Environment and Ecology 42 (4) : 1570—1576, October—December 2024
Article DOI: https://doi.org/10.60151/envec/PELM1873
ISSN 0970-0420

Standardization of Various Chemical Seed Priming on Seed Quality Parameters in Black Gram (*Vigna mungo*)

A. Midhul Rana, G. Sathiyanarayanan

Received 11 March 2024, Accepted 25 August 2024, Published on 18 October 2024

ABSTRACT

Black gram is an important pulse crop in India. It is a major source of dietary protein for the poor people and provides nutritional security. It is mostly grown by the small and marginal farmers under resource constraints situation particularly in rainfed and rice fallow conditions. Seed priming is one such effective technology to achieve high growth, vigor, better stand establishment. The current study aimed to study the standardization of various chemical on crop growth in black gram. A laboratory experiment was conducted in Factorial Completely Randomized Design (FCRD) with three replications using various concentrations (1%, 2%, 3% and 4 %) as first factor and different durations (4 and 6 h) of priming as second factor and different chemicals such as $ZnSO_4$, $MnCl_2$, $MgSO_4$, $CaCl_2$, KCl and KNO_3 as third factor. Seeds were primed with different chemicals in different concentrations and in different duration evaluated for its quality parameters to find out suitable seed priming technique. Among all treatments seed priming with $ZnSO_4$ 1% for 6 hours recorded higher germination (98%), longest root length (22.17 cm), shoot length (19.15 cm), higher seedling dry matter production (0.93 g seedlings-10), fresh weight (8.93 g seedlings-10) and vigor index (4004) than control under laboratory experiment. The results indicate that use of $ZnSO_4$ 1% for 6 hours enhances the seed performance regarding seed quality characters.

Keywords Seed priming, Zinc sulphate, Seed quality.

A. Midhul Rana[1], G. Sathiyanarayanan[2]*

[1]PhD Scholar, [2]Associate Professor

[1,2]Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar 608002, India

Email: mailto:sathiyaa2005@gmail.com
*Corresponding author

INTRODUCTION

Black gram (*Vigna mungo* (L.) Hepper), is an important short duration pulse crop with chromosome number 2n=22. It is popularly known as urdbean. Black gram is a protein rich food, containing about 26% of protein, which is almost three times that of cereals. In India, it ranks fourth among the major pulses. It is a warm-season crop that thrives in tropical and subtropical regions, making it an essential component of the agriculture sector in countries such as India, Pakistan, Bangladesh and Myanmar. India is the world's largest producer as well as consumer of black gram (Raju 2019). In India, black gram is third most important pulse crop grown under rainfed, rice fallow, irrigated conditions and during *kharif, rabi* and summer seasons, which matures in 90-100 days and it enriches soil with nitrogen (Swaminathan *et al.* 2020). India produces about 24.5 lakh tonnes of Urd bean annually from about 4.6 million hectares of area, with an average productivity of 533 kg per hectare in 2020-21 (Anon 2020). Among the pulses, black gram is an important grain legume with protein having easily digestible and low flatulence content. It is highly rich in phosphoric acid. It contains about 25% protein, 56% carbohydrates, 2% fat, 4% minerals and 0.4% vitamins. According to Sathiya *et al.* (2017), the primary reasons for pulses low production include the use of inferior seed, poor crop management, and cultivation in dry, marginal soils. The important characteristics of black gram seed is, it loses the viability very shortly.

Seed priming is a controlled hydration process followed by drying of seeds, which allows the seeds to imbibe water and start internal biological processes essential for germination, but it does not allow the seed to germinate. In this technique radical emergence does not occur but germination processes start. Seed priming found effective for legumes, the yields of legume crops were enhanced considerably by priming seeds before sowing. In addition to hydration, priming also reduces the sensitivity of seed to external environmental factors (Afzal *et al.* 2016). During seed priming various physiological and biochemial changes takes place in seeds which favors germination and increased antioxidant activities and improved repair process. Hydration- dehydration treatment reduces the membrane damage and it maintains mitochondrial function. The effectiveness of hydration and dehydration treatment in maintenance of vigor and viability of seed. Seed priming with chemicals is one of the best treatments to control the deterioration process. It contains antioxidants, such that it controls seed deterioration process. Hence the present study was undertaken to study the effect of various chemical seed priming on seed quality.

