Influence of Seed Invigouration Treatments on Nutrient Uptake and Soil Nutrient Status of Grain Cowpea [Vigna unguiculata (L.) Walp]

Anju B. Raj, Sheeja K. Raj, K. Prathapan¹, N.V. Radhakrishnan¹

ABSTRACT

Background: Cowpea [Vigna unguiculata (L.) Walp] is the most widely cultivated pulse crop of Kerala. Deficiencies of micronutrients viz., Zn and B are a common problem in cowpea. Foliar nutrition is very effective to correct the micronutrient deficiencies in pulses but it is too laborious. Seed pelleting and priming are two simple cost-effective methods to overcome the micronutrient deficiencies. The present study aimed to study the effect of seed invigouration with zinc sulphate and borax and to evaluate its effect along with Trichoderma viride on nutrient uptake and soil nutrient status of grain cowpea.

Methods: The experiment was conducted at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala. The experiment was conducted in RBD with 8 seed invigouration treatments and a control during Rabi 2018.

Result: Seed invigouration treatments had significant effect on nutrient uptake and nutrient availability. Seeds primed in ZnSO₄ 0.05 per cent for 4 h recorded the highest NPK uptake by crop, the highest soil organic carbon content, available N and Zn status. Zinc uptake by crop and available soil K status were recorded the highest in seeds primed in ZnSO₄ 0.05 per cent for 4h + Trichoderma viride seed treatment 10 g kg⁻¹ seed. Boron uptake by crop and available soil B and P status were recorded the highest in seeds pelleted with borax 100 mg kg⁻¹ seed. Hence it can be concluded that seed primed in ZnSO₄ with 0.05 per cent for 4 h improved the Zn availability and uptake and seed pelleting with borax 100 mg kg⁻¹ improved the B availability and uptake of grain cowpea.

Key words: Borax, Grain cowpea, Seed pelleting, Seed Priming, Trichoderma viride, ZnSO₄.

INTRODUCTION

Cowpea [Vigna unguiculata (L.) Walp] is an important multipurpose pulse crop of Kerala in coverage and preference. Being a legume crop, it is an integral part of sustainable agriculture. Seed invigouration is a term which can be used for both seed pelleting and priming. Seed priming is a simple, cost effective pre-sowing treatment which ensures rapid and uniform germination with better stand establishment and crop yield in many crop plants. It has been successfully demonstrated in field crops, pulses and oil seeds (Harris et al., 2007; Rehman et al., 2011). The success of seed priming depends on crop species, priming media, concentration of priming solution and duration of priming. Raj et al. (2020) reported that seed priming with ZnSO₄ significantly enhanced the germination parameters in grain cowpea and higher Zn content in cowpea seedlings. Scott (1989) described seed pelleting as a pre-sowing physical seed management procedure. In seed pelleting the seed-soil interface at the rhizosphere region is improved by applying growth promoting substances or substances with protective, nutritive and invigourative function on the seed surface. Seed pelleting ensures easy planting, uniformity in size, uniform stress tolerance and nourishment to the seedlings (Nargis, 1995 and Peterhalmer, 2003).

Seed invigouration significantly improved the nutrient uptake and nutrient availability in many crops. Ajouri et al. (2004) observed that barley seeds primed in Zn 10 mg kg⁻¹ seed increased the Zn content from 94 to 216 mg kg⁻¹. Johnson et al. (2005) opined that nutripriming enhanced the Zn and B uptake in chickpea. Priming with optimal concentrations of Zn and B increased the Zn content from 40-60 to 500-800 mg kg⁻¹ and B content from 10 to 80–100 mg kg⁻¹. In maize hybrid DK-919, seed priming with Zn 2 per cent followed by foliar application of Zn 2 per cent improved the Zn content of grain (28.55 mg kg⁻¹) compared to control (19.88 mg kg⁻¹) (Afzal et al., 2015). Munir et al. (2018) revealed that wheat seeds primed in ZnO nanoparticle 100 ppm significantly enhanced the Zn content...
in grain by 64 per cent, shoot by 65 per cent and root by 45 per cent over control. With this background the present investigation was carried out with an objective to assess the effect of seed invigouration with zinc sulphate and borax and to evaluate its effect along with *Trichoderma viride* on nutrient uptake and soil nutrient status of grain cowpea.

