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Research Article

Seed priming with different levels and sources of zinc on the seed germination and seedling growth of barnyard millet (*Echinocola frumentacea*)

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Abstract
Seed priming with zinc increases the seed germination and seedling growth of many crops. The present study aimed to investigate the effect of seed priming with different levels and sources of zinc on seed germination and seedling growth of barnyard millet variety MDU1. A germination experiment was conducted with various Zn sources and concentrations viz., T_1- Non-primed seeds (control); T_2-water priming; T_3-GA_3 priming; T_4-T_6: seed priming with 0.10%, 0.25% & 0.50% $ZnSO_4$; T_7- T_9: seed priming with 0.10%, 0.25% & 0.50% Zn EDTA; T_{10}-T_{12}: seed priming with 0.10%, 0.25% & 0.50% Zn citrate and the experimental design was a completely randomized design (CRD) which were replicated five times. The seeds of MDU1 variety were treated with different sources and levels of Zn for 12h and the seed germination study was carried out for 15 days. After 15 days, the germination percentage, speed of germination, germination energy, germination index and the seedling growth parameters such as, root length, shoot length, vigour index and seedling dry weight were recorded. Seed priming with 0.50% $ZnSO_4$ performed better in increasing the germination percentage (99%), speed of germination (76.2%), germination energy (69.4%), germination index (3.91) and seedlings growth parameters like shoot length (14.7cm), root length (16.5cm), seedlings dry weight (0.44g), vigour index I (3099) and II (44.6), Zn content (21.9 mg kg^{-1}) & its uptake (5.54 mg g^{-1}). This was closely followed by seed priming of Zn EDTA at 0.25% and Zn citrate at 0.50%. From this study, it can be concluded that seed priming with 0.50% $ZnSO_4$ could be used to improve the germination and seedling growth of barnyard millet which was also economical.

Keywords: Barnyard millet, Germination, Seed priming, Seedling growth parameters, Zn sources and levels

INTRODUCTION

Barnyard millet (*Echinochloa* spp.) is an important millet crop grown in subtropical India, Japan, and China as a substitute for rice under natural precipitation. It is the fastest-growing millet, produces a crop in a short period of time and is known for its good yield and high nutritional value. It is also a highly digestible protein source and an excellent source of dietary fibres. The grain contains high protein (15.1%), fat (3.20-9.84%), crude fibre (5.35-7.90%), total mineral (2.02%) and total carbohydrate (68.8%, Trivedi *et al*., 2017). Barnyard millet is considered as 'Nutri cereal' for food, feed and fodder and is the fourth most produced minor millet worldwide.

Although barnyard millet is nutritionally superior to other cereals, its utilization is very limited due to the presence of anti-nutrients like phytates, polyphenols and tannins which reduce the bioavailability of micronutrients, particularly Zn and Fe, by chelation (Chandel *et al.,* 2014, Renganathan and Vanniyarajan, 2018).

Zinc is one of the important micronutrient essential for the completion of plant life cycle, being found in all enzymes related to the metabolism of plants and also increases the biosynthesis of chlorophylls and carotenoids, stimulating the photosynthetic system in plants. It is a precursor for the important amino acid tryptophan involved in auxin synthesis and is responsible for plant growth and development. Further, Zn content in barnyard millet is also comparatively lesser (1.5 to 7.5 mg 100 g^{-1}). Hence increasing the grain zinc content is essential to improve the dietary requirement of human beings to address malnutrition issues (Neto and Michel, 2020).

Seed priming is considered to be a prominent strategy that improves seedling establishment by increasing the pre-gemination metabolic activity resulting in a better germination rate and plant growth (Farooq *et al*., 2019). Priming increases the weight of utilized seed reserve and seedling dry weight as compared to non-primed seeds. The vigor enhancement by hormones as priming agents might be due to increased cell division within the apical meristem of the seedling root, which caused an increase in seedling growth (Maasoumeh *et al.,* 2014). In the last two decades, seed priming, an effective seed invigoration method, has become a common seed treatment technique to increase the rate and uniformity of seedling emergence. Priming is a method which improves the seed performance under stress conditions and allows the metabolic processes necessary for germination. In priming, seeds are soaked in different solutions with high osmotic potential, which prevents the seeds from absorbing enough water for radicle protrusion, thus suspending the seeds in the lag phase. Seed priming is widely recommended as pre-sowing seed treatment, proven for its beneficial effect and also is a technique of controlled hydration (soaking in water) which results in more rapid germination. This technique also enhances the seed quality and improving the overall germination and seed storage in a wide range of crop species (Balaji and Narayana, 2019). Good germination is very important for small millets. Uneven seedling growth and poor germination leads to great crop loss. Primed seeds emerge faster and grow vigorously, permitting early DNA replications, increasing RNA replication, enhancing embryo growth, repairing deteriorated seed parts, and reducing metabolite leakage (Iswariya *et al.,* 2019). In this context, an attempt was made to study the effect of seed priming of different sources and levels of Zn on seed germination and seedling growth of barnyard millet (MDU1)

