Influence of seed hardening treatments on growth, gas exchange and yield parameters in black gram under drought condition

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Received: 18-11-2014 Accepted: 21-04-2015 DOI: 10.18805/lr.v0iOF.7480

ABSTRACT

The present investigations were carried out to study the influence of various seed hardening treatments on growth and yield parameters in black gram under drought condition. The black gram cv. VBN 3 was imposed with various seed hardening treatments (i.e.,) MnSO$_4$ @ 100 ppm, ZnSO$_4$ @ 100 ppm, Cobalt nitrate @ 1 %, Sodium molybdate @ 100 ppm, KCl @ 100 ppm, Pungam leaf extract @ 1 %, Prosopis leaf extract @ 1% and GA$_3$ @ 40 ppm. The above treated seeds along with control were evaluated for their seed quality parameters, growth, gas exchange and yield parameters under laboratory and drought field condition. The study revealed that seeds hardened with prosopis leaf extract @1% recorded higher seed yield, yield attributing characters and many seed quality characters as compared to other treatments and control under drought condition.

Key words: Black gram, Prosopis, Seed hardening, Seed quality.

INTRODUCTION

Pulses are the most important seed crops in India because of their low cost and rich source of high quality protein and essential amino acids. They play a major role in providing a balanced protein component in the diet of the people of developing countries and share a major portion of the vegetarian diet. It also enriches the soil fertility and health in terms of addition of nitrogen and organic matter. Among the pulses, the urdbean or blackgram [Vigna mungo (L.) Hepper], occupies an unique place for its use as seed and vegetable, and it is grown both as pure and mixed crop along with maize, cotton, sorghum and other millets. In India, it is cultivated both in kharif and rabi seasons in an area of 31.00 lakh hectares with a production of 14.00 lakh tonnes and productivity of 451.61 Kg ha$^{-1}$. In Tamil Nadu, area under blackgram cultivation is 3.41 lakh hectares, production is 1.21 lakh tonnes and productivity is 354.84 kg ha$^{-1}$ (FAO, 2011).

The low productivity in pulses is due to the reason that pulses are grown mostly in marginal and rainfed areas. The main constraint in raising the productivity levels of pulses in drylands are inadequate soil moisture and poor fertility status of the soil. To overcome the adverse environmental conditions like low rainfall and low soil moisture which prevent the germination and establishment of seedlings, seed hardening is given as a pre-sowing treatment. Seed hardening (wetting and drying) appears to impart drought tolerance and increase seed germination followed by better and quicker seedling emergence. Short term hydration of seeds before planting greatly benefits stand establishment but use of chemicals like potassium or sodium phosphate would give additional advantage. Seed priming/hardening is a common practice followed to enhance seed performance with respect to rate and uniformity of germination (De Lespinay et al., 2010). Hydropriming, osmopriming, hardening and osmohardening have been optimized for vigour enhancement in rice (Farooq et al., 2005, 2006a; Basra et al., 2006). Osmohardening with CaCl$_2$ was found most effective by recording higher emergence index and emergence percentage (Muhammad Farooq et al., 2006).

Hence, a study was undertaken in black gram cv. VBN 3 with the objective to evaluate the influence of various seed hardening treatments on growth and yield under drought condition.

MATERIALS AND METHODS

The present investigations were carried out at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University Annamalai Nagar to study the influence of various seed hardening treatments on growth and yield parameters in black gram under drought condition. Freshly harvested bulk seeds of black gram cv. VBN 3 were imposed with the following seed treatments.

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The seeds were first, pre-conditioned by keeping in between two layers of moist gunny bag for one hour. Then they were soaked for one hour in water at 1/3 volume of seeds and quickly air dried in shade to their original moisture content. The pre-conditioned seeds were soaked for one hour in respectively nutrient solutions like ZnSO₄ @ 100 ppm or MnSO₄ @ 100 ppm or leaf extracts like pungam (Pongamia pinnata) leaf extract (1%) or prosopis (Prosopis jouliflora) leaf extract (1%) at 1/3 volume of seeds and air dried in shade to their original moisture content.