MATERIALS AND METHODS

Genetically pure seeds of black gram (*Vigna mungo*) cv VBN 8 obtained from ICAR - Krishi Vigyan Kendra, Sandhiyur, Salem served as the base material for the study. Laboratory experiments were conducted at Seed Science and Technology Laboratory, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University.

Treatment details:

T_0 - Control
T_1 - Chemical priming with $ZnSO_4$ 1%, 2%, 3%, 4%
T_2 - Chemical priming with $MnCl_2$ 1%, 2%, 3%, 4%
T_3 - Chemical priming with $MgSO_4$ 1%, 2%, 3%, 4%
T_4 - Chemical priming with $CaCl_2$ 1%, 2%, 3%, 4%
T_5 - Chemical priming with KCl 1%, 2%, 3%, 4%
T_6 - Chemical priming with KNO_3 1%, 2%, 3%, 4%

Soaking duration: D1- 4h, D2- 6h.

After cleaning and grading, the seeds were soaked in respective priming solutions at different volume of seeds for four and six hours. Then the seeds were air dried under the shade to bring back to their original moisture content and used for sowing. The primed seeds were evaluated for the following seed quality characters i.e., germination percentage (%), root length (cm), shoot length (cm), fresh weight (g seedlings-10), dry weight (g seedlings -10), vigor index along with unprimed seeds. The experiment was carried out with four replications in Factorial Completely Randomized Design (FCRD).

RESULTS AND DISCUSSION

In the present study, the primed seeds showed better germination pattern and high vigor level than non-primed seeds. Seed priming boosts the imbibition and metabolic processes resulting in enhanced seed germination, germination uniformity, and seedling growth and development in both normal and stress conditions (Nayban *et al.* 2017).

$ZnSO_4$, which is made up of Zn^{+2} and SO_4^{-2} ions. Zinc ion plays multiple role in plant such as stem elongation, root development, synthesis of starch, protein, and auxin hormone. Second ion of $ZnSO_4$ is SO_4^{-2} ion, which plays important role in sulfur uptake and the assimilation into cysteine amino acid.

Table 1. Effect of various chemical seed priming on germination (%) of black gram seeds.

Treatment	4 hrs 1%	2%	3%	4%	Mean	6 hrs 1%	2%	3%	4%	Mean	B×C interaction 1%	2%	3%	4%	Grand mean
T_0	85	83	86	85	85	85	84	87	85	86	88	87	88	89	87
T_1	91	89	94	86	90	**98**	**95**	90	92	93	89	93	94	87	91
T_2	86	90	96	92	91	86	96	92	89	92	86	92	93	91	92
T_3	88	85	92	95	90	91	86	96	89	91	90	85	94	93	90
T_4	93	87	91	85	89	95	91	86	88	90	95	89	88	87	89
T_5	86	94	91	88	88	96	91	86	88	89	91	93	88	88	90
T_6	91	94	85	88	90	86	94	97	87	91	94	93	87	90	91
Mean	89	90	91	89	89	92	93	90	89	91	90	89	90	89	90

	T	C	D	TC	CD	TD	TCD
SEd	0.39	0.32	0.22	0.76	0.45	0.55	1.10
CD (p=0.05)	0.77	0.63	0.44	1.54	0.89	1.09	2.18
CD (p=0.01)	1.02	0.83	0.59	2.04	1.18	1.44	2.88

The identification of the salient feature of SO_4^{-2} ion for plant growth, development and vigor and crop yield, as well as the nutritional feature of sulfur for human and animal's diets. Zinc plays an important role in nucleic acid and protein synthesis and helps in utilization of phosphorus and nitrogen in seed formation and development. The second phase of seed development requires adequate amount of zinc dependent upon auxin for seed development.