MATERIALS AND METHODS

A germination study was conducted in the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University (TNAU), Coimbatore, to study the effect of seed priming of various Zn sources and levels on the establishment and growth of barnyard millet. Genetically pure seeds of barnyard millet variety MDU1 were obtained from the Department of Plant Breeding and Genetics, AC&RI, Madurai. A known quantity of seeds (25 seeds) was treated with different zinc sources such as zinc sulphate, Zn EDTA and Zn citrate at varying concentrations (0, 0.10, 0.25 and 0.50%) along with GA_3 and water priming for 12 hours as standard check. After the expiry of time, seeds were shade dried until getting the optimal moisture content and the seeds were used for germination study by roll paper towel method. After 15 days, the seedlings were observed for seed germination and seedling growth

Table 1. Formulae used to determine selected seedling characteristics

S. No.	Formula	Reference
1.	Germination percentage = $\frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$	ISTA (2007)
2.	Speed of germination (%) = $\frac{\text{Number of seeds germinated at 72h}}{\text{Number of seeds germinated at 168 h}}$	Krishnaswai and Seshu (1990)
3.	Germination index (GI) = $\frac{\frac{\text{No. of seeds germinated in the first count}}{\text{Days of first count}} + \ldots + \text{No. of seed germinated in the final count}}{\text{Days of final count}}$	Association of Official Seed Analysis (AOSA,198)
4.	Vigor index I = Germination (%) x [Root length (cm) + Shoot length (cm)]	Abdul–Baki and Anderson (1973)
5.	Vigor index II = Germination (%) x Seedling dry weight (g)	

parameters. The experiment was conducted with two factors in a completely randomized design (CRD).

Seed priming with 12 treatments comprising different zinc sources and levels on barnyard millet was carried out and the treatment details were: T_1- Non-primed seeds (control); T_2-water priming; T_3-GA_3 priming; T_4-T_6 : seed priming with 0.10%, 0.25% and 0.50% $ZnSO_4$; T_7- T_9: seed priming with 0.10%, 0.25% and 0.50% Zn EDTA; T_{10}-T_{12}: seed priming with 0.10%, 0.25% and 0.50% Zn citrate. The observations were recorded at 10 and 15 days after germination and the seedlings were evaluated as normal seedlings, hard and dead. The germination indices, namely germination percentage, speed of germination, germination energy, Vigour index I and II were calculated using the formula given in Table 1. Germination energy was expressed as the percentage of seeds germinated at 72 h (Bam *et al*., 2006).

Five normal seedlings were selected randomly from each of the treatments and used for measuring all the parameters. Root length was measured from the collar region to the tip of the primary root and the mean values were calculated and expressed in centimeter. The shoot length was measured from the collar region to the tip of the primary leaves and the mean values were expressed in centimeters. For the dry weight of the seedling, the seedlings were dried in the shade for 24 h and kept in an oven maintained at 70^0C until getting constant weight. After the drying period, the seedlings were cooled in closed desiccator for 30 minutes, weighed and the mean was expressed as g per seedlings (Gupta, 1993).

The seedlings were digested with triple acid mixture (9:2:1 mixture of HNO_3: H_2SO_4: $HClO_4$) and the volume was made with double distilled water to measure the zinc content present in the seedlings using atomic absorption spectrophotometer (AAS, Model PM Avanta, Lindsay and Norvell, 1978). The Zn content and its uptake by the seedlings were determined after 15 days. The zinc uptake by the seedlings was calculated using zinc content present in the seedlings and seedlings' dry weight, which was expressed in mg g^{-1}.