**Laboratory evaluation:** The above treated seeds along with the control were surface sterilized with 0.1% (w/v) HgCl₂ for 3 minutes and then washed thoroughly with glass distilled water. External water potential of -3.0 bars was prepared by using Poly Ethylene Glycol (PEG) 6000 as per the method described by Michel and Kaufmann (1973) and used for this experiment as the mungbean seedling survives only up to the osmotic potential of -3.0 bar. Surface sterilized seeds of different treatments were soaked in PEG solution for five hours. Pre-soaked seeds were then allowed to develop seedlings in -3.0 bar PEG solution for 7 days under indoor laboratory condition following standard glass plate technique (Nandi and Bera, 1995) and observed for the seed quality parameters viz., speed of germination, germination (%), root length (cm), shoot length (cm), dry matter production (g seedling⁻¹) and vigour index.

**Field Evaluation:** Field trials were conducted during 2012-2013 adopting randomised block design (RBD) with three replications under dry land condition. The plot size was 4x2.5 m². The crop was raised with the spacing of 30x15 cm and recommended package of practices for black gram were followed. The crop was irrigated with once in 8 days to induce drought condition. Proper irrigation was done at critical stages of flowering and pod formation and observations on growth, gas exchange and yield parameters were recorded.

Plant height was recorded by measuring the height of plant from ground level to the tip of main branch using a meter scale and the mean value was expressed in centimeter. Total number of branches plant⁻¹ was counted and the mean number of branches plant⁻¹ was recorded as whole number. The roots of 10 uprooted plants were washed carefully to free the adhering soil particles under a stream of tap water and the number of nodules present in the tap root and in lateral roots was counted and the nodule number was expressed as whole number (Sundaram, 1998).

The biomass production was recorded from ten seedlings selected at random separately, uprooted with root system intact and were washed to remove the soil particles, placed in a paper cover, shade dried for 24h and then in the hot air oven maintained at 100°C for 24h. The dried plants were cooled in a desiccator for 30 minutes and the mean weight was recorded in grams. Number of days taken from sowing to first flowering at any node of plant in each of the plots was recorded and the mean value is expressed as days to first flowering in whole number. Number of days taken from sowing to 50 per cent flowering in the total population was recorded and the mean value is expressed as days to 50% flowering in whole number.

The total chlorophyll was calculated using the formula as suggested by Yoshida et al. (1971) and expressed as mg/g. Leaf photosynthetic rate, transpiration rate, stomatal conductance and intercellular CO₂ concentration were measured from two, uppermost fully expanded leaves on intact plants in the field using LICOR-6400×T Portable Photosynthetic System (Lioncon, USA). All these estimations and measurements were made between 10.00-11.00 A.M on the five replicates for each treatment.

At maturity, the pods obtained in each of the plants were measured for their length using scale. Excluding the stalk, the length was measured from the base to the tip of the pod and the mean pod length was expressed in centimetres. The number of pods plant⁻¹ was counted and the mean number of pods plant⁻¹ was arrived at and expressed as whole number.

The pod yield plant⁻¹ at maturity was recorded by using an electronic balance in randomly selected plants and the mean pod yield was arrived at and expressed in grams. The pods used for recording pod length were split longitudinally and the number of seeds in each pod was counted. Mean number of seeds pod⁻¹ was calculated and reported as whole number.

The pods from ten tagged plants in each treatment were hand shelled. The seeds were cleaned and weighed in an electronic balance and the mean seed yield plant⁻¹ was expressed in grams. The seeds thus obtained were cleaned and weighed to arrive at the plot yield. Seed yield was computed per hectare from the seed yield obtained per plot in each of the treatment and, expressed in Kg ha⁻¹. Eight replicates of 100 seeds were drawn from each treatment randomly, weighed in an electronic balance and the mean weight was expressed as 100 seed weight in grams (ISTA, 1999). All the data were analysed statistically with appropriate tools and expressed as mean values.
RESULTS AND DISCUSSION

Seed quality parameters: In the present study, the laboratory analysis revealed that the 1% *prosopis* leaf extract hardened seeds recorded the highest values for speed of germination (12.33), germination percentage (99%), root length (17.36 cm), shoot length (28.26 cm), dry matter production (0.28 g) and vigour index (4515) when compared to other treatments and control (Table 1). The percentage increase over the control was recorded as 4.2, 28.5, 21.7, 16.7 and 29.4, respectively. Similar results were reported by Srimathi et al. (2007) and Kamaraj and Padmavathi (2012) in green gram. This could be due to the modification of physiological and biochemical nature of the seeds so as to get the characters that were favorable for drought resistance (Hencel, 1964). The percentage of germination is an excellent indicator for survival and growth potential of seed. The *prosopis* leaf extract (1%) hardened seeds would become physiologically advanced by carrying out some of the initial steps of germination and the subsequent improvement in germinability.

