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

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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 $ZnSO_4$ 0.05 per cent for 4h 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 seed primed in $ZnSO_4$ 0.05 per cent for 4 h + *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 $ZnSO_4$ 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*, $ZnSO_4$.

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 $ZnSO_4$ 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

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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, Balaramapuram, 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 Bhagyalakshmy. The experiment comprised of 9 treatments replicated thrice. The design adopted for the study was randomized block design (RBD). The treatments were: T_1 (seed pelleting with borax 50 mg kg^{-1} seed), T_2 (seed pelleting with borax 100 mg kg^{-1} seed), T_3 (seed priming with $ZnSO_4$ 0.025 per cent for 4 h), T_4 (seed priming with $ZnSO_4$ 0.05 per cent for 4 h), T_5 (T_1 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed), T_6 (T_2 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed), T_7 (T_3 + *Trichoderma viride* seed treatment@ 10 g kg^{-1} seed),T_8 (T_4 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed) and a control (T_9). 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 $ZnSO_4$ 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 azometine-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 T_4 (seed priming with $ZnSO_4$ 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 T_4 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 $ZnSO_4$ priming registered higher Zn uptake by the grain. In the present experiment, cowpea seeds primed in $ZnSO_4$ 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

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

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Grain	Haulm	Total uptake	Grain	Haulm	Total uptake	Grain	Haulm	Total uptake
T_1: Seed pelleting with borax 50 mg kg^{-1} seed	46.69	45.40	92.10	13.48	15.10	28.59	29.56	32.96	62.52
T_2: Seed pelleting with borax 100 mg kg^{-1} seed	43.37	43.70	87.07	17.02	15.79	32.82	30.58	29.74	60.32
T_3: Seed priming with $ZnSO_4$ 0.025 per cent for 4 h	44.31	43.94	88.25	14.88	15.64	30.53	30.35	32.43	62.78
T_4: Seed priming with $ZnSO_4$ 0.05 per cent for 4 h	49.43	46.96	96.38	14.73	20.83	35.56	31.17	32.53	63.70
T_5: T_1 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	47.49	32.50	79.99	11.84	10.99	22.83	28.67	23.18	51.85
T_6: T_2 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	47.81	40.42	88.23	12.38	17.28	29.66	29.48	28.74	58.22
T_7: T_3 + *Trichoderma viride* seed treatment@ 10 g kg^{-1} seed	51.64	32.76	84.40	15.33	10.87	26.20	24.68	19.74	44.41
T_8: T_4 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	40.88	25.57	66.45	12.85	8.47	21.32	30.68	18.45	45.60
T_9: Control	32.83	18.48	51.31	8.28	6.41	14.69	16.47	16.94	33.41
SEm (±)	3.23	3.07	3.41	0.58	0.86	1.08	1.69	1.94	2.99
CD (0.05)	9.763	9.271	10.321	1.741	2.614	3.271	5.106	5.852	9.061

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 $ZnSO_4$ primed seeds than in borax pelleted seeds. Sinha *et al*. (2000) observed a positive Zn × B interaction in mustard.

Effect of seed invigouration 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 invigouration 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 invigouration 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 invigouration treatments, higher organic carbon content was observed in T_4 (seeds primed in $ZnSO_4$ 0.05 per cent 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_8 (T_1 + *Trichoderma viride* seed treatment 10 g kg seed^{-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 invigouration treatments (Table 3). Compared to control, all seed invigouration 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

