growth yet small seeds could also be used for successful jack bean production.

Keywords : Seed Size, Jack Beans, Germination, Seedling Vigor, Crop Performance

1 Introduction

Seed size is one of the seed quality components that influence plant seedling growth and establishment as well as seed yield. Poor seed quality will result in decreased germination and emergence rates, low viability, and low resistance to unfavorable environmental conditions, and low seedling growth rates [1]. Seed size indicates the number of available food reserves during germination, which is frequently correlated with seedling vigor, the germination rate, emergence rate, establishment success, and plant growth performance [2-5].

[1] Corresponding author: my_ayda@yahoo.com

The relationship between seed size, germination ability, and seed vigor is affected by the species and environmental conditions. The large seed was reported to have better field performance than the small seed [6]. Genotypes with large seed sizes were also shown to be better adapted to drought stress as compared to small seeds [7,8]. In peanuts, enhanced final germination in larger seeds also led to an improvement in the germination index and the seedling vigor index [9]. A study in Symphonia globulifera revealed that large seed sizes exhibited the highest germination rate and seedling growth performance, which was followed by medium and small seed sizes [10]. A significant difference in final seed germination was also observed in Onobrychis viciifolia between small, medium, and large seed sizes [2]. Karki et al. [11] found that germination percentage, germination rate, and mean daily germination were highest in the large seed size class when compared to small seed size. On the contrary, several studies found that seed size had no significant effect on germination percentage [12], seedling dry weight, seedling vigor, and seedling length [13]. Furthermore, small seeds were reported to have a higher germination percentage than larger seeds [14] and germinated faster, and grew taller in the saline environments [15].

The impact of seed size on seedling emergence and plant growth has been well-documented in many crops. However, the information on the influence of the seed size on the seedling performance in jack beans is limited. The jack bean has a long and linear sword-shaped seedpod which may result in different-sized seeds within a single pod as a result of the difference in assimilate supply, individual seed growth rate, and cotyledon cell number [16]. A study compared the pod lengths of C. cathartica, C. ensiformis, and C. gladiata, which were 10.11 cm, 30.95 cm, and 32.13 cm, respectively [17]. A study of seed germination on jack bean by Hapsari & Widajati [18] revealed that C. ensiformis seeds germinate on the eighth day, but C. gladiata begins on the ninth.

There hasn't been much research on the relationship between jack bean seed size and germination quality. Uneven stand establishment from the sowing of mixed seeds of a species may resulting in plant vigor and size variability [19]. Thus, the research objective was to investigate the effect of seed size on germination and seedling vigor of jack beans.

2 Methods

2.1 Materials and study location

A local jack bean cultivar from Tanggamus Lampung (Indonesia) was used in the study. The research was conducted in the screenhouse of the Indonesian Legume and Tubers Crop Research Institute (ILETRI) in Malang, East Java (Indonesia) from June to July 2022. The study site was located at 8° 2′ 56.4″S 112° 37′ 30″E at an elevation of 445 m asl.

2.2 Research design and experiment

A completely randomized design was used in the study, with seed size as treatment, and repeated three times. The seed size consisting of large (± 1.81 g), medium (± 1.40 g), and small seed sizes (± 0.95 g). The seeds of each seed-size category were taken as many as 25 seeds for germinating. Seed germination test with heat-sterilized sand media. The sand was sterilized by drying at 150°C for 12 h. Each seed was planted to a depth of 2 cm. Every day at 08.00 pm, the sand medium was watered to maintain the humidity.

2.3 Data observation and analysis

Data were recorded on seed germination, seed vigor, and the performance of seedling morphology. The germination rate was estimated using the parameter of emerging cotyledon (EC) and normal germination (Germination Percentage, GP). The germination percentage was obtained by observing germinated seeds daily during the first eight days after sowing. The seedling observations consist of emerging cotyledons and normal seedlings. A seed is referred to as an emerging cotyledon when it has reached a length of around 1 cm. Normal seedlings are those that have formed leaves but have not yet opened, with normal shoot development. Abnormal seedlings were those whose essential features (such as the epicotyl, hypocotyl, cotyledon, and roots), were distorted, degraded, or did not well develop. The observation on the seedling height, seedling epicotyl and hypocotyl length, cotyledon dry weight, shoot dry weight, and root dry weight on the eighth day after sowing. The performance of seed vigor was assessed based on the Mean Daily Germination (MDG) [20], Peak Value (PV) and Germination Value (GV) [21], Germination Index (GI) [22], and Seedling Vigour Index I (SVI1) [23]. The relationship between those variables is calculated using correlation analysis [24].