The first step of germination is formation of GA3 and hydrolytic enzyme that aid in translocation of food material in simpler form to the germinating radicle (Copeland, 1995). The reason for higher germination of *prosopis* leaf extract treated seed is the presence of greater hydration of colloids, higher viscosity and elasticity of protoplasm, increase in bound water content, lower water deficit and more efficient root system (May et al., 1962). Leaf extract of *prosopis* contains, GA3 in traces and micronutrients especially zinc. These biocontents might synergistically interact with aminoacids especially tryptophan to form the indole acetic acid (IAA) in germinating seeds to bring about enhancement in seedling growth (Lu et al.,1983).

Early germination may be due to the greater hydration of colloids and higher viscosity of protoplasm and cell membrane that allows the early entrance of moisture that activates the early hydrolysis of reserve food materials in the seed as compared to untreated seeds. Prosopis leaf extract contains plant mineral nutrients like nitrogen (5.6%), phosphorus (P2O5-0.9%), potassium (K2O-3.11%) and calcium (CaO-1.0%) (Nadeem Binzia, 1992). The higher germination might be due to the role of calcium as an enzyme cofactor in germination process by increasing protein synthesis as reported by Christiansen and Foy (1979). The stimulatory effect on germination and the growth of seedlings of hardened seed could be due to the fertilizing effect resulting from the nutrient release from damaged or decayed tissue of storage organ by hydrolysis (Orr et al., 2005).

The increase in dry weight was claimed to be due to enhanced lipid utilization through glyoxalate cycle, a primitive pathway leading to faster growth and development of seedling to reach autotropic stage well in advance of others and enabling them to produce relatively more quantity of dry matter. Ultimately it leads to the cause for hike in vigour index by hardening treatment. Similar results were reported by Nagaraj (1996) and Tamilmani (2012) in black gram and Prakash et al. (2013).

Biometric parameters: The above hardened seeds were evaluated under drought condition and the biometrical, gas exchange and yield parameters were observed. It revealed that the seeds hardened with 1% *prosopis* leaf extract recorded higher values for the biometrical traits viz., plant height, number of branches, number of nodules and biomass

<table>
<thead>
<tr>
<th>Treatment (T)</th>
<th>Speed of germination (Speed)</th>
<th>Germination (%)</th>
<th>Root length (cm)</th>
<th>Shoot length (cm)</th>
<th>Dry matter production (g seedling-1)</th>
<th>Vigour index</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>11.60</td>
<td>95(77.12)</td>
<td>13.50</td>
<td>23.23</td>
<td>0.24</td>
<td>3489</td>
</tr>
<tr>
<td>T1</td>
<td>12.50</td>
<td>97(80.73)</td>
<td>16.66</td>
<td>27.26</td>
<td>0.26</td>
<td>4285</td>
</tr>
<tr>
<td>T2</td>
<td>12.11</td>
<td>97(81.25)</td>
<td>17.03</td>
<td>27.36</td>
<td>0.26</td>
<td>4326</td>
</tr>
<tr>
<td>T3</td>
<td>11.86</td>
<td>96(79.04)</td>
<td>16.10</td>
<td>25.86</td>
<td>0.25</td>
<td>4042</td>
</tr>
<tr>
<td>T4</td>
<td>11.73</td>
<td>96(78.52)</td>
<td>15.86</td>
<td>24.16</td>
<td>0.25</td>
<td>3865</td>
</tr>
<tr>
<td>T5</td>
<td>12.3</td>
<td>96(78.98)</td>
<td>16.36</td>
<td>26.83</td>
<td>0.26</td>
<td>4161</td>
</tr>
<tr>
<td>T6</td>
<td>12.13</td>
<td>98(82.05)</td>
<td>17.30</td>
<td>28.24</td>
<td>0.27</td>
<td>4465</td>
</tr>
<tr>
<td>T7</td>
<td>12.33</td>
<td>99(83.46)</td>
<td>17.36</td>
<td>28.26</td>
<td>0.28</td>
<td>4515</td>
</tr>
<tr>
<td>T8</td>
<td>11.46</td>
<td>95(77.58)</td>
<td>15.43</td>
<td>24.4</td>
<td>0.24</td>
<td>3774</td>
</tr>
<tr>
<td>Mean</td>
<td>12.0</td>
<td>96.55</td>
<td>16.17</td>
<td>26.19</td>
<td>0.25</td>
<td>4103.01</td>
</tr>
<tr>
<td>SED</td>
<td>0.0047</td>
<td>0.2830</td>
<td>0.0187</td>
<td>0.0566</td>
<td>0.0024</td>
<td>2.4551</td>
</tr>
<tr>
<td>CD (P=05)</td>
<td>0.0099</td>
<td>0.6000</td>
<td>0.0397</td>
<td>0.1200</td>
<td>0.0050</td>
<td>5.2047</td>
</tr>
</tbody>
</table>