Zinc sulphate superiority is probably due to role of zinc ion in synthesis of protein, function of cell membrane and elongation of cells. The improvement in germination, seedling growth and vigor index brought about by zinc as a priming agent at optimum concentration might be due to its action during early stages of seedling development. But higher concentration of zinc has detrimental effects as it suppresses cell division in meristematic cells. From the present study it was noticed that increase in concentration of zinc sulphate beyond 1% showed negative effect on seed quality parameters.

Among the various chemical priming, germination percentage was highest for $ZnSO_4$ 1% (6 hrs) primed seeds recorded 98% followed by KNO_3 3% (97%) (6hrs) and the lowest value was recorded for control 2% (84%) (6 hrs) (Table 1). Plants take up zinc as a divalent cation (Zn^{2+}) from the soil. It is a strong nutrient for plant growth and development

Table 2. Effect of various chemical seed priming on dry weight (g seedling $^{-10}$) of black gram seeds.

Treatment	4 hrs 1%	2%	3%	4%	Mean	6 hrs 1%	2%	3%	4%	Mean	B×C interaction 1%	2%	3%	4%	Grand mean
T_0	0.60	0.61	0.58	0.59	0.69	0.71	0.62	0.63	0.77	0.71	0.60	0.68	0.77	0.71	0.69
T_1	0.79	0.69	0.86	0.62	0.74	**0.93**	0.83	0.80	0.75	0.81	0.72	0.80	0.86	0.68	0.77
T_2	0.68	0.87	0.89	0.79	0.78	0.64	0.89	0.81	0.73	0.77	0.64	0.79	0.85	0.76	0.76
T_3	0.67	0.61	0.77	0.87	0.73	0.84	0.63	0.90	0.74	0.76	0.76	0.63	0.84	0.81	0.75
T_4	0.88	0.71	0.80	0.65	0.76	0.65	0.91	0.84	0.74	0.79	0.90	0.77	0.72	0.70	0.77
T_5	0.64	0.70	0.83	0.76	0.77	0.89	0.83	0.68	0.73	0.75	0.79	0.85	0.72	0.74	0.78
T_6	0.78	0.86	0.61	0.68	0.73	0.82	0.92	0.65	0.75	0.78	0.85	0.84	0.63	0.71	0.76
Mean	0.74	0.72	0.80	0.73	0.74	0.81	0.82	0.74	0.74	0.77	0.75	0.77	0.77	0.73	0.75

	T	C	D	TC	CD	TD	TCD
SEd	0.008	0.007	0.005	0.017	0.010	0.012	0.024
CD (p=0.05)	0.016	0.014	0.010	0.034	0.020	0.024	0.048
CD (p=0.01)	0.022	0.018	0.013	0.045	0.026	0.032	0.063

Table 3. Effect of various chemical priming on fresh weight (g seedling^{-10}) of black gram seeds.

	4 hrs					6 hrs					B×C interaction				Grand
Treatment	1%	2%	3%	4%	Mean	1%	2%	3%	4%	Mean	1%	2%	3%	4%	mean
T_0	7.10	6.87	6.73	6.33	6.85	6.88	7.15	6.41	6.76	6.89	7.99	6.71	7.71	6.62	7.33
T_1	6.49	6.88	8.43	7.79	7.36	**8.93**	8.89	8.22	7.82	8.10	7.68	8.15	8.55	7.19	7.89
T_2	8.42	7.40	8.87	6.74	7.86	6.81	8.76	7.86	7.13	7.54	6.37	7.82	8.15	7.46	7.45
T_3	6.79	6.25	7.66	8.60	7.32	8.43	6.99	8.91	7.82	8.04	7.61	6.62	8.28	8.21	7.68
T_4	7.95	6.65	6.96	6.36	6.98	6.94	8.90	7.05	7.65	7.93	8.43	7.54	7.01	7.09	7.52
T_5	6.54	8.67	7.73	7.09	7.51	8.66	7.91	6.53	7.31	7.60	7.60	8.29	7.13	7.20	7.55
T_6	7.92	8.58	6.53	7.16	7.54	8.70	8.09	6.95	7.62	7.84	8.31	8.33	6.72	7.39	7.69
Mean	7.32	7.40	7.69	7.29	7.35	8.01	8.18	7.59	7.56	7.71	7.71	7.63	7.65	7.31	7.58