$$\text{Mean Daily Germination (MDG)} = \frac{Germinated\ seeds}{Number\ of\ days}\ x\ 100\% \quad (1)$$

$$\text{Peak Value (PV)} = \frac{Highest\ number\ of\ germinated\ seeds}{Number\ of\ seeds}\ x\ 100\% \quad (2)$$

$$\text{Germination Value (GV)} = \frac{Peak\ Value}{Mean\ Daily\ Germination} \quad (3)$$

Germination Index (GI) = $\frac{G_i}{D_i} + \ ... \ + \ \frac{G_n}{D_n}$, where G_i = number of seeds germinated on ith day (D_i), and G_n = number of seeds germinated on final counting day (D_n)

Seedling Vigour Index I (SVI1) = $\frac{L\ x\ GP}{100}$, where L= seedling length (root length + shoot length) in cm, and GP = germination percentage

3 Results and discussion

3.1 Seed germination

The medium-sized seeds exhibited the highest EC value on the fifth day (90%), followed by small seeds (80%), and large seeds (55%). On the sixth day, medium-sized seeds had a 100% EC value, large seeds had a 90% EC value, and small seeds had an 80% EC value) (Figure 1). The EC growth pattern reveals that medium and small seed sizes grow at a faster rate than large seed sizes.

The germination rate based on the FGP, on the sixth day, the small seeds had reached 95%, the medium-sized seeds had reached 80%, and the large seeds reached only 60% (Figure 2). On the seventh day, the germination percentage of small seeds remains steady, but the medium and large seeds increased. On the eighth day count, the maximum germination percentage for the large seed was similar to the small seeds was 95%, and for the medium seed was 90%.

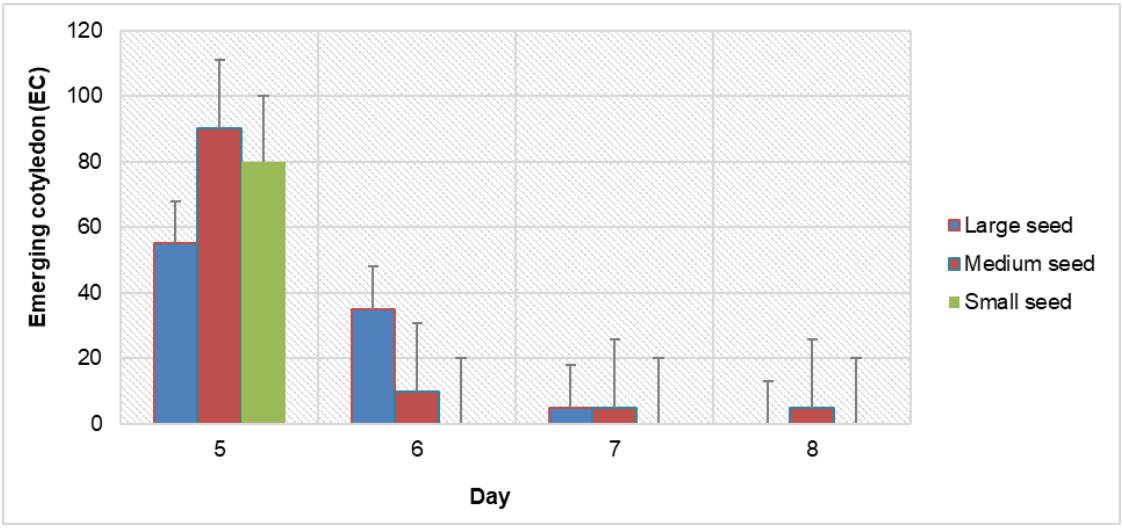


Fig. 1. The emerging cotyledon (EC) from small, medium, and large seed size of jack bean