**MATERIALS AND METHODS**

Experiment was conducted during *Rabi* season of 2018 at Coconut Research Station, Balaramaparam, Kerala, India with an objective to find out the effect of seed invigouration on the nutrient uptake and soil nutrient availability of grain cowpea by different priming and pelleting treatments. The variety used for the study was Bhagyalakshmi. The experiment comprised of 9 treatments replicated thrice. The design adopted for the study was randomized block design (RBD). The treatments were: T₁ (seed pelleting with borax 50 mg kg⁻¹ seed), T₂ (seed pelleting with borax 100 mg kg⁻¹ seed), T₃ (seed priming with ZnSO₄ 0.025 per cent for 4 h), T₄ (seed priming with ZnSO₄ 0.05 per cent for 4 h), T₅ (seed priming with ZnSO₄ 0.05 per cent for 4 h), T₆ (T₁ + *Trichoderma viride* seed treatment 10 g kg⁻¹ seed), T₇ (T₂ + *Trichoderma viride* seed treatment 10 g kg⁻¹ seed), T₈ (T₃ + *Trichoderma viride* seed treatment 10 g kg⁻¹ seed), T₉ (T₄ + *Trichoderma viride* seed treatment 10 g kg⁻¹ seed) and a control (T₀). For pelleting, borax was mixed thoroughly with the adhesive @ 200 mL kg⁻¹ seed, seeds were individually coated with this mixture and shade dried. For priming, seeds were soaked in respective concentrations of ZnSO₄ solution and shade dried before sowing. *Trichoderma viride* seed treatment was done ten minutes before sowing. The soil of the experimental area was acidic in reaction, medium in organic carbon content (0.650 per cent), medium in available soil N (301.05 kg ha⁻¹), medium in available soil P (20.52 kg ha⁻¹), low in available soil K (94.08 kg ha⁻¹), deficient in available soil Zn (0.457 mg kg⁻¹ soil) and deficient in soil available B (0.018 mg kg⁻¹ soil). Composite soil samples were collected before and after the experiment and analysed for soil organic carbon content (Walkley and Black, 1934), available soil N (Subbaiah and Asija, 1956), available soil P (Jackson, 1973), available soil K (Jackson, 1973), available soil Zn (Lindsay and Norwell, 1978) and available B (Hesse, 1971). The N, P, K, Zn and B uptake by pod, haulm and total uptake by crop was determined at harvest stage by multiplying the respective nutrient content with the dry matter. Nitrogen content was estimated by microkjeldhal method (Jackson, 1973), P content by vanamolybdate phosphoric yellow method (Jackson, 1973), K content using flame photometer (Jackson, 1973), Zn content using atomic absorption spectrophotometer (Lindsay and Norwell, 1978) and B content by azomethine-H calorimetric method (Wolf, 1971). The data were statistically analysed and the treatment means were compared at 5 per cent probability.

**RESULTS AND DISCUSSION**

**Effect of seed invigouration treatments on nutrient uptake by crop**

Uptake of N, P, K, Zn and B uptake by the crop at harvest was markedly influenced by seed invigouration treatments (Table 1 and 2). Compared to control, seed invigouration treatments registered higher uptake, due to higher dry matter production recorded in these treatments. Nutrient uptake by crop is related to nutrient content in the plant and dry matter production; dry matter production in turn depends on the photosynthetic ability of the plant. Enhanced seedling vigour resulting from the fast and uniform crop establishment might have led to the development of higher number of branches with more leaves with higher leaf area and chlorophyll content. This might have increased the photosynthetic rate and uptake of nutrients in seed invigouration treatments. Tabassum et al. (2013) observed that increased availability of nutrients also accelerated the physiological processes which in turn influenced the nutrient uptake.

Among the seed invigouration treatments, total uptake as well as uptake of N, P and K by the grain was the highest in T₆ (seed priming with ZnSO₄ 0.05 per cent for 4 h). This might be due to higher dry matter accumulation and higher content of N, P and K registered in the treatment. Higher uptake of N, P and K by grain in T₆ might be due to the role of Zn in activating the enzymes present in the chloroplast and cytoplasm viz., carbonic anhydrase, fructose-1, 6-bisphosphate and aldolase enzymes and this will lead to the transport of photosynthates from source to sink. Marschner and Cakmak (1989) pointed out that deficiency of Zn resulting in the accumulation of carbohydrate in plant leaves. Pooniya and Shivay (2013) pointed out that Zn fertilization significantly improved the N and K uptake in Basmati rice grain and straw. Khattak et al. (2006) reported that Zn nutrition improved the N uptake by maize crop. Similarly, Karki et al. (2005) observed an increase in the uptake of nutrients due to Zn fertilization.

