

Original Research Article

The effects of hydro priming intervals on the germination and yield of kidney beans (*Phaseolus vulgaris* L.) in the humid forest zone of Cameroon

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Hydro-priming which is an act of allowing the seed to be hydrated followed by dehydration that initiates germination without radicle emergence is a very important seed treatment technique for rapid germination and uniform stand establishment in various grain crops. This experiment was conducted in 2017 in Buea, Cameroon to evaluate the appropriate hydro-priming interval on germination, growth and yield of beans (*Phaseolus vulgaris* L.). The experiment was conducted in a Completely Randomized Block Design, with five treatments, replicated thrice. The Five treatments were: T1 (Unprimed or control), T2 (Hydro-primed for 6 hours), T3 (Hydro-primed for 12 hours), T4 (Hydro-primed for 18 hours), and T5 (Hydro-primed for 24 hours). Data were collected on percentage germination, plant height, stem diameter, number of leaves per plant, number of pods, pod weight and grain yield. The result revealed there was a significant increase in days ($P < 0.05$) in the germination percentage of some primed seeds and unprimed seeds across the treatment. There was not any significant difference ($P > 0.05$) in plant height, leaf number number of leaves, plant girth from T1 to T5. There was a significant difference ($P < 0.05$) in the number of pods among the primed treatments. Yield of beans also showed a significant difference ($P < 0.05$) with unprimed and primed plants. Seeds of T2, T3, T4, T5 produced the following yields 11.1 kg/ha, 22.3 kg/ha, 172.3 kg/ha, 277.8 kg/ha more than unprimed seeds (control), respectively. This study showed that hydro primed seeds for 6 hours produced the best growth and development aspect as well as the yield, despite the low germination percentage as compared to the unprimed and the other primed seeds.

Keywords: Beans, germination, growth, hydro-priming, interval, yield

1. INTRODUCTION

Legumes are the third biggest family of flowering plants, with more than 650 genera and 18,000 species [1]. Legumes have a major influence to diet as good sources of protein, carbohydrates, a number of water-soluble vitamins, and minerals [2]. Beans are one of the longest-cultivated legumes and serve as an excellent source of protein throughout the World

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history [3]. Beans (*Phaseolus vulgaris*) are crops that prefer warm temperatures to develop appropriately and they can grow well with corn or any other vegetable. Shurtleff and Aoyag [4] reports that maturity of beans is typically 55–60 days from planting to harvest.

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According to Abdulrahmani et al. [5], seed germination is usually the most critical stage in seedling establishment. The water absorbed by the seed stimulates enzymes, which facilitate mobilization and translocation of reserves. Thus, absorption of water is an essential step for the metabolism of stored starch and protein in the seed [6]. This, in turn, is vital in ensuring nutrient supply to the germinating embryo and to generate energy for the start of active germination and seedling development. The duration and extent of imbibition for seed germination depends on the cultivar, species and relative availability of moisture [7]. Hydration under high moisture conditions can affect proper germination, mainly because of nutrient leakage.

Seed germination, seedling emergence and crop establishment are key aspects of agricultural and horticultural production and are important components of seed and seedling vigour. These factors are related to the early development of the crop and may be linked to resistance to early-season stresses and final yield [8]. A method to increase the rate and uniformity of germination is the priming or physiological progress of the seed lot [9,10].

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Hydro-priming involves soaking seeds in water before sowing [11] and may or may not be followed by air-drying of the seeds. Hydro-priming may improve seed germination and seedling emergence under both saline and non-saline conditions [12]. Roy and Srivastava [13] found that soaking wheat kernels in water improved their germination rate under saline conditions.

Seed priming which is an act of allowing the seed to be hydrated followed by dehydration that initiates germination without radicle emergence [14,15], has been used to improve germination, reduce seedling emergence time, improve stand establishment and yield [16]. Many seed priming techniques have been established, including hydro-priming (soaking in water), halo-priming (soaking in inorganic salt solutions), osmopriming (soaking in solutions of different organic osmotic), thermo-priming (treatment of seeds with low or high temperatures), solid matrix priming (treatment of seed with solid matrices) and bio-priming (hydration using biological compounds) [17].

The beneficial effects of priming have been revealed for many cultivable crops such as barley [5], maize [18], chickpea [19], sugar beet [20] and sunflower [21]. Harris et al. [22] demonstrated that on-farm seed priming (soaking seeds overnight in water) markedly improved establishment and early vigour of upland rice, maize and chickpea, resulting in faster development, earlier flowering and maturity and higher yields. These effects of priming are associated with the restoring and constructing up of nucleic acids, increased synthesis of proteins as well as the mending of membranes [23].