Data analysis

The analysis of variance (ANOVA) was carried out to test the effect of treatments on the growth and development of barnyard millet. The data obtained from different components were statistically analyzed to find out the significance of the difference among the treatments. Mean comparison was performed using the least significant differences test (LSD) at P = 0.05 (Vanniarajan and Chandirakala, 2020).

RESULTS

Seed germination indices

There was a significant influence of treatments on the seed germination indices presented in Table 2. The maximum germination occurred on 15th day and statistically, the mean germination percentage ranged from 85-99.5%. The highest germination percentage was associated with the seed priming of 0.50% $ZnSO_4$ (99.2%) followed by 0.25% Zn EDTA (96.8%) and 0.50% Zn citrate (93.6%) as compared to unprimed seeds as control (88%). The seeds primed with 10 ppm GA_3 (93.6%) also showed a higher germination per-

Table 2. Effect of seed priming of different levels and sources of Zn on seed germination parameters of barnyard millet

Seed Priming treatments	Germination percentage (%)		Speed of germination (%)	
	10th day	15th day	10th day	15th day
T_1-Un primed seeds	76.8^f	88.0^f	51.3^f	49.1^f
T_2-Water primed	80.8^{de}	92.0^{de}	53.4^{ef}	51.5^{ef}
T_3-GA3 @10 ppm	84.0^{cd}	93.6^{cd}	56.4^{def}	53.2^{def}
T_4-Zinc sulphate - 0.10%	84.8^{bc}	96.8^{bc}	66.1^c	57.9^c
T_5-Zinc sulphate - 0.25%	86.4^{ab}	99.2^{ab}	73.2^a	63.6^a
T_6-Zinc sulphate - 0.50%	90.4^a	99.2^a	76.2^a	69.4^a
T_7-Zinc EDTA - 0.10%	79.2^{ef}	89.6^{ef}	63.6^c	57.4^c
T_8-Zinc EDTA - 0.25%	87.2^{ab}	96.8^{ab}	70.9^{ab}	65.6^{ab}
T_9-Zinc EDTA - 0.50%	86.4^{bc}	94.4^{bc}	65.4^{bc}	61.2^{bc}
T_{10}-Zinc Citrate - 0.10%	77.6^f	88.8^f	57.7^{de}	53.0^{de}
T_{11}-Zinc Citrate- 0.25%	79.2^{ef}	90.4^{ef}	62.8^{cd}	55.8^{cd}
T_{12}-Zinc Citrate - 0.50%	82.4^{cd}	93.6^{cd}	64.7^c	58.2^c
	SEd	CD (P=0.05)	SEd	CD (P=0.05)
T	1.51	3.01	2.50	4.96
D	0.62	1.23	1.02	2.03
TxD	2.14	4.25	3.54	7.02

*Values followed by the same letter within a column do not differ significantly (ANOVA, LSD test, P ≤ 0.05)

Table 3. Effect of Seed Priming of different levels and sources of Zn on germination energy and germination index of barnyard millet after 15 DAS

Seed priming treatments	Germination energy (%)	Germination index
T_1-Un primed seeds	50.8^{f}	3.39^{f}
T_2-Water primed	52.1^{ef}	3.55^{de}
T_3-GA3 @10 ppm	54.6^{def}	3.66^{cd}
T_4-Zinc sulphate - 0.10%	57.9^{bcde}	3.73^{bc}
T_5-Zinc sulphate - 0.25%	63.7^{ab}	3.81^{ab}
T_6-Zinc sulphate - 0.50%	69.4^{a}	3.91^{a}
T_7-Zinc EDTA - 0.10%	55.6^{cdef}	3.47^{ef}
T_8-Zinc EDTA - 0.25%	62.0^{bc}	3.79^{ab}
T_9-Zinc EDTA - 0.50%	61.0^{bcd}	3.73^{bc}
T_{10}-Zinc Citrate - 0.10%	50.4^{f}	3.42^{f}
T_{11}-Zinc Citrate- 0.25%	55.9^{cdef}	3.49^{ef}
T_{12}-Zinc Citrate - 0.50%	58.2^{bcde}	3.66^{cd}
SEd	3.430	0.062
CD (P=0.05)	6.898	0.125

Values followed by the same letter within a column do not differ significantly (ANOVA, LSD test, $P \leq 0.05$)

centage as compared to water priming (92%) and unprimed seeds (88%). The speed of germination ranged from 53.7- 80% and the highest speed of germination occurred with the seeds primed with 0.50% $ZnSO_4$ (76.2%) followed by 0.25% Zn EDTA (70.9%) and 0.50% Zn citrate (64.7%). The lowest germination speed was recorded in unprimed control (51.3%).