Zinc and B uptake were also significantly influenced by seed invigouration treatments (Table 2). Seed invigouration treatments recorded higher uptake of Zn and B compared to control. Better crop growth attained by the early establishment of seedlings might have resulted in better absorption and uptake of major nutrients along with micronutrients Zn and B. Among the seed invigouration treatments, treatments involving ZnSO₄ priming registered higher Zn uptake by the grain. In the present experiment, cowpea seeds primed in ZnSO₄ 0.05 percent enhanced the Zn uptake of cowpea grain by 40.2 per cent. The result is in agreement with the observation of Harris et al. (2007) who observed that Zn priming significantly increased the grain Zn concentration in maize and is a low-cost technology to augment the Zn content in grain. Slaton et al. (2001) and Miraj et al. (2013) also reported that nutripriming significantly enhanced the Zn uptake by rice seedlings. Borax pelleted seeds also recorded higher Zn uptake compared to control. The result is in conformity with the observation of Debnath et al. (2018) who observed that application of B along with recommended dose of fertilizers increased the B uptake in grain cowpea. The B uptake by grain was the highest in ZnSO₄ primed seeds than in borax pelleted seeds. Sinha et al. (2000) observed a positive Zn x B interaction in mustard.
Influence of Seed Invigoration Treatments on Nutrient Uptake and Soil Nutrient Status of Grain Cowpea (Vigna unguiculata...)

Table 1: Effect of seed invigoration treatments on N, P and K uptake by crop at harvest, kg ha\(^{-1}\)

| Treatments                                      | Grain | Haulm | Total uptake |
|------------------------------------------------|-------|-------|--------------|
| **N uptake (kg ha\(^{-1}\))**                  |       |       |              |
| Grain                                          | 44.69 | 45.40 | 90.10        |
| T\(_1\) seed pelleting with borax 50 mg kg\(^{-1}\) seed | 42.37 | 43.20 | 85.57        |
| T\(_2\) seed pelleting with borax 100 mg kg\(^{-1}\) seed | 43.31 | 43.94 | 87.25        |
| T\(_3\) seed priming with ZnSO\(_4\) 0.025 per cent for 4 h | 44.43 | 46.26 | 90.69        |
| T\(_4\) seed priming with ZnSO\(_4\) 0.05 per cent for 4 h | 47.49 | 49.32 | 96.81        |
| T\(_5\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 47.81 | 49.74 | 97.55        |
| T\(_6\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 51.64 | 53.58 | 105.22       |
| T\(_7\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 40.88 | 42.82 | 83.70        |
| T\(_8\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 42.83 | 43.80 | 86.63        |
| Control                                        | 32.23 | 33.07 | 65.30        |

| **P uptake (kg ha\(^{-1}\))**                  |       |       |              |
| Grain                                          | 13.48 | 15.10 | 28.59        |
| T\(_1\) seed pelleting with borax 50 mg kg\(^{-1}\) seed | 12.60 | 14.25 | 26.85        |
| T\(_2\) seed pelleting with borax 100 mg kg\(^{-1}\) seed | 14.88 | 16.53 | 31.41        |
| T\(_3\) seed priming with ZnSO\(_4\) 0.025 per cent for 4 h | 14.73 | 16.48 | 31.21        |
| T\(_4\) seed priming with ZnSO\(_4\) 0.05 per cent for 4 h | 11.84 | 13.53 | 25.37        |
| T\(_5\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 10.99 | 12.63 | 23.62        |
| T\(_6\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 12.95 | 14.64 | 27.59        |
| T\(_7\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 12.85 | 14.54 | 27.39        |
| T\(_8\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 12.85 | 14.54 | 27.39        |
| Control                                        | 14.88 | 16.47 | 31.35        |