In line with this research, several studies on other plant species also found that the small seed grows faster than the large seed, because the small seeds have a thinner seed coat and a bigger surface area to absorb water to break dormancy, which results in a shorter germination time [25-27]. In sunflowers, small seeds were also found to germinate and grew more rapidly under NaCl stress [28]. Another study has recorded that the germination rate significantly increased by decreasing seed size in *Triticum aestivum* [29]. According to Kaya and Day [28], small seeds with a low hull rate absorbed water rapidly when compared to large seeds, leading to early germination. On the other hand, some studies reported that larger seeds germinate faster than small seeds [6,30]. Shahi et al. [31] recorded that the highest rate of germination in the large-sized seeds was 91.9%, followed by medium-sized seeds (89.7%), and small-sized seeds (82.8%). Furthermore, they suggested that different-sized seeds contain varying amounts of starch and other energy stores, which essential for enhancing germination and the early growth of seedlings. Germination also depends on the seed's capacity to use reserves more effectively by mobilizing seed reserves for the germination features [32].

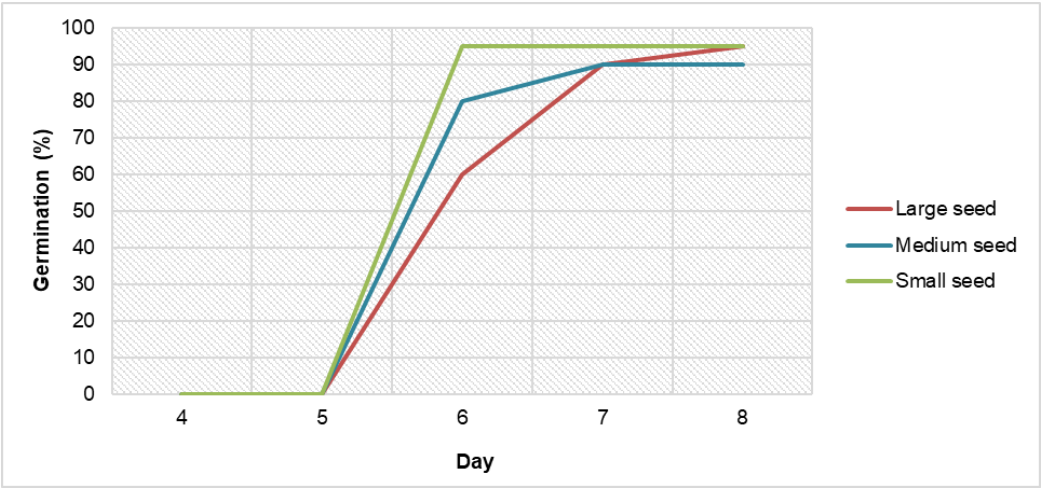


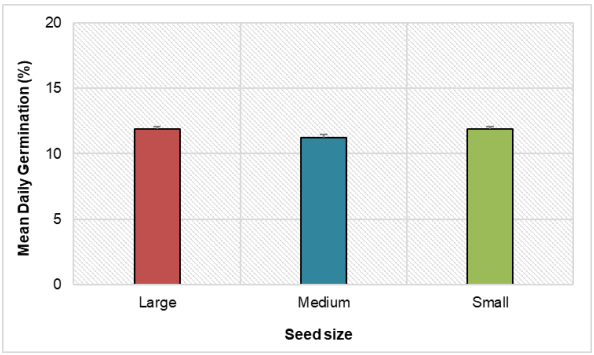
Fig. 2. The emerging cotyledon (EC) from small, medium, and large seed size of jack bean

3.2 Seed vigor

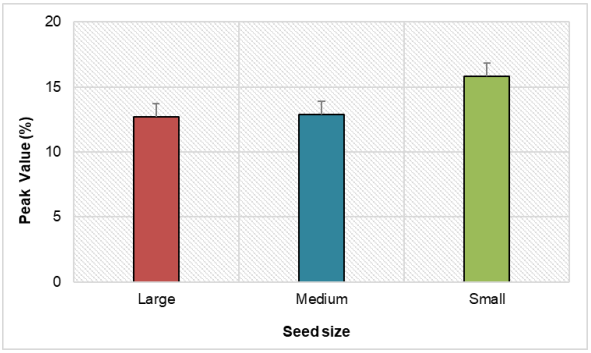
In the present study, seed vigor criteria included mean daily germination (MDG), peak value (PV), germination value (GV), germination index (GI), and seed vigor index1 (SVI1) (Figure 3). The small and large seeds size has a similar MDG value (11.88), while the medium seed size had a value of 11.25 (Figure 3a). MDG is an index of daily germination speed [33]. A study also obtained a maximum value of MDG in a large seed-size class [11].