(Figures in parentheses are arcsin transformation values)
Table 2: Influence of seed hardening treatments on growth characters in black gram cv. VBN 3 under drought condition.

<table>
<thead>
<tr>
<th>Treatment(T)</th>
<th>Plant height (cm)</th>
<th>Number of branches plant(^{-1})</th>
<th>Number of nodules plant(^{-1})</th>
<th>Biomass production (g)</th>
<th>Days to 1(^{st}) flowering</th>
<th>Days to 50% flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>T(^0)</td>
<td>23.30</td>
<td>3.30</td>
<td>7.70</td>
<td>11.63</td>
<td>27.33</td>
<td>34.53</td>
</tr>
<tr>
<td>T(^1)</td>
<td>25.76</td>
<td>3.60</td>
<td>9.23</td>
<td>14.11</td>
<td>25.93</td>
<td>33.43</td>
</tr>
<tr>
<td>T(^2)</td>
<td>26.16</td>
<td>3.80</td>
<td>10.16</td>
<td>14.21</td>
<td>26.20</td>
<td>33.53</td>
</tr>
<tr>
<td>T(^3)</td>
<td>25.06</td>
<td>3.50</td>
<td>8.76</td>
<td>13.76</td>
<td>25.73</td>
<td>34.46</td>
</tr>
<tr>
<td>T(^4)</td>
<td>24.60</td>
<td>3.43</td>
<td>8.36</td>
<td>13.66</td>
<td>25.63</td>
<td>32.76</td>
</tr>
<tr>
<td>T(^5)</td>
<td>25.46</td>
<td>3.56</td>
<td>9.06</td>
<td>13.91</td>
<td>25.63</td>
<td>32.93</td>
</tr>
<tr>
<td>T(^6)</td>
<td>26.53</td>
<td>3.96</td>
<td>10.66</td>
<td>14.52</td>
<td>26.76</td>
<td>34.23</td>
</tr>
<tr>
<td>T(^7)</td>
<td>27.40</td>
<td>4.30</td>
<td>11.20</td>
<td>14.78</td>
<td>25.4</td>
<td>32.76</td>
</tr>
<tr>
<td>Mean</td>
<td>25.38</td>
<td>3.64</td>
<td>9.19</td>
<td>13.7</td>
<td>26.20</td>
<td>33.52</td>
</tr>
<tr>
<td>SEd</td>
<td>0.1274</td>
<td>0.0566</td>
<td>0.1415</td>
<td>0.0665</td>
<td>0.1132</td>
<td>0.0941</td>
</tr>
<tr>
<td>CD (P=05)</td>
<td>0.2700</td>
<td>0.1200</td>
<td>0.3001</td>
<td>0.133</td>
<td>0.2400</td>
<td>0.1996</td>
</tr>
</tbody>
</table>

Production which were 27.4 cm, 4.3, 11.2 and 14.78 g, respectively and the percentage increase over the control were recorded as 17.6, 30.3, 45.4 and 27.0, respectively and also recorded early days to 1\(^{st}\) (25.4) and 50 \% flowering (32.76) (Table 2).