| **K uptake (kg ha\(^{-1}\))**                  |       |       |              |
| Grain                                          | 29.56 | 31.17 | 60.73        |
| T\(_1\) seed pelleting with borax 50 mg kg\(^{-1}\) seed | 29.32 | 30.93 | 60.25        |
| T\(_2\) seed pelleting with borax 100 mg kg\(^{-1}\) seed | 30.53 | 32.14 | 62.67        |
| T\(_3\) seed priming with ZnSO\(_4\) 0.025 per cent for 4 h | 30.56 | 32.14 | 62.67        |
| T\(_4\) seed priming with ZnSO\(_4\) 0.05 per cent for 4 h | 31.17 | 32.78 | 63.95        |
| T\(_5\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 30.67 | 32.28 | 63.95        |
| T\(_6\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 29.48 | 31.09 | 60.57        |
| T\(_7\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 28.68 | 30.29 | 58.97        |
| T\(_8\) + Trichoderma viride seed treatment 10 g kg\(^{-1}\) seed | 28.68 | 30.29 | 58.97        |
| Control                                        | 29.66 | 31.27 | 60.93        |

Effect of seed invigoration on organic carbon content and available nutrient status

As compared to initial nutrient status, nutrient status of soil after the experiment was improved (Table 3). This was due to the fact that, being a leguminous crop, cowpea have the ability to fix atmospheric N and tap nutrients from deeper layers (Melero et al., 2007). The result is in consonance with the observation of Amanullah et al. (2007). Thamburaj (1991) revealed that raising legumes in rotation increased the NPK content of soil. Jensen et al. (2012) also reported that inclusion of legumes in rotation significantly improved the soil organic carbon and available nutrients in the soil.

Post-harvest organic carbon content of soil was significantly influenced by seed invigoration treatments (Table 3). In general, an enhancement in organic carbon content of soil was observed in all the treatments compared to initial soil status. The enhancement in organic carbon content observed in all the treatments might be due to the uniform application of FYM 20 t ha\(^{-1}\), biological N fixation, addition of organic residues and exudation of root exudates in to the soil by the crop root as well as the symbiotic N fixing bacteria associated with the crop. Seed invigoration treatments registered higher organic carbon content compared to control. This might be due to the enhanced crop growth resulting from the better seedling establishment and improved nodulation observed in these treatments. Lynch and Whips (1990) revealed that about 40 per cent of dry matter accumulated by the plant was released into the rhizosphere as root exudates. Among the seed invigoration treatments, higher organic carbon content was observed in T\(_4\) (seeds primed in ZnSO\(_4\) 0.05 percent for 4 h) which was statistically comparable with T\(_1\) and T\(_2\) (seeds pelleted with borax 50 and 100 mg kg\(^{-1}\) seed), T\(_3\) (seeds primed in ZnSO\(_4\) 0.025 per cent for 4 h) and T\(_5\) (T\(_1\) + *Trichoderma viride* seed treatment 10 g kg\(^{-1}\) seed\(^{-1}\))\(_{1}\). This was also due to the increased nodulation and higher dry matter production observed in these treatments. Organic substances (organic acid, amino acid, sugars, vitamins, mucilage etc.) released into the rhizosphere during the crop growth as well as due to the addition of organic matter in the form of FYM and leaf fall might have enhanced the organic carbon content of soil (Hasanuzzaman et al., 2019).

Available N, P, K, Zn and B status of soil was also significantly influenced by seed invigoration treatments (Table 3). Compared to control, all seed invigoration treatments registered higher availability of N, P, K, Zn and B. The better crop establishment and better rooting allow the crop to tap nutrients from the deeper layers. Further organic matter addition due to the falling of senescent leaves and atmospheric N fixation by the symbiotic N fixing bacteria present in the nodule also contribute to the increased availability of N, P and K. Chatterjee and Bandyopadhyay (2017) reported that seed treatment with micronutrients have prominent effect on the availability of major nutrients.

The available N status of all the treatments are in medium range. Availability of N was found to be higher in...
Influence of Seed Invigouration Treatments on Nutrient Uptake and Soil Nutrient Status of Grain Cowpea [Vigna unguiculata...]

Table 2: Effect of seed invigouration treatments on Zn and B uptake by crop at harvest, kg ha⁻¹.