Similar patterns can be seen in the PV, GV, and GI values (Figure 3b-3d). The large seed sizes have the lowest value, followed by medium-sized seeds, and small seed sizes have the highest value for all those three seed vigor parameters. The PV value for small seed-sized seeds was 15.83, while medium and large seed-sized seeds had PV values of 12.86 and 12.68, respectively. The GV values ranged from 1.33 (for small seeds) to 1.07 (for large seeds). Small, medium, and large seeds had GI values of 57.28, 55.44, and 45.73, respectively.

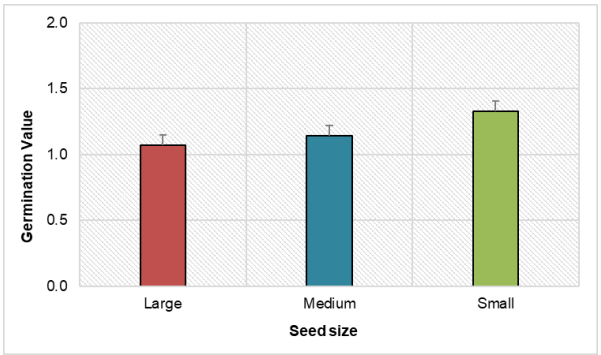
SVI1 is a seed vigor benchmark based on FGP values and seedling length. The medium-sized seeds had the greatest SVI1 value, followed by small seeds, and the large seeds had the lowest. In peanuts, it was reported that a greater seedling length vigor index was observed when medium-sized seeds were used [3]. According to Damalas et al. [20], seedling vigor determines the ability for rapid germination, uniform emergence, and normal seedling development. Seedling early vigor refers to the establishment of vigorous seedlings in any environmental condition and is commonly related to seed vigor [34]. According to a study, the grain yield of common bean was reportedly influenced by the seed vigor, and using low-vigor seeds can reduce grain yield by up to 20% [35].

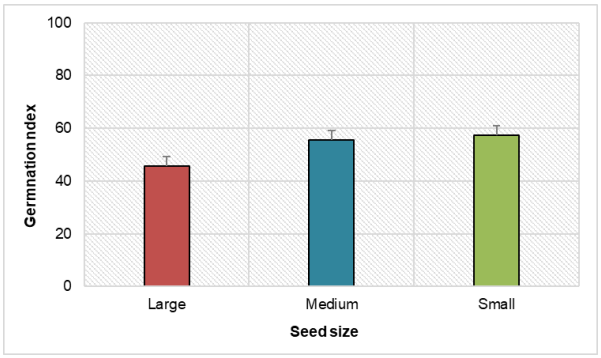


(a)



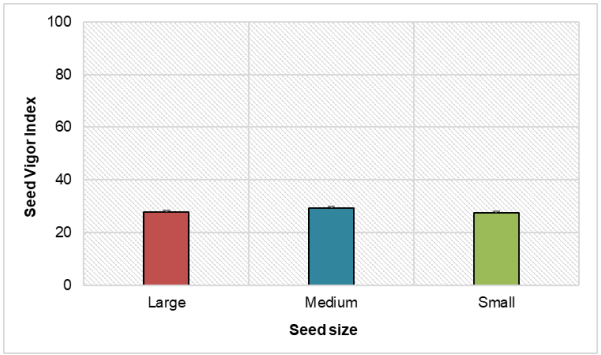
(b)





(c)

(d)