Table 3 explains the significant influence of treatments on the germination energy and germination index. The highest germination energy was found with seeds primed with 0.50% $ZnSO_4$ (69.4%) as compared to 0.25% Zn EDTA (62%)> 0.50% Zn citrate (58.2%). Gibberellic acid (GA3) priming showed higher germination energy (54.6%) than water priming (52.1%) and unprimed seeds (50.8%). The highest germination index was observed in seeds primed with 0.50% $ZnSO_4$ (3.91%) for 12 hrs as compared to 0.25% Zn EDTA (3.79%) and 0.50% Zn citrate (3.66%) seed priming. The lowest germination index was observed in unprimed seeds (3.39%) as compared to GA_3 priming (3.66%) and water priming (3.55%).

Seedlings growth parameters

The effect of seed priming on seedlings growth parameters is depicted in Table 4. The longest shoot length was observed in seeds primed with 0.50% $ZnSO_4$ (14.7cm) followed by 0.25% Zn EDTA (13.5 cm) and 0.50% Zn citrate (12.0 cm) and the shortest shoot was observed in unprimed seeds (9.71cm). The seeds primed with 10 ppm of GA_3 (10.9 cm) and water (10.2 cm) also showed considerable improvement in the shoot length compared to unprimed seeds but were lesser than those primed with various Zn sources. Similarly, the longest root length was recorded with seed priming of 0.50%, 0.25% and 0.50% with $ZnSO_4$ (16.5 cm), Zn EDTA (15.7cm) and Zn citrate (12.7cm), respectively. But the lowest root length of 10.8 cm was recorded in un-primed seeds, which showed the least performance when compared to GA_3 priming at 10 ppm (12.8 cm) and water priming (11.8 cm).

Fig. 1 explains the effect of seed priming on barnyard millet's seedling length and dry weight. The highest seedling length was observed with 0.50% $ZnSO_4$ seed priming (31.2 cm) followed by 0.25% Zn EDTA (29.2 cm) and 0.50% Zn citrate (25.5cm) and the poorest seedling length was recorded in unprimed seedlings (20.5 cm). The effect of seed priming with various levels and sources of Zn on the dry weight of seedlings showed that, the highest dry weight was observed in 0.50% $ZnSO_4$ (0.44g) seed priming, followed by 0.25% Zn EDTA (0.43g) and 0.50% Zn citrate (0.41g) as compared to un-primed seeds (0.34 g).

Seedling vigor

The effect of seed priming treatments on seedling vigor is presented in Fig. 2 and the vigor index was calculated using the seedling length and seedling dry weight. The highest vigor index I was observed with the seed priming of 0.50% $ZnSO_4$ (3099) followed by 0.25% Zn EDTA (2836), and 0.50% Zn citrate (2392). The poorest performance of barnyard millet seedlings was observed in unprimed control (1805). The vigor index II was calculated using the seedling dry weight and the highest index was observed with 0.50% $ZnSO_4$ priming (44.6),