| Treatments                                                                 | Zn uptake (kg ha⁻¹) | B uptake (kg ha⁻¹) |
|----------------------------------------------------------------------------|----------------------|--------------------|
|                                                                           | Grain               | Haulm              | Total uptake | Grain   | Haulm   | Total uptake |
| T₁: seed pelleting with borax 50 mg kg⁻¹ seed                             | 0.217               | 0.088              | 0.305        | 0.285   | 0.079   | 0.364        |
| T₂: seed pelleting with borax 100 mg kg⁻¹ seed                            | 0.217               | 0.077              | 0.294        | 0.346   | 0.073   | 0.419        |
| T₃: seed priming with ZnSO₄ 0.025 per cent for 4 h                         | 0.221               | 0.090              | 0.310        | 0.279   | 0.097   | 0.376        |
| T₄: seed priming with ZnSO₄ 0.05 per cent for 4 h                          | 0.213               | 0.102              | 0.315        | 0.307   | 0.104   | 0.410        |
| T₅: T₁ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.206               | 0.082              | 0.289        | 0.282   | 0.078   | 0.360        |
| T₆: T₂ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.221               | 0.087              | 0.308        | 0.301   | 0.088   | 0.399        |
| T₇: T₃ + Trichoderma viride seed treatment@ 10 g kg⁻¹ seed                 | 0.216               | 0.094              | 0.310        | 0.215   | 0.083   | 0.298        |
| Tₘ: T₅ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.236               | 0.093              | 0.329        | 0.245   | 0.112   | 0.356        |
| Tₙ: control                                                                | 0.186               | 0.061              | 0.246        | 0.239   | 0.059   | 0.298        |
| SEm (±)                                                                    | 0.008               | 0.004              | 0.009        | 0.018   | 0.007   | 0.025        |
| CD (0.05)                                                                  | 0.0248              | 0.0131             | 0.027        | 0.056   | 0.021   | 0.075        |

Table 3: Effect of seed invigouration treatments on organic carbon, available N, P, K, Zn and B status of soil after the experiment.

| Treatments                                                                 | Organic carbon (%) | Available N (kg ha⁻¹) | Available P (kg ha⁻¹) | Available K (kg ha⁻¹) | Available Zn (mg kg⁻¹ soil) | Available B (mgkg⁻¹ soil) |
|----------------------------------------------------------------------------|-------------------|----------------------|-----------------------|-----------------------|-----------------------------|-----------------------------|
| T₁: seed pelleting with borax 50 mg kg⁻¹ seed                             | 0.920             | 363.78               | 41.89                 | 117.39                | 0.861                       | 0.115                       |
| T₂: seed pelleting with borax 100 mg kg⁻¹ seed                            | 0.976             | 338.69               | 48.63                 | 125.77                | 0.577                       | 0.140                       |
| T₃: seed priming with ZnSO₄ 0.025 per cent for 4 h                         | 0.977             | 363.78               | 37.95                 | 135.41                | 1.237                       | 0.057                       |
| T₄: seed priming with ZnSO₄ 0.05 per cent for 4 h                          | 1.018             | 376.31               | 35.70                 | 131.60                | 1.484                       | 0.073                       |
| T₅: T₁ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.883             | 319.27               | 38.37                 | 126.50                | 1.199                       | 0.088                       |
| T₆: T₂ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.864             | 329.59               | 38.51                 | 127.23                | 0.808                       | 0.088                       |
| T₇: T₃ + Trichoderma viride seed treatment@ 10 g kg⁻¹ seed                 | 0.852             | 329.78               | 29.09                 | 149.14                | 1.912                       | 0.051                       |
| Tₘ: T₅ + Trichoderma viride seed treatment 10 g kg⁻¹ seed                  | 0.896             | 338.69               | 27.64                 | 146.37                | 2.223                       | 0.080                       |
| Tₙ: control                                                                | 0.663             | 313.59               | 22.78                 | 98.73                 | 0.403                       | 0.021                       |
| SEm (±)                                                                    | 0.044             | 16.43                | 2.82                  | 6.62                  | 0.034                       | 0.004                       |
| CD (0.05)                                                                  | 0.1317            | 49.679               | 8.515                 | 20.006                | 0.1033                      | 0.012                       |

treatments with higher organic carbon content. The result is in accordance with the findings of Sakin (2012) who reported that high soil organic carbon enhanced the N content of the soil. Available P status in the soil after the experiment was found to be high in all the treatments. However, the treatments having high Zn content registered lower available P content compared to those treatments having low Zn content. This might be due to the antagonism exists between Zn and P and also due to the formation of insoluble zinc phosphate. Similar observations were also made by Balai et al. (2017). Available K status was comparatively higher in treatment T₅ and T₆ (seeds primed in ZnSO₄ 0.025 and 0.05 per cent + Trichoderma viride seed treatment 10 g kg⁻¹ seed) compared to other seed inviguration treatments which might be due to lower K uptake registered in these treatments.