Rapid and uniform field emergences are the two essential pre-requisites to increase the yield. Uniformity and percentage of seedling emergence, yield attributing characters of direct seeded crop have major impact on final yield and quality (Niranjanamurthy et al., 1991) in different crops. The Prosopis hardening supplies the bio active materials such as GA like substances to seed, which play an important role in enhancing the seed vigour and seed germination. It leads to the rapid growth under drought condition (Saitoh et al., 1991). Paddy seeds hardened with KCl 1% followed by pelleting with pongam leaf powder @ 200g/kg recorded increased growth and biometric characters (Prakash et al., 2013).

Plant height is very important criterion for a crop in providing more places for flower production leading to better fruit production. Dawson (1965) also observed that significant increase in plant height, number of tillers, shoot weight and yield in ragi due to seed hardening with water alone. The rationale for preplant seed treatment is to mobilize the seeds their own resources in addition to the external resources for maximum improvement in stand establishment and yield. Physiological seed treatments that enhance the performance of seed are based primarily on seed hydration and dehydration (May et al., 1962). Deotale et al. (1998) reported that when soybean seeds were treated with 0-150 ppm GA\(_3\), the highest leaf area was obtained with 100 ppm.

The Prosopis leaf extract hardening treatments might have improved the growth of plant during early stage of the crop with increased vigour and associated stronger root system which in turn might have favoured the derivation of available soil moisture and nutrients enabling better growth that resulted in higher yield (Jegathambal, 1996). Generally the seedlings with initial vigour performed better and utilize all the available resources for better growth. The initial vigour of the prosopis leaf extract invigorated seeds might have induced the seedling growth and enabled better nutrient absorption by the foliage, thus encouraging quick growth and increased plant height with increased number of branches.

The increase in dry weight was claimed to be due to enhanced lipid utilization and enzyme activity due to the presence of bioactive substances like auxin in prosopis leaf extract (Rathinavel and Dharmalingam, 1999) and development of seedling to reach autotrophic stage and enabling them to produce relatively more quantity of dry matter which discerning the cause for the hike in vigour index by hardening treatment. This may be due to the beneficial effect of prosopis leaf extract seed hardening which activates the growth promoting substances and translocation of secondary metabolites to the growing seedling.

Physiologically active substances might have activated the embryo and other associated structures which resulted in the absorption of more water due to cell wall elasticity and development of stronger and efficient root system and that would have ultimately resulted in higher vigour index (Rangaswamy et al., 1993). Many researchers also reported the benefits of seed hardening with prosopis and pongam leaf extracts to overcome the adverse condition (Rathinavel and Dharmalingam, 2000) in uppam cotton; Khan Bahadar Marwat and Muhammad Azim Khan, 2006 in wheat and Renugadevi et al., 2008 in cluster bean). The above observations were in agreement with the present study. Physiological parameters: The physiological parameters such as total chlorophyll content, photosynthesis, transpiration, intercellular CO\(_2\) concentration and stomatal
conductance were found to be higher in 1% prosopis leaf extract hardening treatment, which was recorded as 1.96 mg g⁻¹, 25.87 mg CO₂ m⁻²s⁻¹, 10.61 mg H₂O m⁻³s⁻¹, 265.38 mol mol⁻¹ and 0.78 mol mol⁻²s⁻¹ respectively (Table 3). The percentage increase over the control was 25.6, 9.5, 44.9, 17.0 and 62.5, respectively.

Chlorophyll is the most important compound as it is involved in photosynthate production (Mishra and Srivastava, 1983). When nitrogen is supplied either through inorganic or organic source to the crop, the increase in chlorophyll occurs (Austin et al., 1973). Because of the invigorating effect of prosopis hardening, the plants absorbed more nutrients from the soil and utilized for more chlorophyll production resulting in enhanced photosynthetic activity of the hardened plants. Parwar and Kadam (1981) also reported that in wheat, seed hardening with CaCl₂ and NaCl improved the uptake of nitrogen and enhanced the metabolic activity (Karivaratharaju and Ramakrishnan, 1985) and thereby the plant height, dry matter production and yield increased in ragi.