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
T_1: Seed pelleting with borax 50 mg kg^{-1} seed	0.217	0.088	0.305	0.285	0.079	0.364
T_2: Seed pelleting with borax 100 mg kg^{-1} seed	0.217	0.077	0.294	0.346	0.073	0.419
T_3: Seed priming with $ZnSO_4$ 0.025 per cent for 4 h	0.221	0.090	0.310	0.279	0.097	0.376
T_4: Seed priming with $ZnSO_4$ 0.05 per cent for 4 h	0.213	0.102	0.315	0.307	0.104	0.410
T_5: T_1 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.206	0.082	0.289	0.282	0.078	0.360
T_6: T_2 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.221	0.087	0.308	0.301	0.088	0.389
T_7: T_3 + *Trichoderma viride* seed treatment@ 10 g kg^{-1} seed	0.216	0.094	0.310	0.215	0.083	0.298
T_8: T_4 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.236	0.093	0.329	0.245	0.112	0.356
T_9: 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)
T_1: Seed pelleting with borax 50 mg kg^{-1} seed	0.920	363.78	41.89	117.39	0.861	0.115
T_2: Seed pelleting with borax 100 mg kg^{-1} seed	0.976	338.69	48.63	125.77	0.577	0.140
T_3: Seed priming with $ZnSO_4$ 0.025 per cent for 4 h	0.977	363.78	37.95	135.41	1.237	0.057
T_4: Seed priming with $ZnSO_4$ 0.05 per cent for 4 h	1.018	376.31	35.70	131.60	1.484	0.073
T_5: T_1 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.883	319.27	38.37	128.50	1.199	0.088
T_6: T_2 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.864	329.59	38.51	127.23	0.808	0.088
T_7: T_3 + *Trichoderma viride* seed treatment@ 10 g kg^{-1} seed	0.852	329.78	29.09	149.14	1.912	0.051
T_8: T_4 + *Trichoderma viride* seed treatment 10 g kg^{-1} seed	0.896	338.69	27.64	146.37	2.223	0.080
T_9: 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

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 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 T_7 and T_8 (seeds primed in $ZnSO_4$ 0.025 and 0.05 per cent + *Trichoderma viride* seed treatment 10 g kg^{-1} seed) compared to other seed invigouration treatments which might be due to lower K uptake registered in these treatments.

Seed invigouration 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 invigouration 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 $ZnSO_4$ 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 $ZnSO_4$ @ 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 $ZnSO_4$ 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 $ZnSO_4$ @ 0.025 per cent for 4 h.

Conflict of interest

The authors declare that they have no conflicts of interest.

REFERENCES

Afzal, I., Noor, M.A., Bakhtavar, M.A., Ahmad, A. and Haq, Z. (2015). Improvement of spring maize performance through physical and physiological seed enhancements. Seed Science Technology. 43(2): 238-249.

Ajouri, A., Asgedom, 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., Sathyamoorthi, 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 the 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., Tuladahar, 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. (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.

Melero, 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 fertili--zation. 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., Sultana, 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., Kashif, 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. doi: 10.18805/LR-4099.

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.

Sakin, 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 boron and zinc on growth and metabolism of mustard. Communications in Soil Science and Plant Analysis. 31 (1 and 2): 41-49.

Slaton, N.A., Wilson, C.E., Ntamatungiro, S., Norman, R.J. and Boothe, D.L. (2001). Evaluation of zinc seed treatments for rice. Agronomy Journal. 93: 152-157.

Subbiah, B.V. and Asija, G.L.A. (1956). A rapid procedure for the estimation of available nitrogen in soil. Current Science. 25: 259-360.

Suman, B.M. (2018). Nutrient scheduling for upland rice intercropped in coconut (*Oryza sativa* L.). MSc. (Ag) thesis, Kerala Agricultural University, Thrissur, 154p.

Tabassum, D., Akhtar, A. and Inam, A. (2013). Effect of wastewater irrigation on growth, physiology and yield of mustard. International Journal of Botany and Research. 3: 27-34.

Thamburaj, S. (1991). Research Accomplishments in Tapioca at Tamil Nadu Agricultural University. In: Green Book on Tapioca. [Gupta, A.K. (Ed.)]. pp: 17.

Walkley, A.J. and Black, C.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. Soil Sci. 37: 29-38.

Wolf, B. (1971). The determination of boron in soil extracts, plant materials, compost, manure, water and nutrient solutions. Communications in Soil Science and Plant Analysis. 2: 363-374.