Organic and inorganic substances have a major role in the plant growth and development of storage bodies of plants. Pre-soaking of seeds in water may alter the mobilization of both inorganic and organic substances from the storage organs to the developing embryo in some species [24]. Priming also enhances the activities of anti-oxidative enzymes in treated seeds [25,26].

Some researchers have considered hydro-priming a key technology that is simple and cost-effective, the impact of which is very high in terms of enhanced yield [17]. Hydro-priming is a very simple, economic and environmentally friendly type of seed priming [19,27].

Sprouting and seedling establishment are critical stages in the plant life cycle. In crop production, stand establishment determines plant density, uniformity and management decisions [28]. Planting high-quality seeds with high germination percentage are important in agriculture, especially in mechanized and industrialized systems. Beans are the most consumed and demanded legume in all regions of Cameroon as it is a cheap and affordable source of protein. For example, a kilogram of meat cost 3000 CFA francs ₣ than a kilogram of beans which cost 500 CFA francs ₣ (Referece). Therefore, farmers in Cameroon should be encouraged to produce more of the crop to meet up with the demand. Providing adequate plant protein source for the increasing population is the most challenging problem because of low seed viability, poor plant establishment especially as a result of hard seed coats, and water shortage at crucial times during crop growth. Crop yield is directly related to germination and difficulties in germination will affect its yield. There are various ways of enhancing germination, of which hydro priming is one of them. However, if the stress effect can be alleviated at the germination stage by hydro priming, an excellent establishment will be attained by the crop. Thus, this research was undertaken to evaluate the appropriate hydro priming interval on germination, growth and yield of beans.

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2. MATERIAL AND METHODS

2.1 Experimental design and field layout

This study was conducted at the agricultural research farm of Pan African Institute for Development – West Africa (PAID-WA), Buea from August to October 2017. The Institute lies between longitudes 8° 5' E and 9° 32'E and latitudes 3° 50'N and 4° 22' N. Mount Cameroon, an active volcanic mountain is also found in this region, and it has erupted 6 times in the previous century, adding essential nutrients into the soils that are volcanic [29]. This area has two main seasons, the dry (November-February) and the rainy season (March-October). Annual rainfall ranges between 300mm to 5,000mm. Crops such as rubber, oil palms, plantains, banana, cereals and vegetables are cultivated in this area [29].

A 73.44 m² land was cleared, raked, ploughed and harrowed using cutlass and hoe laid out using ranging poles, pegs, tape, strings. The land was divided into five plots and a Completely Randomized Block Design was carried out. Three replicates of 24.48 m² with each replicate having a 3m x 1m (3m²) plot size each with a plant population of 160,000 plants/ha. The plots were 0.3 m apart while the replicates blocks were 0.6 m apart. Five treatments were used with each treatment replicated thrice. The treatments were as follows: T1 (Unprimed or control), T2 (Hydro primed for 6 hours), T3 (Hydro primed for 12 hours), T4 (Hydro primed for 18 hours), and T5 (Hydro primed for 24 hours.) ~~The experimental design was a Completely Randomized Block Design, with five treatments and three replicates.~~

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2.2 Seed Preparation and Sowing

A local variety of kidney bean (*Phaseolus vulgaris* L.) seeds was ~~ere~~ used in this experiment. Hydration was done by completely immersing the seeds in 0.5L of water in a container, and then the hydrated seeds were air dried at room temperature for two hours. Two seeds were planted per stand with a planting distance of 25x25 cm, in August 2017. ~~Plants~~ were thinned to 1 per stand after two weeks of sowing to allow ~~them plants~~ receive an adequate supply of nutrients. Weeds were frequently controlled by hand during crop growth and development. Insects were also controlled by ~~the~~ application of insecticide (Pacha) at the rate of 25ml in 15L of water.

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2.3 Data Collection

Ten (10) plants were randomly selected and tagged from each of the plots for data collection. Data ~~were as~~ collected on percentage germination, plant height, stem diameter,

number of leaves per plant, number of pods, pods weight and grain yield. The data for plant height, stem diameter and number of leaves per plant were collected weekly for five weeks. Percentage germination (PG) was calculated using the formula according to Bormann et al. (2002), as cited in [30].

$$PG = (Sg \div St) \times 100 \quad (\text{where; } Sg = \text{germinated seed and } St = \text{total seed planted})$$

2.4 Data analysis

Data collected were analysed using a one-way analysis of variance (ANOVA) using Minitab Statistical Software package version 17 at 1- 5% probability level. The treatment means were compared and separated using Tukey's method at 5% probability level. Results analyses were presented in tables and figures.