	T	C	D	TC	CD	TD	TCD
SEd	0.06	0.05	0.04	0.13	0.07	0.09	0.19
CD (p=0.05)	0.12	0.10	0.08	0.26	0.15	0.18	0.37
CD (p=0.01)	0.17	0.14	0.10	0.34	0.20	0.24	0.49

also functions as a co-factor of various enzymes such as Cu-Zn superoxide dismutase, RNA polymerase, alcohol dehydrogenase, carbonic anhydrase (Aboutalebian and Nazari 2017). It is an important structural, functional and regulatory co-factor of various enzymes which help to increase the activity of biochemical and physiological mechanisms in plants. Zn is an important component for the metabolism of carbohydrates and auxins, protein synthesis. The probable reason for higher germination in 1% $ZnSO_4$ primed seeds could be due to greater hydration of colloids, higher viscosity and elasticity of protoplasm, increase inbound water content, lower water deficit, more efficient root system and increased metabolic activity (Raj *et al.* 2019). Similar results were found in Sen and Puthur (2020) in *Oryza* crop, Hussain *et al.* (2016) in rice, Vanitha and Kathiravan (2019) in pigeonpea.

For dry weight, seeds primed with $ZnSO_4$ 1% recorded higher value 0.93g seedling-10 for 6 hours followed by KNO_3 2% (0.92 g seedling-10) (6 hrs) and the least value were recorded for control 2% (6 hrs) (0.62 g seedling-10) (Table 2). Similarly, for fresh weight $ZnSO_4$ 1% recorded higher value (8.93 g seedling-10) for 6 hours and control recorded lowest value (6.41 g seedling-10) (Table 3). $ZnSO_4$ as a constituent of dehydrogenase enzyme, an activator of

Table 4. Effect of various chemical priming on root length (cm) of black gram seeds.

	4 hrs					6 hrs					B×C interaction				Grand
Treatment	1%	2%	3%	4%	Mean	1%	2%	3%	4%	Mean	1%	2%	3%	4%	mean
T_0	18.25	19.32	20.81	20.04	19.69	19.65	18.46	18.54	18.32	19.56	20.32	19.82	18.76	19.32	19.89
T_1	20.14	19.35	19.49	18.63	19.76	22.17	19.94	21.47	20.76	21.10	20.04	20.76	21.19	19.69	20.42
T_2	20.56	20.71	20.92	19.28	19.77	19.82	21.92	21.24	20.57	20.89	19.21	20.62	21.03	20.30	20.29
T_3	19.33	18.59	20.09	20.71	19.68	20.95	19.67	21.71	20.18	19.97	20.14	19.13	20.90	20.45	20.15
T_4	20.90	19.40	20.13	18.62	19.75	21.34	21.96	19.76	20.53	20.90	21.43	20.37	19.95	19.58	20.33
T_5	18.57	20.71	19.88	19.24	19.60	21.68	20.86	19.61	19.97	20.53	20.12	20.78	19.74	19.61	20.06
T_6	19.58	20.43	18.60	18.75	19.25	21.87	21.19	19.63	20.49	20.80	20.72	20.81	18.94	19.62	20.02
Mean	19.52	19.63	20.01	19.33	19.64	21.04	20.57	20.57	20.42	20.53	20.28	20.32	20.07	19.79	20.16