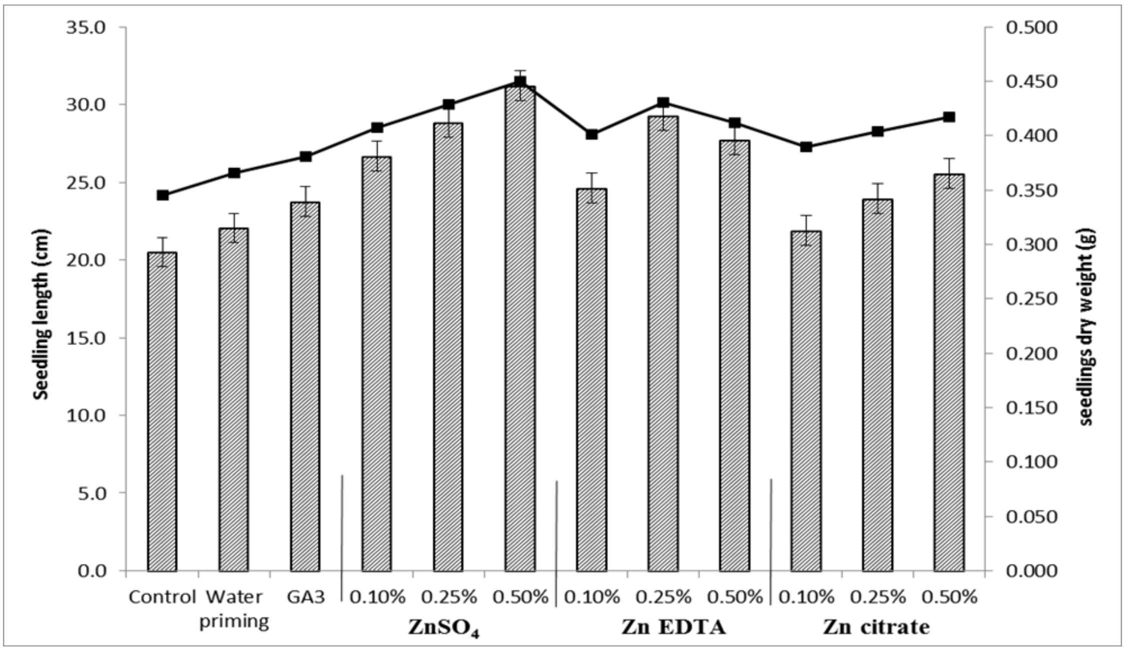

Fig.1. *Seed Priming of different levels and sources ofZn on total seedling length and seedling dry weight of barnyard millet (Error bars indicate standard error)*

followed by 0.25% Zn EDTA (41.7) and 0.50% Zn citrate (39.0) as compared to unprimed control (30.4).

Zn content and Zn uptake

The effect of seed priming on Zn content and its uptake by the barnyard millet seedlings calculated on 15th day are presented in table 5. The highest zinc content was associated with the seed priming of 0.50% $ZnSO_4$ (21.9 mg kg^{-1}), followed by 0.25% Zn EDTA (19.8 mg kg^{-1}) and 0.50% Zn Citrate (20.4 mg kg^{-1}) as compared to unprimed seeds (17.9 mg kg^{-1}). The highest zinc uptake was observed with 0.50% $ZnSO_4$ (5.54 mg g^{-1}), which was closely followed by 0.25% Zn EDTA (4.87 mg g^{-1}) and 0.50% Zn Citrate (5.01 mg g^{-1}). The lowest zinc uptake was found in unprimed seeds (3.56 mg g^{-1}).

DISCUSSION

Seed germination characteristics

Seed germination and its establishment are important for any crop's growth. Including Zn improves the germination percentage, speed of germination, germination

Table 4. Effect of seed priming of different levels and sources of Zn on seedling length of barnyard millet

Seed priming treatments	Shoot length (cm)		Root length (cm)	
	10th day	15th day	10th day	15th day
T_1-Un primed seeds	8.18^{h}	9.71^{h}	8.54^{j}	10.8j
T_2-Water primed	8.51^{gh}	10.2^{gh}	9.00^{ij}	11.8^{ij}
T_3-GA3 @10 ppm	8.92^{efg}	10.9^{efg}	9.71^{gh}	12.8^{gh}
T_4-Zinc sulphate - 0.10%	10.4^{cd}	12.6^{cd}	$11.^{4de}$	14.0^{de}
T_5-Zinc sulphate - 0.25%	11.1^{b}	13.8^{b}	12.2^{bc}	15.0^{bc}
T_6-Zinc sulphate - 0.50%	11.6^{a}	14.7^{a}	13.2^{a}	16.5^{a}
T_7-Zinc EDTA - 0.10%	9.60^{ef}	11.5^{ef}	10.0^{fg}	13.0^{fg}
T_8-Zinc EDTA - 0.25%	10.6^{abc}	13.5^{abc}	12.5^{ab}	15.7^{ab}
T_9-Zinc EDTA - 0.50%	10.1^{bd}	12.9^{bd}	11.5^{cd}	14.7^{cd}
T_{10}-Zinc Citrate - 0.10%	9.20^{g}	10.1^{g}	9.47^{hi}	11.7^{hi}
T_{11}-Zinc Citrate- 0.25%	9.62^{f}	11.2^{f}	10.3^{fg}	12.7^{fg}
T_{12}-Zinc Citrate - 0.50%	10.3^{de}	12.0^{de}	11.0^{ef}	13.5^{ef}
	SEd	CD(P=0.05)	SEd	CD(P=0.05)
T	0.345	0.685	0.412	0.818
D	0.141	0.280	0.168	0.334
TxD	0.488	0.970	0.583	1.157