3. RESULTS AND DISCUSSION

3.1 Effects of hydro priming on the germination percentage of kidney bean seeds.

Figure 1 shows that seeds primed for 6h (T2) had the highest germination percentage (21.50%) 3 days after planting (DAP). But as from the 4 DAP to the 6 DAP unprimed seeds (Control) had the highest germination percentage of 38.89% and 83.68%, respectively. Generally, it was observed that there were significant increases in days ($P < 0.05$) in the germination percentage of some primed seeds and unprimed seeds across the treatment (Table 1). Not all the primed seed showed increased in germination percentage 5 Days after Planting (DAP). This is because the mean maximum germination percentage mean (52.08 %) was observed in unprimed seed (T1), while the mean for minimum germination percentage mean (21.27 %) was found with seed primed for 24h (T5).

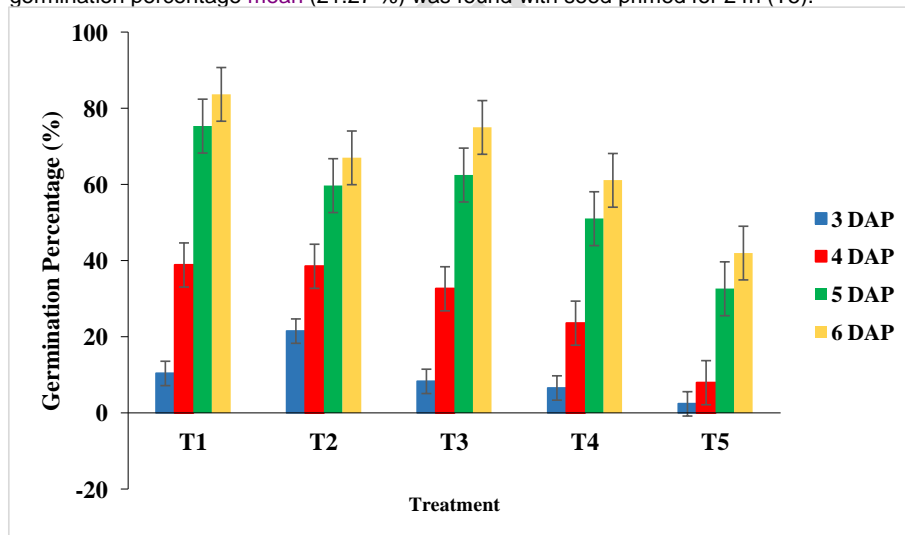


Fig. 1. Effect of hydro priming on the germination percentage of kidney bean seeds

T1 = Unprimed Seed (Control), T2 = Primed 6h T3 = Primed for 12h T4 = Primed for 18 h T5 = Primed for 24h

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3.2 Effects of hydro priming on the germination percentage, growth and development of kidney bean plants.

There was no significant increase ($P > 0.05$) in plant height from T1 to T5 (Table 1). The maximum mean plant height (12.96 cm) was recorded with plants whose seeds were primed for 6h (T2), while plants whose seeds were primed for 24h (T5) had the lowest plant height (11.63 cm).

The primed treatment had no effect on the leaf number of bean (Table 1). The highest mean number of functional leaves (11.69 leaves) was produced by plants whose seeds were primed for 6h (T2) and the mean lowest number of leaves (10.73 leaves) were for plants whose seeds were primed for 24h (T5). The result shows that there was no significant difference ($P > 0.05$) in leaf number within the primed and unprimed plants seed.

There was no significant increase ($P > 0.05$) in plant girth from T1 to T5 (Table 1). However, the maximum mean plant girth (0.28 cm) was recorded in plants whose seeds were primed for 6h (T2) while plants whose seeds were primed for 24h (T5) had the lowest plant girth (0.27 cm).