	T	C	D	TC	CD	TD	TCD
SEd	0.07	0.05	0.04	0.14	0.08	0.10	0.20
CD (p=0.05)	0.14	0.11	0.08	0.28	0.16	0.20	0.40
CD (p=0.01)	0.18	0.15	0.10	0.37	0.21	0.26	0.52

other enzymes, and a constituent for the biosynthesis of IAA and amino acid that favored the synthesis of protein. Sulfur in $ZnSO_4$ also increased the levels of vitamins, biotins, and thiamin and its coenzymes in seeds and increased the growth rate of seedlings (Kavitha and Srimathi 2020). Likewise, due to the active participation in seed physiology, $ZnSO_4$ might have increased the seedling growth, dry matter production. Similar results were found in Sen and Puthur (2020) in *Oryza* crop, Hussain *et al.* (2016) in rice, Vanitha and Kathiravan (2019) in pigeonpea, Mahmood *et al.* (2019) in chickpea.

For root length, seeds primed with $ZnSO_4$ 1% recorded higher value for 6 hours (22.17 cm) followed by $CaCl_2$ 2% (21.96 cm) and control recorded lowest value 4% (18.32 cm) (Table 4). Similarly for shoot length, seeds primed with $ZnSO_4$ 1% recorded higher value (19.15 cm) (6 hrs) followed by $CaCl_2$ 2% (19.10 cm) and control recorded lowest value 4% (16.90 cm) (Table 5). The shoot and root length are fundamental parameters, because roots absorb water and essential nutrients from the soil by having direct contact with it. Whereas, shoot transport the nutrients as well as water to the rest of the plant body. Reason for increasing root length of plants grown from seeds primed with $ZnSO_4$ could be the result of extensibility in cell wall of the embryo. Seed priming treatment caused enhanced in the activity of ROS (reactive oxygen species) scavenging enzymes in order to enhance the plant strength and viability. Same researcher also reported that seed priming with $ZnSO_4$ solution decreased the resistance mechanism of endosperm envelope against growth permitting turgor threshold for germination as compared to non-primed seeds resulting increased shoot and root length (Kavitha and Srimathi 2020). In another study, primed seeds show early seed vigour and significantly enhanced shoot and root length, as a result heavier seedlings production occur due to increased activity of α amylase enzyme (Ullah *et al.* 2019). Similar results were found on seed priming effect on growth parameters of maize, it has been revealed that $ZnSO_4$ seed priming treatment influenced positively shoot and root length of maize and pulses (Ambika and Balakrishnan 2015). Similar results were found in Sen and Puthur (2020) in *Oryza* crop, Hussain *et al.* (2016) in rice, Vanitha and Kathiravan (2019) in pigeonpea.

For vigor index, seeds primed with $ZnSO_4$ 1% (4004) recorded highest value followed by $CaCl_2$ 2% (3983) and lowest value recorded by control 4% (3107) (Table 6). The increased vigor index observed in this treatment might be due to greater early vigor and a higher percentage of germination of the seeds that had reached the autotropic stage well in advance than others. Zinc induced betterment of growth, yield, and seedling establishment could be justified by the role of zinc in enzymatic activities associated with auxin metabolism. Zinc plays a crucial role in the

Table 5. Effect of various chemical priming on shoot length (cm) of black gram seeds.