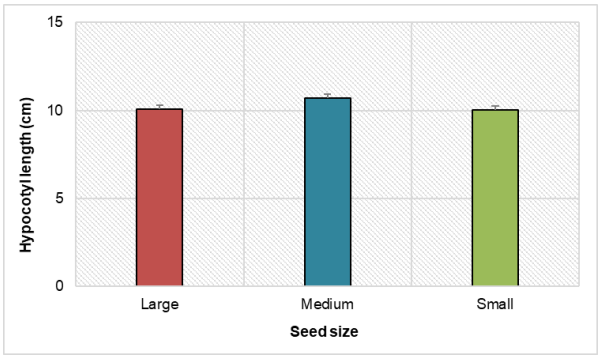


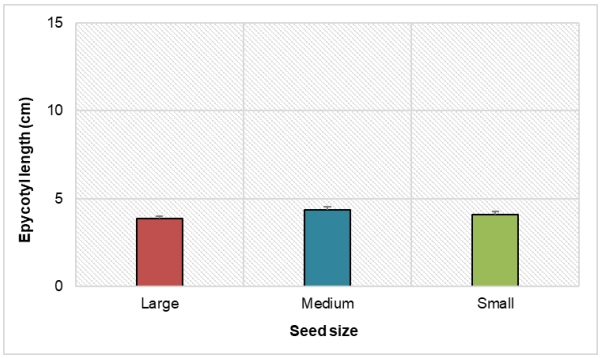
(e)

Fig. 3. The seed vigor parameters of jack bean seedling from small, medium, and large seed sizes: (a) Mean Daily Germination (MDG), (b) Peak Value (PV), (c) Germination Value (GV), (d) Germination Index (GI), and (e) Seed Vigor Index1 (SVI1)

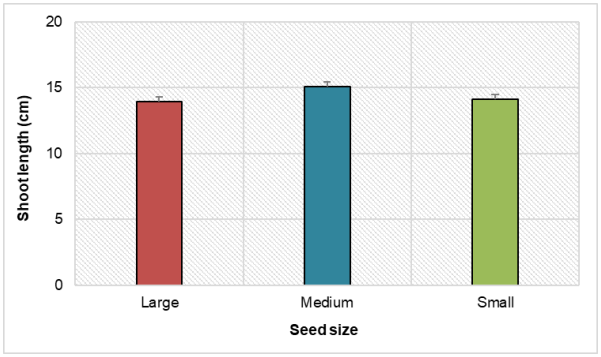
3.3 Seedling morphology

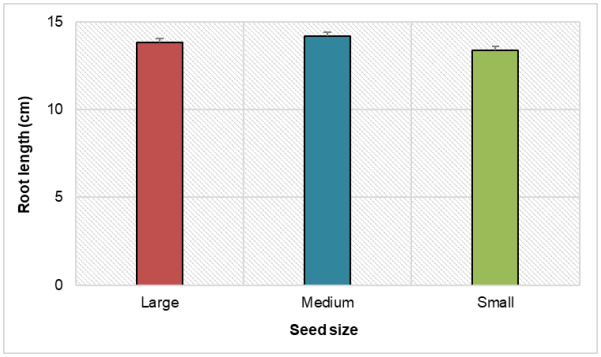
The seedling morphological parameters of jack bean seedlings from small, medium, and large seed sizes was presented in Figure 4. The hypocotyl length, epicotyl length, root length, and seedling length performed better in medium-sized seeds than in small and large-sized seeds (Figure 4, Figure 5). The hypocotyl length in medium-sized seeds is 10.70 cm, the epicotyl length is 4.37 cm, the root length is 14.17 cm, and the total seed length is 15.07 cm. The hypocotyl length and root length of the large seeds were longer than those of the small seeds, resulting in a total seedling length of 13.93 cm for the large seeds. The small seed size outperforms the epicotyl length, which reaches 4.10 cm, resulting in a seedling length of 14.12 cm.