Seed inviguration treatments registered higher available Zn and B content in soil compared to control (Table 3). This might be due to the fact that higher soil organic carbon content prevented the leaching of nutrients and sustained the soil fertility status. Similar observation was also made by Suman (2018). Among the seed inviguration treatments, the treatments having higher post-harvest Zn content registered lower B content. This might be due to the antagonistic effect of Zn on B. The result is in agreement with the findings of Mullah et al. (2015) and Hosseini et al. (2007) who observed that higher Zn availability in soil decreased the B availability in soil.

**CONCLUSION**

It can be concluded from the results that seed invigouration had significant role in nutrient uptake and soil nutrient availability. Seed priming with ZnSO₄ 0.05 per cent recorded the highest total uptake of N, P, K and Zn and it also observed the highest uptake of N and K uptake by grain. The P and Zn uptake by grain was the highest in seed priming with ZnSO₄ @ 0.025 per cent. Total B uptake by crop and uptake by grain was recorded the highest in the treatment seed pelleting with borax @ 100 mg kg⁻¹ seed. Results on nutrient status of soil revealed that seeds primed in ZnSO₄ 0.05 per cent for 4h recorded the highest organic carbon content, available N and Zn status. B and P status was the highest in seed pelleting with borax 100 mg kg⁻¹ seed and K status in seed priming with ZnSO₄ @ 0.025 per cent for 4h.

**REFERENCES**

Afzal, I., Noor, M.A., Bakhtavar, M.A., Ahmad, A. and Haq, Z. (2015). Indian Journal of Agricultural Research
Influence of Seed Invigouration Treatments on Nutrient Uptake and Soil Nutrient Status of Grain Cowpea [Vigna unguiculata...]

Improvement of spring maize performance through physical and physiological seed enhancements. Seed Science Technology. 43(2): 238-249.

Ajouri, A., Aseged, H. and Becker, M. (2004). Seed priming enhances germination and seedling growth of barley under conditions of P and Zn deficiency. Journal of Plant Nutrition and Soil Science. 167(5): 630-636.

Amanullah, M.M., Sathyamoorthy, K., Vaiyapuri, K., Alagesan, A. and Pazhanivelan, S. (2007). Influence of organic manures on the nutrient uptake and soil fertility of cassava (Manihot esculenta Crantz) intercropping systems. Internal Journal of Agricultural Research. 2: 136-144.

Balai, K., Sharma, Y., Jajoria, M., Deewan, P. and Verma, R. (2017). Effect of phosphorus and zinc on growth, yield and economics of chickpea (Cicer arietinum L.). International Journal of Current Microbiology and Applied Science. 6(3): 1174-1181.

Chatterjee, R. and Bandyopadhyay, S. (2017). Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea [Vigna unguiculata (L. Walp.) in acid soil of eastern Himalayan region. Journal of the Saudi Society of Agricultural Sciences. 11: 26-31.

Debnath, P., Pattanaaik, S.K., Sah, D., Chandra, G. and Pandey, A.K. (2018). Effect of boron and zinc fertilization on growth and yield of cowpea (Vigna unguiculata Walp.) in Inceptisols of Arunachal Pradesh. Journal of Indian Society of Soil Science. 66(2): 229-234.

Harris, D., Rashid, A., Miraj, G., Arif, M. and Shah, H. (2007). On-farm seed priming with zinc sulphate solution - A cost-effective way to increase the maize yields of resource-poor farmers. Field Crops Research. 102(2): 119-127.

Hasanuzzaman, M., Anee, T.I., Bhuiyan, T.F., Nahar, K. and Fujita, M. (2019). Emerging role of osmolytes in enhancing abiotic stress tolerance in rice. Advances in Rice Research for Abiotic Stress Tolerance. 2: 677-708.

Hosseini, S. M., Maftoun, M., Karimian, N., Ronaghi, A. and Emam, Y. (2007). Effect of zinc + boron interaction on plant growth and tissue nutrient concentration of corn. Journal of Plant Nutrition. 30(5): 773-781.

Jackson, M.L. (1973). Soil Chemical Analysis (2nd Ed.), Prentice Hall of India (Pvt) Ltd, New Delhi, 498p.

Jensen, E.S., Peoples, M.B., Boddey, R.M., Gresshoff, P.M., Hauggaard-Nielsen, H., Alves, B.J. and Morrison, M.J. (2012). Legumes for mitigation of climate change and their provision of feedstock for biofuels and biorefineries- A review. Agronomy for Sustainable Development. 32(2): 329-364.