Table 1. The effects of hydro priming on the germination percentage, growth and development of kidney bean

Treatment	Growth and Development Parameter/ Germination Percentage			
	Germination Percentage (%)	Plant Height (cm)	Number of Leaves	Plant Girth (cm)
T1	52.08 ^a	11.93 ^a	10.79 ^a	0.27 ^a
T2	46.70 ^{ab}	12.96 ^a	11.69 ^a	0.28 ^a
T3	44.62 ^{ab}	12.41 ^a	10.83 ^a	0.27 ^a
T4	35.59 ^{ab}	12.07 ^a	10.25 ^a	0.27 ^a
T5	21.27 ^b	11.63 ^a	10.73 ^a	0.27 ^a

Values represent Means were separated using Tukey HSD test at $P = 0.05$.

Means with similar letters within column indicate no significant differences among treatments

T1 = Unprimed Seed (Control), T2 = Primed for 6hours, T3 = Primed for 12hours, T4 = primed for 18hours, T5= Primed for 24hours

3.3 Effect of seeds hydro priming on post-harvest of beans

The number of pods showed a significant difference ($P < 0.05$) with the priming treatment of bean (Table 2). The maximum mean number of the pods was (96.25 pods) recorded in plants whose seed were primed for 6h (T2) while the minimum mean number of the pods (60.58 pods) was recorded in plants whose seeds were primed for 24h (T5). Plants whose seeds were not primed (T1) showed no significant difference ($P > 0.05$) with plants whose seeds were primed for 6h (T2) and 12h (T3).

There was a significant difference ($P < 0.05$) in the weight of bean pods with unprimed and primed plants (Table 2). The maximum mean weight of pods (325.33 kg) was recorded in plants whose seeds were primed for 6h (T2) while plant whose seeds were primed for 24h (T5) had the lowest pods fresh weight (229.00 kg). As seen in Table 2, there was a significant difference ($P < 0.05$) amongst plants whose seeds were primed.

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There was a significant difference ($P < 0.05$) in the yield of bean grains with unprimed and primed plants (Table 2). Plants whose seeds were primed for 6h (T2) produced 11.1 kg/ha, 22.3 kg/ha, 172.3 kg/ha, 277.8 kg/ha more than T1, T3, T4 and T5, respectively.

Table 2. The effects of seeds hydro priming on yield of kidney bean plants post-harvest of bean

Yield Parameters			
Treatment	Number of pods	Pods weight (kg)	Yield of grains (kg/ha)
T1	89.17 ^{ab}	303.33 ^{ab}	1005.60 ^a
T2	96.25 ^a	325.33 ^a	1016.70 ^a
T3	79.50 ^b	284.30 ^b	994.40 ^a
T4	66.08 ^c	267.30 ^b	844.40 ^{ab}
T5	60.58 ^c	229.00 ^c	738.90 ^b

Values represent Means were separated using Tukey HSD test at $P = 0.05$.

Means with similar letters within column indicate no significant differences among treatments

T1 = Unprimed Seed (Control), T2 = Primed for 6hours, T3 = Primed for 12hours, T4 = primed for 18hours, T5= Primed for 24hours

3.4 Discussion

Numerous preliminary experiments have been conducted to study the effects of hydropriming on the germination and growth performance of beans (*Phaseolus vulgaris*). In this study, it was revealed that germination percentage of bean differs significantly when bean seeds plants are primed with water.

From the result it showed that hydro priming of bean seeds do not increase the germination percentage of beans—this might be because seeds soaking is not suitable for some plant species, as rapid hydration may cause leakage of essential nutrients out of the seed, resulting in seed damage. This result was not in line with Roy and Srivastava [13] who founded that soaking wheat kernels in water improved their germination rate under saline conditions. It was also not in line with Bajehbaj [31] who evaluated the effects of sodium chloride (NaCl) priming with potassium nitrate (KNO₃) on the germination traits and seedling growth of four *Helianthus annuus* L. cultivars under salinity conditions and reported that germination percentage of primed seeds was greater than that of un-primed seeds.

The increase in growth and development in this study would likely be due to presoaking of seeds in water which may alter the mobilization of both inorganic and organic substances from the storage organs to the developing embryo of the bean. The result of this study was similar to the result of Capron et al. [24] while studying sugar beet and pigeon pea reported that the influence of hydro-priming on improving seed germination was closely linked to the solubilization of phosphorus (P)-subunit of 11-S globulin storage protein and was very effective in the deployment of compounds such as proteins, free amino acids, and soluble sugars from storage organs to growing embryonic tissues under salt stress. In contrast Oh et al. [32] after studying the lipid composition of Korean black soybean (*Glycine max*) seed, including percentages of neutral fats, glycolipids, and phospholipids reported that they

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remain unchanged after soaking in water. However, in view of these contrasting reports, it is not possible for us to draw any strict parallels between mobilization of different inorganic or organic substances due to hydro-priming and plant growth. It is likely that the extent of mobilization of these substances depends on plant species and time period for which seed is subjected to water redrying and sowing.