15
10
5
0
Hypocotyl length (cm)
Large
Medium
Small
Seed size

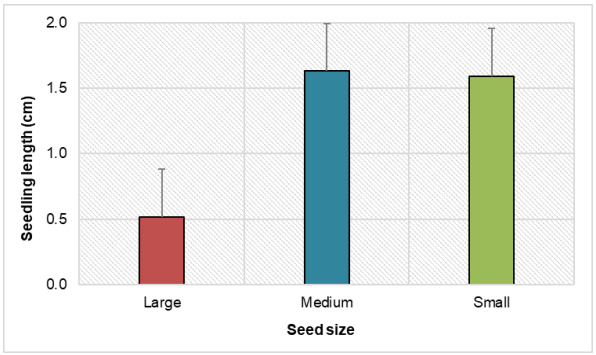

15
10
5
0
Epycotyl length (cm)
Large
Medium
Small
Seed size

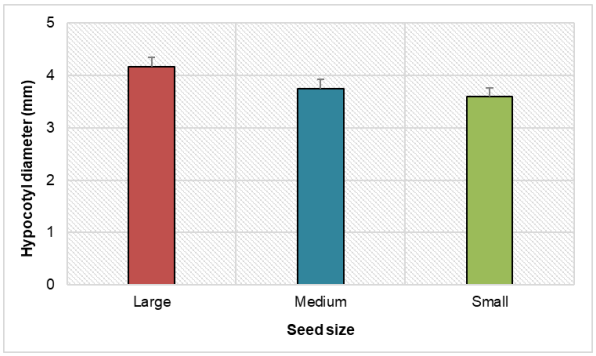
(a) (b)


20
15
10
5
0
Shoot length (cm)
Large
Medium
Small
Seed size

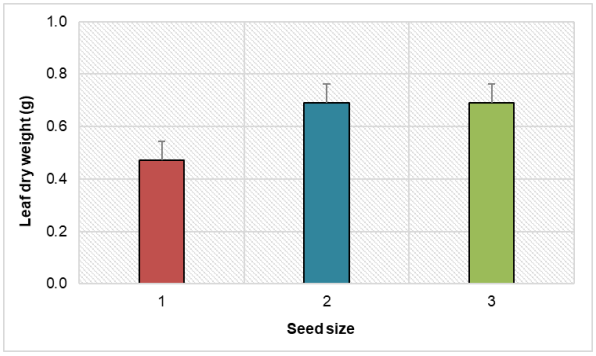

15
10
5
0
Root length (cm)
Large
Medium
Small
Seed size

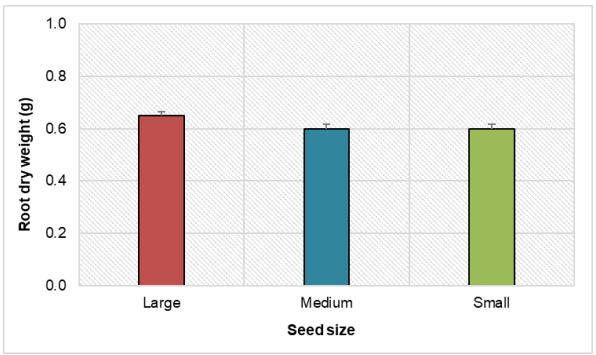
(b) (d)


Seedling length (cm)
2.0
1.5
1.0
0.5
0.0
Large
Medium
Small
Seed size

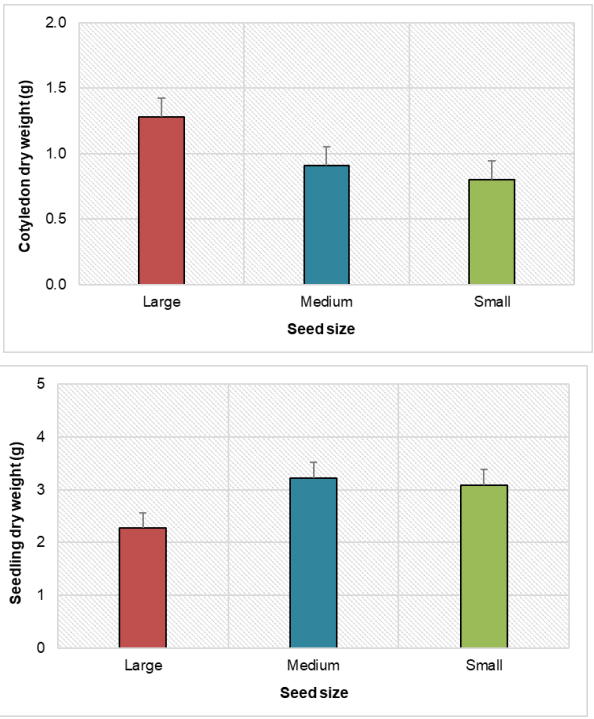

Hypocotyl diameter (mm)
5
4
3
2
1
0
Large
Medium
Small
Seed size

(e) (f)


Leaf dry weight (g)
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
Seed size