Johnson, S.E., Lauren, J.G., Welch, R.M. and Duxbury, J.M. (2005). A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (Cicer arietinum), lentil (Lens culinaris), rice (Oryza sativa) and wheat (Triticum aestivum) in Nepal. Experimental Agriculture. 41(4): 427-448.

Karki, K.B., Tuladhar, J.K., Uprety, R. and Maskey, S.L. (2005). Distribution of micronutrients available to plants in different ecological regions of Nepal. In: Micronutrients in South and South East Asia. [Andersen, P., Tuladhar, J.K., Karki, K.B. and Maskey, S.L. (eds)], Proceedings of An International Workshop, Kathmandu, Nepal, pp.143-151.

Khattak, A.B., Khattak, G.S.S., Mahmood, Z., Bibi, N. and Ihsanullah, I. (2006). Study of selected quality and agronomic characteristics and their interrelationship in Kabuli-type chickpea genotypes (Cicer arietinum L.). International Journal of Food Science and Technology. 2: 1-5.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal. 42: 421-428.

Lynch, J.M. and Whips, J.M. (1990). Substrate flow in the rhizosphere. Plant Soil. 129: 1-10.

Marschner, H.J. and Cakmak, I. (1989). High light intensity enhances chlorosis and necrosis in leaves of zinc, potassium and magnesium deficient bean (Phaseolus vulgaris) plants. Journal of Plant Physiology. 134: 924-934.

Melah, S., Madejón, E., Ruiz, J.C. and Herencia, J.F. (2007). Chemical and biochemical properties of a clay soil under dryland agriculture system as affected by organic fertilization. European Journal of Agronomy. 26 (3): 327-334.

Miraj, G., Shah, H.U. and Arif, M. (2013). Priming maize (Zea mays) seed with phosphate solutions improves seedling growth and yield. Journal of Animal and Plant Sciences. 23: 893-899.

Mullah, M.Z., Sultan, S., Rahman, M.A., Fardous, Z., Islam, M.N., Choudhary, T.R. (2015). Effect of Zn fertilizer on soil status after rice cultivation. International Journal of Soil Science and Agronomy. 2: 67-73.

Munir, T., Rizwan, M., Khashif, M., Shahzad, A., Ali, S., Amin, N., Zahid, R., Alam, M.F.E. and Imran, M. (2018). Effect of zinc oxide nanoparticles on the growth and Zn uptake in wheat (Triticum aestivum L.) by seed priming method. Digest Journal Nanomaterials Biostructures. 13(1): 315-323.

Nargis, S. (1995). Influence of pelleting, magnetic treatment and radiation on the performance of differently aged seeds in tomato (Lycopersicon esculentum Mill), cv. PKM-1. M.Sc. (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore. 124p.

Peterhalmer, (2003). Enhancing seed performance for better yield and quality. Asian Seed Plant Material. 10: 4-6.

Pooniya, V. and Shivay, Y.S. (2013). Enrichment of basmati rice grain and straw with zinc and nitrogen through ferti-fortification and summer green manuring under indo-gangetic plains of India. Journal of Plant Nutrition. 36(1): 91-117.

Raj, A.B., Raj, S.K., Prathapan, K. and Radhakrishnan, N.V. (2020). Nutripriming with zinc sulphate and borax for early growth and seedling vigour in grain cowpea [Vigna unguiculata (L.) Walp]. Legume Research. 43(2): 258-262.

Rehman, H., Bara, S.M.A. and Farooq, M. (2011). Filed appraisal of seed priming to improve the growth, yield and quality of direct seeded rice. Turkish Journal of Agriculture and Forestry. Doi:10.3906/tar-1004-954.

Rakin, E. (2012). Organic carbon organic matter and bulk density relationships in arid-semi arid soils in Southeast Anatolia region. African Journal of Biotechnology. 11(6): 1373-1377.

Scott, J.M. (1989). Seed coatings and treatments and their effects on plant establishments. Advances in Agronomy. 42: 43-83.

Sinha, P., Jain, R. and Chatterjee, C. (2000). Interactive effect of zinc and boron on growth and physiological seed enhancements. Seed Science Technology. 43(2): 238-249.
Influence of Seed Invigouration Treatments on Nutrient Uptake and Soil Nutrient Status of Grain Cowpea (Vigna unguiculata...