Among the gas exchange parameters studied viz., photosynthetic rate, transpiration rate, intercellular CO₂ concentration and stomatal conductance, it was found that plants treated with prosopis leaf extract hardened seeds with 1% (T₆) recorded more photosynthesis and transpiration rates (25.87 mg CO₂ m⁻²s⁻¹ and 10.61 mg H₂O m⁻³s⁻¹) followed by seeds hardened with 1% pungam leaf extract (T₃) (25.63 mg CO₂ m⁻²s⁻¹ and 9.98 mg H₂O m⁻³s⁻¹) and untreated seed (T₀) (23.62 mg CO₂ m⁻²s⁻¹ and 7.32 mg H₂O m⁻³s⁻¹). For the intercellular CO₂ concentration and stomatal conductance, higher values were recorded by plants treated with prosopis leaf extract hardened seeds with 1% (T₆) (265.38 µ mol mol⁻¹ and 0.78 mol m⁻²s⁻¹) followed by hardening with 1% pungam leaf extract (T₃) (258.99 µ mol mol⁻¹ and 0.75 mol m⁻²s⁻¹) and untreated seeds (T₀) (226.63 µ mol mol⁻¹ and 0.48 mol m⁻²s⁻¹). Similar observations of increased gas exchange parameters viz., leaf photosynthetic rate, transpiration, stomatal conductance and intercellular CO₂ concentration with flyash treatment was reported by Anbarasan (2011) in cowpea and Prakash et al. (2013) in rice. Kalpana kumar and Dubey (2003) attributed increase in chlorophyll content to the enhancement in the photosynthetic efficiency in terms of carbohydrate content with the application of flyash.

A study with surface sterilised seeds of mungbean (Vigna radiata L. Wilczek cv. T-44) soaked in 0, 10⁻⁹, 10⁻⁶, or 10⁻¹⁰ M aqueous solution of 28-Homobrassinolide (HBR) for 4, 8, or 12 h. grown in earthen pots, sampled at 30, 40, and 50 DAS revealed that net photosynthetic rate, leaf chlorophyll content, carboxic anhydrate activity (E.C. 4.2.1.1), carboxylation efficiency, stomatal conductance, and seed yield at harvest were enhanced by the HBR treatment. Among the various concentrations and durations, 8h treatment with 10⁻⁶ M HBR was found to be the best (Fariduddin et al., 2003).

Application of glycine betaine as a pre-sowing seed treatment was found to be ineffective in altering the gas exchange characteristics of wheat plants, although available reports are showing the positive effect of exogenously applied glycine betaine on different crops e.g., pea and turnip (Makela et al., 1998), tobacco (Ma et al., 2006) and tomato (Makela et al., 1999). Frommhold et al. (1987) reported increased photosynthetic rates and decreased CO₂ compensation point in tobacco seedlings treated with thioura. Paddy seeds of cv. ADT 43 hardened with KCl 1% followed by pelleting with pungam leaf powder @ 200g/kg recorded increased gas exchange characters (Prakash et al. (2013).

**Yield parameters:** Among the seed treatments, 1% prosopis leaf extract hardened seeds (T₆) recorded highest pod length, more number of pods plant⁻¹, maximum pod yield plant⁻¹, number of seeds pod⁻¹, seed yield plant⁻¹ and ha⁻¹ and
Table 4: Influence of seed hardening treatment on yield attributes in blackgram cv. VBN 3 under drought condition.