Root dry weight (g)
1.0
0.8
0.6
0.4
0.2
0.0
Large
Medium
Small
Seed size

(g) (h)



(i) (j)

Fig. 4. The seedling morphology parameters of jack bean seedling from small, medium, and large seed sizes: (a) hipocotyl length, (b) epicotyl length, (c) shoot length, (d) root length, (e) seedling length, (f) hipocotyl diameter, (g) leaf dry weight, (h) root dry weight, (i) cotyledon weight, (j) total seedling dry weight

Fig. 5. The performance of jack bean seedling from small (S), medium (M), and large (L) seed sizes

In terms of seedling length (1.63 g) and total seedling dry weight (3.22 g), the medium seed size was superior. Large seed size is superior in terms of cotyledon dry weight (1.28 g) and root dry weight (0.65 g). The medium seed size (3.22 g) had the highest seedling dry weight, followed by the small seed size (3.09 g), and the large seed size (2.27 g). According to Dunlap and Barnett [36], different seedling sizes and perhaps regularity of growth were regarded as functions of germination patterns, which were significantly influenced by seed size and weight. Furthermore, different seed sizes with varying quantities of starch and other food storage could be one of the factors influencing plant germination and growth expression [11]. The seed size also influences the water intake and subsequent growth parameters of the cultivars [28].

In this study, medium and large seed sizes showed better seedling performance than small seeds. This may be related to the high concentration of storage compounds present in large seeds. As a result of their larger size and greater protein and carbohydrate stores, larger seeds germinate more readily [30]. Several studies in other plants reported that a

larger seeds size showed better vigor in seedling dry weight [37,38], the seedling height, seedling width, and seedling biomass [39,40]. A study noticed that seedlings from heavy seeds generated heavier seedlings than seedlings from intermediate- and light-weight seed groups [41]. A study in soybean suggested that seeds with high dry weight tend to generate seedlings with high dry weight due to the high availability of reserves. Furthermore, proteases, lipases, and amylases may be active, which hydrolyzes reserve compounds and facilitates the usage of soluble substances that are mobilized and utilized in the embryonic axis [42].

3.4 Interrelationship between characters

The correlation analysis showed that the variables relating to seed vigor and GP did not significantly correlate. However, the GP and seed vigor characters were determined by the emerging cotyledon, germination, and a number of morphological characteristics of the seedling (Figure 6). The non significant correlation between the vigor parameters was also found in another study [43]. In this study, the EC5 had a significant positive correlation with GI characteristics, also the seedling length. However, the emerging cotyledon after the fifth day had a significant negatively correlation with most of the germination and vigor variables. The seedling length was strongly determined by the character of the hypocotyl length and epicotyl length, meanwhile, the seedling length (shoot and root length) was significantly negatively correlated with GP and MDG. Another study in common beans found a significant relationship among germination parameters, but there was no relationship between root length with most of the growth parameters [44].

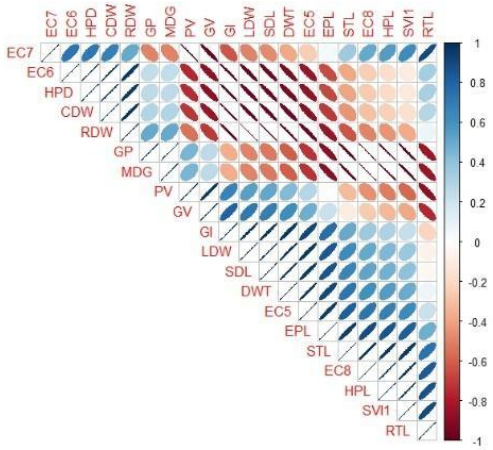


Fig. 6. Correlogram (correlation matrix) for the germination, seed vigor, and seedling parameters in jack bean. Blue color represents positive and red color represents negative correlations. Color intensity indicates the strength of correlation, so the stronger the correlation, the darker the color. Thin ellipsoid figures show significant ($p < 0.05$) correlations, while figures towards spherical shape show insignificant correlations

4 Conclusions

The small seeds had a higher percentage of germination on the sixth day and a better-emerging cotyledon on the fifth day than the medium and large seed sizes. Small seeds also showed greater vigor than medium and large seeds. The medium-sized seeds produce better seedling morphology than small or large seeds.

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