	4 hrs					6 hrs					B×C interaction				Grand
Treatment	1%	2%	3%	4%	Mean	1%	2%	3%	4%	Mean	1%	2%	3%	4%	mean
T_0	16.35	17.45	17.85	16.27	16.56	17.67	18.54	17.40	16.90	17.21	16.45	17.11	16.80	17.38	16.91
T_1	16.53	16.92	17.91	17.33	16.89	19.15	17.20	18.54	17.85	18.17	17.52	18.15	18.58	17.26	17.88
T_2	17.28	17.91	18.62	16.67	17.62	16.96	19.01	18.37	17.60	17.98	16.75	17.96	18.14	17.47	17.58
T_3	17.84	16.74	17.19	18.49	17.58	18.38	16.99	19.09	17.71	18.04	17.83	16.86	18.50	18.10	17.82
T_4	18.39	16.94	17.62	16.49	17.36	18.47	19.10	17.34	17.81	18.11	18.75	17.70	17.34	17.15	17.73
T_5	16.61	18.47	17.88	17.21	17.54	18.89	18.40	16.94	17.74	17.99	17.75	18.44	17.41	17.47	17.77
T_6	17.78	18.32	16.62	17.81	17.48	18.78	17.89	17.05	17.23	17.70	18.28	18.11	16.76	17.20	17.59
Mean	17.38	17.43	17.49	17.23	17.38	18.22	17.51	17.82	17.66	17.88	17.62	17.76	17.64	17.43	17.61

	T	C	D	TC	CD	TD	TCD
SEd	0.06	0.05	0.03	0.12	0.07	0.08	0.17
CD (p=0.05)	0.12	0.10	0.07	0.24	0.14	0.17	0.33
CD (p=0.01)	0.16	0.13	0.09	0.31	0.18	0.22	0.44

Table 6. Effect of various chemical priming on vigour index of black gram seeds.

Treatment	4 hrs 1%	2%	3%	4%	Mean	6 hrs 1%	2%	3%	4%	Mean	B×C interaction 1%	2%	3%	4%	Grand mean
T_0	3210	3165	3412	2964	3297	3854	3554	3302	3107	3461	3421	3633	3272	3111	3394
T_1	3033	3250	3652	3449	3346	**4004**	3941	3747	3359	3596	3325	3628	3746	3203	3475
T_2	3469	3253	3764	3047	3378	3164	3930	3631	3397	3530	3098	3590	3642	3423	3438
T_3	3210	2990	3484	3742	3362	3592	3153	3917	3372	3508	3401	3072	3701	3568	3435
T_4	3654	3174	3436	2985	3312	**3983**	3623	3130	3375	3528	3819	3399	3283	3180	3420
T_5	3025	3722	3449	3207	3351	3881	3560	3119	3319	3470	3453	3641	3284	3263	3410
T_6	3400	3643	2979	3162	3292	3182	3700	3264	3470	3576	3674	3671	3114	3216	3443
Mean	3299	3339	3455	3269	3340	3624	3662	3468	3382	3534	3455	3519	3435	3280	3422

	T	C	D	TC	CD	TD	TCD
SEd	21.32	17.41	12.31	42.64	24.62	30.15	60.30
CD (p=0.05)	42.32	34.55	24.43	84.64	48.87	60.85	119.70
CD (p=0.01)	56.03	45.75	32.34	112.06	64.69	79.23	158.48

efficiency of growth regulation as a structural component and cofactor (Rudani *et al.* 2018). Mallikarjuna *et al.* (2020) have given molecular evidences about direct correlation of zinc availability of plants with regulation of ethylene, auxin, gibberellins, and cytokinin like growth regulators hence implying the role in growth and development of plants. Similar results were found in Hussain *et al.* (2016) in rice, Vanitha and Kathiravan (2019), in pigeonpea.

Significant differences were observed due to seed priming treatments, concentration and soaking durations in a variety Black gram VBN 8. Between the soaking durations, $ZnSO_4$ 1% 6h recorded higher germination (98%), longest root length (22.17 cm), shoot length (19.15 cm), higher seedling dry matter production (0.93g seedlings-10), fresh weight (8.93g seedlings-10) and vigour index (4004) whereas 4h recorded (96%, 20.91cm, 18.62 cm, 0.89 g seedlings -10, 8.87 g seedlings -10, 3764).

CONCLUSION

Thus, the standardization of various chemical priming seed treatment on seed quality in Black gram cv VBN 8 revealed that $ZnSO_4$ 1% concentration for 6 hours recorded the higher seeds quality when compared to other treatments and control.