Values followed by the same letter within a column do not differ significantly (ANOVA, LSD test, P ≤ 0.05)

Table 5. Effect of seed priming of different levels and sources of Zn on Zn content and its uptake by barnyard millet

Seed priming	Zn content (mg g^{-1})	Zn uptake (mg g^{-1})
T_1-Un primed seeds	17.9^{e}	3.56^{e}
T_2-Water primed	18.4^{de}	$3.82d^{e}$
T_3-GA3 @10 ppm	18.8^{de}	4.07^{cde}
T_4-Zinc sulphate - 0.10%	19.8^{bcd}	4.47^{bcd}
T_5-Zinc sulphate - 0.25%	21.0^{ab}	5.00^{ab}
T_6-Zinc sulphate - 0.50%	21.9^{a}	5.54^{a}
T_7-Zinc EDTA - 0.10%	18.9^{cde}	4.09^{cde}
T_8-Zinc EDTA - 0.25%	19.8^{bcd}	4.87^{ab}
T_9-Zinc EDTA - 0.50%	20.9^{ab}	4.73^{bc}
T_{10}-Zinc Citrate - 0.10%	18.7^{de}	4.08^{cde}
T_{11}-Zinc Citrate- 0.25%	19.8^{bcd}	4.70^{bc}
T_{12}-Zinc Citrate - 0.50%	20.4^{bc}	5.01^{ab}
Sed	0.742	0.330
CD (P=0.05)	1.492	0.664

Values followed by the same letter within a column do not differ significantly (ANOVA, LSD test, P ≤ 0.05)

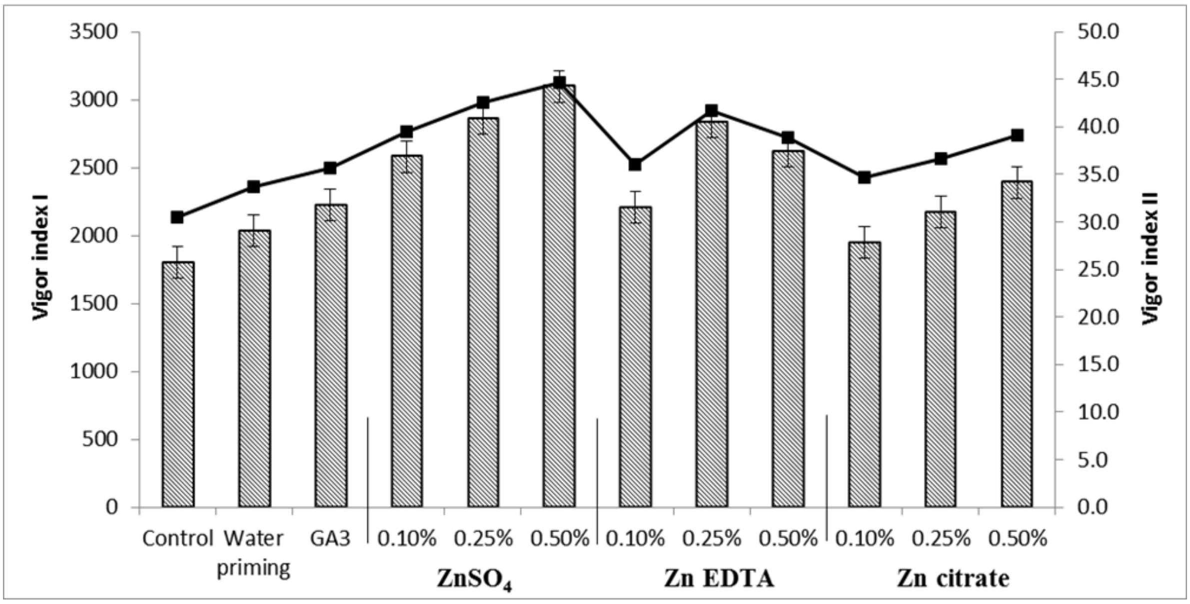

Fig. 2. *Seed Priming of different levels and sources of Zn on vigor index I and II of barnyard millet (Error bars indicate standard error)*

energy, germination index of the crops. Significant differences were observed with the treatments and their interactions (Tables 2 and 3). The seed germination percentage and germination speed ranged from 85 to 99.5% and 53.7 to 80%, respectively, depending on the sources and levels of Zn priming treatments. Similarly, Rahman *et al.* (2014) also indicated that higher germination indices were in seeds primed with micronutrients which could be due to the involvement of Zn in the synthesis of DNA, RNA and proteins during the seed priming (Afzal *et al*., 2008).