The increase in the number of the pods, weight of pods and grain yield of bean across the plant primed for 6h (T2) may be as a result of promoting effects on plants at the initial and later developmental stages. This promoting effects at later stages can be due to alteration in various metabolic phenomena responsible for enhanced yield. This was similar with the result of Bastia et al. [33] working on hydro-priming of safflower (*Carthamus tinctorius*) seed for 12 h -resulted in higher number of plants, capitula per plant, grains per capitulum, 1000 seed weight, grain yield, and oil content compared to untreated seed. Similar improvements were observed in maize, rice, chickpea [22], and pearl millet [34] grown under dry-land conditions. Ashraf and Foolad [17] reported that the precise mechanisms by which application of this simple technique can achieve sometimes quite dramatic improvements in plant growth and seed yield in saline or non-saline conditions remain unclear.

4. CONCLUSION

The study showed that priming does not really affect the germination percentage of bean but seed primed for 6h had the best results in the growth and yield of bean plants. Priming seeds for more than 6h does not guarantee to increase the germination percentage, growth and yield of plants. A further research is needed to evaluate the performance of hydro priming on other bean cultivars commonly planted around this area.

REFERENCES

1. Lewis G, Schirer B, Mackinder B, Lock M. "Legumes of the World"; Royal Botanical Gardens: Kew, United Kingdom. 2005
2. Rodriguez, C., Frias J., Vidal-Valverde, C., Hernandez, A. "Correlations between some nitrogen fractions, lysine, histidine, tyrosine and ornithine contents during the germination of peas, beans, and lentils". Food Chemistry. 2008;108:245-252.
3. Chazan M. World Prehistory and Archaeology: Pathways through Time. Pearson Education, Inc. ISBN 0-205-40621-1. 2008.
4. Shurtleff W, Aoyag, A. (2013). "Early Named Soybean Varieties in the United States and Canada: Extensively Annotated Bibliography and Sourcebook". Soy info Center. Retrieved 18 November 2017 – via Google Books.
5. Abdulrahmani B, Ghassemi-Golezani K, Valizadeh M, Feizi-Asl V.. Seed priming and seedling establishment of barley (*Hordeum vulgare* L.). J. Food. Agri. Environ. 2007;5:179-184.
6. Kikuchi K, Koizumi M, Ishida N, Kano H. Water intake by dry beans observed by micro-magnetic resonance imaging. Ann. Bot. 2006;98:545-553.

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Hilly M, Adams ML, Nelson SC. A study of digit fusion in the mouse embryo. Clin Exp Allergy. 2002;32(4):489-98.

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Hugo JT, Mondal SC. Parallels between tissue repair and embryo morphogenesis: a conceptual framework. Global Health. 2006;16:4. Accessed 29 March 2012. Available: <http://www.globalizationandhealth.com/content/1/1/14>.

7. Copeland L, McDonald MB. Seed science and technology. Chapman and Hall, New York. 1995

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8. Tavakoli Kakhki HR, Kazemi M, Tavakoli H. Analysis of seed size effects on seedling characteristics of different types of wheat (*Triticum aestivum* L.) cultivars. *Asian Journal of Plant Sciences*. 2008;35:1-6.

9. Finch-Savage WE. The use of population-based threshold models to describe and predict the effects of seeded environments on germination and seedling emergence of crops. In: Benech-Arnold RL and Sanchez R eds. *Handbook of Seed Physiology*. Food Product Press, New York, 2004;51-84.

10. Halmer P. Methods to improve seed performance in the field. In: Benech-Arnold RL and Sanchez R eds. *Handbook of Seed Physiology*. Food Product Press, New York; 2004;125-156.

11. Pill WG, Necker AD. The effects of seed treatments on germination and establishment of Kentucky bluegrass (*Poa pratense* L.). *Seed Sci. Technol.* 2001;29: 65-72.

12. Hamid A, Mohammad RE, Ahmad G. The Effect of Hydropriming and Halopriming on Germination and Early Growth Stage of Wheat (*Triticum aestivum* L.). *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*. 2010;4(8):551-555.

13. Roy NK, Srivastava AK. Effect of presoaking seed treatment on germination and amylase activity of wheat (*Triticum aestivum* L.) under salt stress conditions. *Rachis*. 1999;18:46-51.