<table>
<thead>
<tr>
<th>Treatment (T)</th>
<th>Pod length (cm)</th>
<th>Number of pods plant⁻¹</th>
<th>Pod yield plant⁻¹ (g)</th>
<th>Number of seeds pod⁻¹</th>
<th>Seed yield plant⁻¹ (g)</th>
<th>Seed yield ha⁻¹ (kg)</th>
<th>Hundred seed weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₀</td>
<td>4.53</td>
<td>20.93</td>
<td>6.04</td>
<td>5.44</td>
<td>3.55</td>
<td>705.11</td>
<td>4.07</td>
</tr>
<tr>
<td>T₁</td>
<td>4.76</td>
<td>24.53</td>
<td>6.32</td>
<td>6.27</td>
<td>4.12</td>
<td>764.75</td>
<td>4.17</td>
</tr>
<tr>
<td>T₂</td>
<td>4.86</td>
<td>25.20</td>
<td>6.32</td>
<td>6.27</td>
<td>4.20</td>
<td>772.41</td>
<td>4.21</td>
</tr>
<tr>
<td>T₃</td>
<td>4.70</td>
<td>23.40</td>
<td>6.20</td>
<td>6.10</td>
<td>3.76</td>
<td>745.37</td>
<td>4.13</td>
</tr>
<tr>
<td>T₄</td>
<td>4.60</td>
<td>22.23</td>
<td>6.14</td>
<td>5.79</td>
<td>3.66</td>
<td>733.02</td>
<td>4.12</td>
</tr>
<tr>
<td>T₅</td>
<td>4.66</td>
<td>23.93</td>
<td>6.26</td>
<td>6.17</td>
<td>3.78</td>
<td>756.00</td>
<td>4.16</td>
</tr>
<tr>
<td>T₆</td>
<td>4.96</td>
<td>25.80</td>
<td>6.44</td>
<td>6.36</td>
<td>4.22</td>
<td>779.00</td>
<td>4.26</td>
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<td>T₇</td>
<td>5.23</td>
<td>26.30</td>
<td>7.25</td>
<td>6.49</td>
<td>4.24</td>
<td>876.52</td>
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<td>Mean</td>
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<td>23.77</td>
<td>6.33</td>
<td>6.04</td>
<td>3.89</td>
<td>751.12</td>
<td>4.16</td>
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<td>SED (P=05)</td>
<td>0.0991</td>
<td>0.1886</td>
<td>0.0517</td>
<td>0.0283</td>
<td>0.0047</td>
<td>1.0614</td>
<td>0.0028</td>
</tr>
<tr>
<td>CD (P=05)</td>
<td>0.2101</td>
<td>0.3997</td>
<td>0.1096</td>
<td>0.0600</td>
<td>0.0100</td>
<td>2.2502</td>
<td>0.0600</td>
</tr>
</tbody>
</table>

100 seed weight which were 5.23 cm, 26.3, 7.25 g, 6.49, 4.24 g, 786.52 kg ha⁻¹ and 4.27, respectively. The percentage increases over the control were recorded as 15.5, 25.7, 20, 19.3, 19.4, 11.5 and 4.9, respectively (Table 4). Similar results were reported by Sathiy Narayanan et al. (2013) and Srimathi et al. (2007) in green gram. The increased grain yield with CaCl₂ @ 2% followed by ZnSO₄ @ 0.1% may be attributed to increased growth and yield parameters as well higher photosynthesis, stomatal diffusive resistance and reduced transpiration rate (Pawar et al., 2003).

Muhammad Farooq (2009) reported that osmohardening with KCl performed better and it was followed by osmohardening with CaCl₂ and ascorbate priming in improving growth, yield and quality of transplanted rice.

Osmohardening with CaCl₂ recorded the best yield followed by hardening and osmohardening with KCl (Muhammad Farooq et al., 2006). Osmoregulation with KCl or CaCl₂ improved germination, kernel yield (due to more tillers, 1000 kernel weight) and grain quality (due to improved kernel protein and kernel water absorption ratio (Farooq et al., 2006c). More than one pre-sowing treatment causing an increase in seed weight and it was reported by Vijaya (1996) in cowpea and blackgram, Maheshwari (1996) in Soyabeen and Jayaseelan (1997) in redgram and greengram. Paddy seeds of cv ADT 43 hardened with KCl 1% followed by pelleting with pongam leaf powder @ 200g/kg recorded the increased yield characters (Prakash et al., 2013).

Clusterbean seeds treated with thiourea @ 500 ppm significantly increased plant height, leaf area, dry matter production and seed yield under rainfed condition which were attributed to increase in net photosynthetic rate, chlorophyll content and metabolism (Garg et al., 2006). Increased activities of photosystem PS 2 and PS1 and total superoxide dismutase, glutathione reductase, and glutathione-S-transferase were reported in seeds of pearl millet cv. HHB 67 pre-soaked in sulphydryl compounds viz., dithiothreitol, thioglycollic acid, thiourea and cysteine. (Ramaswamy et al., 2007). The above observations were in agreement with the present study.

Thus, the influence of various seed hardening treatments on growth and yield parameters in black gram under drought condition revealed that 1% prosopis leaf extract hardened seeds recorded higher growth, seed yield and seed quality and physiological characters as compared to other treatments and control.

REFERENCES