REFERENCES

Aboutalebian MA, Nazari S (2017) Seedling emergence and activity of some antioxidant enzymes of canola (*Brassica napus*) can be increased by seed priming. *The Journal of Agricultural Science* 155(10):1541–1552.

Afzal I, Rehman HU, Naveed M, Basra SMA (2016) Recent advances in seed enhancements. In New challenges in seed biology-basic and translational research driving seed technology. Intech Open Science, pp 47–74. http://dx.doi.org/10.5772/64791

Ambika S, Balakrishnan K (2015) Enhancing germination and seedling vigor in cluster bean by organic priming. *Scientific Research and Essays* 10: 298–301.

Anonymous (Agricultural Statistics at a Glance 2020) Directorate of Economics & Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Govt of India, New Delhi.

Hussain S, Khan F, Hussain HA, Nie L (2016) Physiological and biochemical mechanisms of seed priming-induced chilling tolerance in rice cultivars. *Frontiers in Plant Science* 7:116.

Kavitha S, Srimathi P (2020) Influence of seed priming with micro- nutrients followed by rhizobium seed coating on seed vigor, crop growth and seed yield in redgram cv VBN 3. *Journal of Pharmacognosy and Phytochemistry* 9(5): 563-567.

Mahmood A, Kanwal H, Kausar A, Ilyas A, Akhter N, Ilyas M, Nisa Z, Khalid H (2019) Seed priming with zinc modulate growth, pigments and yield of chickpea, under water deficit conditions. *Applied Ecology and Environmental Research* 17(1):147-160.

Mallikarjuna MG, Thirunavukkarasu N, Sharma R (2020) Comparative transcriptome analysis of iron and zinc deficiency in maize (*Zea mays* L.). *Plants* 9 (12): 1812.

Nayban G, Mandal AK, De BK (2017) Seed priming: A low-cost-climate-resilient tool for improving germination, growth and productivity of mungbean. *SATSA Mukhaptra Annual Technical Issue* 21:162–172.

Raj AB, Raj SK, Prathapan K, Radhakrishnan NV (2019) Nutri-priming with zinc sulphate and borax for early growth and seedling vigour in grain cowpea (*Vigna unguiculata* (L.) Walp). *Legume Research* 43: 258-262.

Raju M (2019) Study on constraints and adoption of black gram seed production technologies by farmers of Cauvery delta zone of Tamil Nadu. *Journal of Pharmacognosy and Phytochemistry* 8: 1031 - 1035.

Rudani K, Patel V, Kalavati P (2018) The importance of zinc in plant growth- review. *International Research Journal of Natural and Applied Sciences* 5 (2): 38–48.

Sathiya G, Prakash M, Kumar R (2017) Effect of integrated seed treatments on growth, seed yield and quality parameters in black gram (*Vigna mungo* (L.) Hepper). *Indian Journal Agricultural Research* 51(6): 556-561.

Sen A, Puthur JT (2020) Influence of different seed priming techniques on oxidative and antioxidative responses during the germination of *Oryza sativa* varieties. *Physiology and Molecular Biology of Plants* 26: 1–15.

Swaminathan C, Surya R, Subramanian E, Arunachalam P (2020) Challenges in pulses productivity and agronomic opportunities for enhancing growth and yield in black gram (*Vigna mungo* (L.) Hepper): A review. *Legume Research - An International Journal,* pp 1-9.

Ullah AA, Farooq M, Hussain M, Ahmad R, Wakeel A (2019) Zinc seed priming improves stand establishment, tissue zinc concentration and early seedling growth of chickpea. *The Journal of Animal and Plant Sciences* 29(4): 1046-1050.

Vanitha C, Kathiravan M (2019) Response of pigeonpea to season, halopriming and plant bioregulators intervention in relation to plant physiology and yield potential. *Indian Journal of Agricultural Research* 53 (2): 190-195.