14. McDonald MB. Seed deterioration physiology, repair and assessment. *Seed Sc. and Technol.* 1999; 27:177-237.

15. Modi AT. Assessment of pepper seed performance using desiccation sensitivity. *Seed Sci. Technol.* 2005;33:19-30.

16. Khan AA. Preplant physiological seed conditioning, pp. In: Janick J. (Eds.). *Horticultural Reviews*. John Wiley and Sons, New York; 1992;131-181

17. Ashraf M, Foolad MR. Pre-sowing seed treatment a shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Advances in Agron.* 2005;88:223–271.

18. Parera CA, Cantliffe DJ. Pre-sowing seed priming. *Hortic. Rev.* 1994;16:109-141.

19 Ghassemi-Golezani K, Sheikhzadeh-Mosaddegh P, Valizadeh M. Effects of hydro-priming duration and liParera, C. A. and D. J. Cantliffe (1994). Pre-sowing seed priming. *Hort. Rev.* 2008b ;16:109-141.

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20. Sadeghian SY, Yavari N. Effect of warer-deficit stress on germination and early seedling growth in sugar beet. *J. Agron. Crop Sci.* 2004;190:138-144.

21. Singh BG. Effect of hydration-dehydration seed treatments on vigour and yield of sunflower. *Ind. J. Plant Physiol.* 1995;38:66-68.

22. Harris D, Joshi A, Khan PA, Gothakar P, Sodhi PS. On-farm seed priming in semi-arid agriculture: Development and evaluation in corn, rice and chickpea in India using participatory methods. *Exp. Agric.* 1999;35:15-29.
23. McDonald MB. Seed priming. In: Black, M. and Bewley, JD. (Eds.). *Seed Technology and Its Biological Basis*. Sheffield Academic Press, Sheffield, England; 2000; 287-325.
24. Capron I, Corbineau F, Dacher F, Job C, Come D, Job D. Sugar beet seed priming: Effects of priming conditions on germination, solubilization of 1 I-S globulin and accumulation of LEA proteins. *Sci Res.* 2000;10:243-254.
25. Wang HY, Chen C, Sung JM. Both warm water soaking and solid priming treatments enhance antioxidation of bitter melon seeds germinated at sub-optimal temperature. *Seed Sci. Technol.* 31:47-56. mited irrigation on field performance of chickpea. *Res. J. Seed Sci.* 2003;1:34-40.
26. Hsu CC, Chen CL, Chen JJ, Sung JM. Accelerated aging-enhanced lipid peroxidation in bitter melon seeds and effects of priming and hot water soaking treatments. *Sci. Horti.* 2003;98:201-212.
27. Thornton JM, Powell AA. Short term aerated hydration for the improvement of seed quality in *Brassica oleracea* L. *Seed Sci. Res.* 1992;2:41-49.
28. Cheng Z, Bradford KJ. Hydrothermal time analysis of tomato seed germination responses to priming treatments. *J. Exp. Bot.* 1999;33:89-99.
29. Endeley RE, Ayonghe SN, Tchuenteu F. A preliminary hydrogeological baseline study of water sources around Mount Cameroon. *Journal of the Cameroon Academy of Sciences.* 2001;1(3):127-185.
30. Ogbuehi HC, Madukwe DK, Ashilonu P. Assessment of hydro priming of seeds on performance of morphological indices of bambara groundnut (*Vigna subterrenea* Linn.) Landrace. *Global Journal of Biology, Agriculture and Health Sciences.* 2013;2(2):17-22.
31. Bajehbaj AA. The effects of NaCl priming on salt tolerance in sunflower germination and seedling grown under salinity conditions. *African J. Biotech.* 2010;9:1764-1770.
32. Oh MK, Rhee SH, Cheigh HS. Changes of lipid composition of Korean black soybean before and after soaking. *J. Korean Soc. Food Nutri.* 1992;21:29-35.
33. Bastia DK, Rout AK, Mohanty SK, Prusty AM. Effect of sowing date sowing methods and seed soaking on yield and oil content of rainfed safflower grown in Kalahandi, Orissa. *Indian J. Agron.* 1999;44:621-623.
34. Kumar A, Gangwar JS, Prasad SC, Harris D. On-farm seed priming increases yield of direct-sown finger millet in India. *Intl. Sorghum Millets News.* 2002;43:90-92.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

DAP: Day After Planting.

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