In a study, Ullah *et al*. (2019) observed improved seed germination, emergence and seedling growth of chickpea with Zn seed priming at 0.001 to 0.0001 M Zn solution. This was attributed to the involvement of Zn in radicle development and the early stages of coleoptile growth and auxin synthesis . Varier *et al*. (2010) reported that the improvement in germination parameters due to seed priming Zn treatments could be due to the increased Zn content in seeds and its involvement in metabolic activities. During priming, the beta subunits of globulin are increased, lipid peroxidation is reduced and the antioxidant activities are enhanced, which are responsible for the improved germination of the seeds. After drying the primed seeds, rapid growth was observed with early radicle and plumule appear-

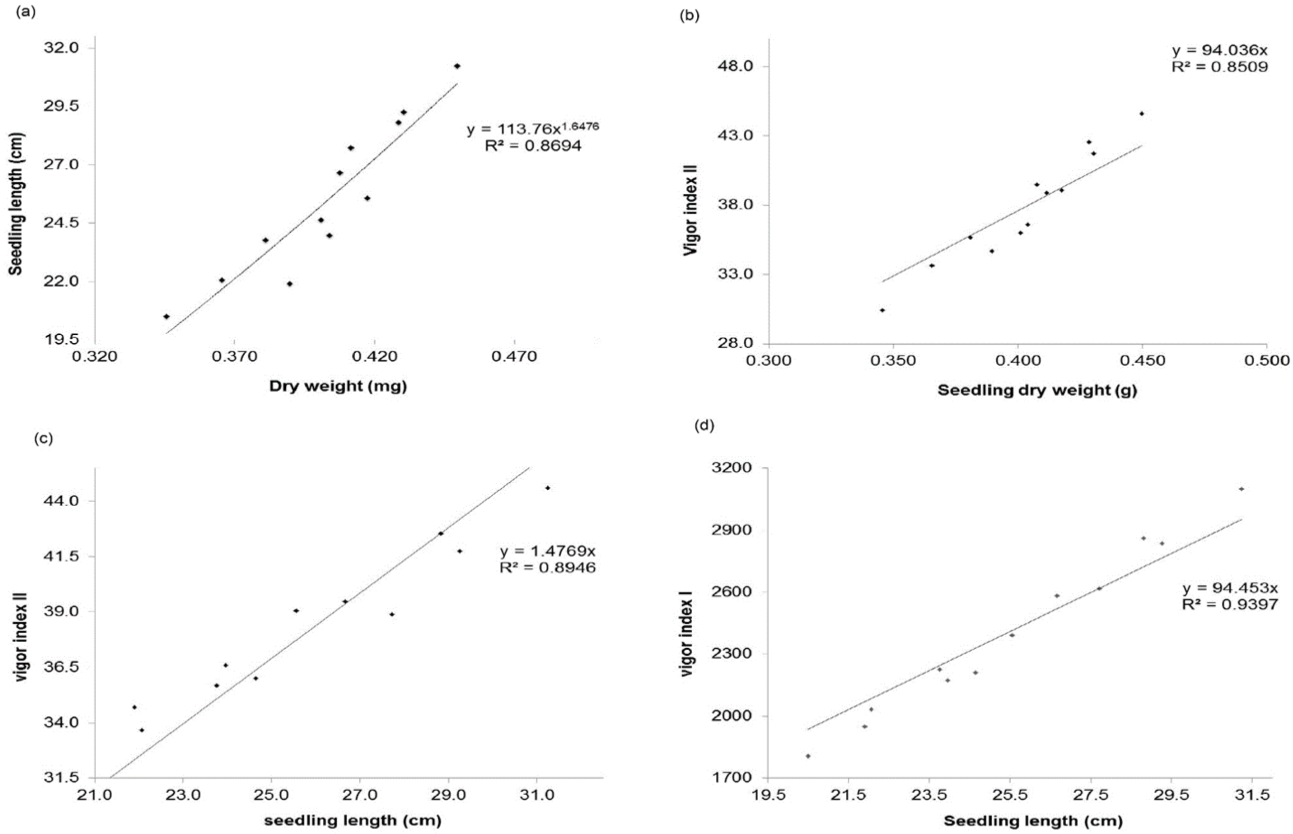

Fig. 3. *Relationship between the seedling dry weight, seedling length and vigor index of barnyard millet*

ance upon re-absorption of water. Moreover, Afzal *et al*. (2008) observed higher levels of amylase activity, ascorbate and phenolic contents in nutrient-primed seeds of two wheat cultivars (Inqlab-91 and SARC-1).

The Zn seed priming increases germination by increasing the activity of enzymatic antioxidants, superoxide dismutase (SOD) and peroxidase (POD) which helps in the utilization of protein and carbohydrate during germination process (Kiran *et al*., 2012). One of the important determinants of the effectiveness of seed priming is the priming sources and their levels. Prasad *et al*. (2012) demonstrated that nano ZnO increased seed germination, seedling vigour, early flowering, and leaf chlorophyll content.

Seedling growth

Seedling emergence and establishment are the two important processes in the growth of plants. Seedling establishment was improved in the seeds primed with Zn as compared to seeds primed with water and GA_3. Seedlings primed with different sources and levels of Zn solutions resulted in higher, thicker and sturdy seedlings. Zeng *et al*. (2012) support these findings with similar conclusions: nutrient seed priming improved the seedling length and weight of maize and soybean, respectively. The accessibility of micronutrients in the seeds play a vital role in protein synthesis and enzyme activities of seedlings. Moreover, micronutrients such as Zn, Mo and B are required for the effective utilization of NPK by a variety of crops (Kaiser *et al*., 2005, Adorni *et al.,* 2020). In addition, this improvement in growth and seedlings developments primed with Zn solutions could be due to the Zn uptake, which activated the germination process. Seeds which are soaked in water for a particular period and dried before seminal root protrusion can develop and grow faster (Sozharajan and Natarajan, 2014). In this study, seeds primed with Zn emerged faster than non-primed seeds. Fig 3(a) explains the effect of seed priming on seedling length and seedling dry weight of barnyard millet variety MDU1. The seedling length was directly proportional to the dry weight of the seedlings and a linear increase in seedling length with the dry weight of seedling was also witnessed in the study. The correlation between seedling length and dry weight is found to be 86%. During priming, imbibitions of nutrients have a direct impact on seed metabolism and seedling emergence. The dry matter production was higher due to different sources and zinc priming levels than un-primed seeds. The improvement in seed vigor was the highest with 0.50% $ZnSO_4$ priming followed by 0.25% Zn EDTA and 0.50% Zn citrate and the least improvement was observed in unprimed control (2836). The interaction between seedling dry weight and vigor index II is presented in Fig 3 (b) which showed a linear increase with the dry weight of seedlings and about 85% correlation was noticed between these two parameters. Similar results were reported by Kumar and Singh (2013). Fig. 3(c) indicates 89% correlation between the seedling length and vigor index II of barnyard millet, indicating the positive relationship between the seedling length and vigor index II of barnyard millet. Fig. 3(d) explains the linear increase in seedling length and vigor index I and the positive correlation between the seedling length and vigor index I was found to be 93%. Similarly, Nciizah *et al*. (2020) observed the highest seed germination and seedling growth with micronutrients (Zn, B and Mo) primed maize crop.

Conclusion

Seed priming with different sources and levels of Zn improved the germination and seedling growth of barnyard millet (MDU1) as compared to seeds primed with GA_3, water and un-primed seeds. Seed priming of 0.50% $ZnSO_4$ was found to improve the seed germination indices and seedling's growth parameters, whereas other sources showed lesser performances. Seed germination and seedling growth parameters such as shoot length, root length, dry weight, germination percentage, speed of germination, germination energy, germination index and vigour index I and II increased with Zn seed priming. Seed priming with 0.50% $ZnSO_4$ for 12h was the most effective treatment for improving the seedling growth parameters of barnyard millet. This was closely followed by 0.25% Zn EDTA and 0.50% Zn citrate compared to seeds treated with 10 ppm GA_3, water and un-primed control. Therefore, it was concluded that seed priming of 0.50% $ZnSO_4$ for 12 h could be recommended as pre-sowing seed treatment for barnyard millet to achieve better germination and seedling vigour.

Conflict of interest

The authors declare that they have no conflict of interest.

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