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Influence of seed priming techniques on growth and yield parameters of maize (*Zea mays* L.)

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Abstract
A field trial was carried out to know the effect of pre-sowing seed hardening on growth and yield of maize. Maize seeds were subjected to seed hardening with nutrients viz., $CaCl_2$ (2%) KH_2PO_4 (1.0%) KCl (2.0%) KNO_3 (1.0%) $ZnSO_4$ (0.5%) and with Plant growth regulators hardening viz : Cycocel (1000 ppm) GA_3 (100 ppm) Ascorbic acid (20 ppm) PEG 6000 (10%) and hydro hardening and their effect was compared with non primed seeds as control. Among the treatments, significantly higher grain yield was recorded in seeds hardened with $CaCl_2$ @ 2.0 percent followed by $ZnSO_4$ 0.5 percent and cycocel 1000 ppm over control. The increase in grain yield may be attributed to improvement in the sink capacity and was evident from improved yield traits *viz.,* cob length, cob diameter, 1000 seed weight seeds weight per plant which were largely influenced by source and was expressed interms of increased growth parameters *viz.,* leaf area and dry matter production and its partition into reproductive parts. Interestingly more positive effect of Ca on plant growth and development was evident when supplied through hardening process. The positive improvement in yield and growth of the crop may be attributed to $CaCl_2$, where in, Ca in the form of calcium pectate, act as a cementing agent for adhering cell walls of plants and regulates new tissue formation viz; root tips, young leaves, and shoot tips avoids distorted growth from improper cell wall formation. Further, Calcium ion (Ca^{2+}) second messenger regulates cell cycle and gene expression which is crucial for plant growth and development particularly so against stresses.

Keywords: Seed hardening, $CaCl_2$, Cycocel, KNO_3 and $ZnSO_4$

Introduction
Maize (*Zea mays* L.) is a queen of cereals and is a 3rd multipurpose important cereal crop next to paddy and wheat with respect to production and consumption. In India it is grown in about 8.67 m ha area, having 22.26 m tonnes production with productivity of 2.57 t ha^{-1} (Anon., 2016) [2]. The instability and poor productivity of maize under drought prone rain fed situation may be due to drastic reduction in plant population or poor crop stand coupled with varying crop maturity. Seedling tolerance to drought and proper crop stand is crucial for crop growth and development to realise sustainability in production. Pre-sowing seed hardening is one of the physiological techniques employed to induce drought tolerance and helps in rapid and uniform germination and emergence of seeds. The various seed hardening components such as concentration of the chemical, selection of the chemical, duration of soaking and seed to solution ratio also influence the different pre-germinative process during seed hardening. In this view, the present investigation was carried out to know the effect of seed hardening chemicals on growth and yield in maize.

Material and Methods
Maize seeds were hardened by soaking for 24 hours with 1:1.5 proportions of seed to solution of various chemicals and soaked seeds were dried back to original moisture content under room temperature. Eleven different seed hardening chemicals were used viz; water (T_2), $CaCl_2$ 2 percent (T_3), KH_2PO_4 1 percent (T_4), KCl 2 percent (T_5), KNO_3 1 percent (T_6), cycocel 1000 ppm (T_7), ascorbic acid 20 ppm (T_8), PEG 6000 10 percent (T_9), GA_3 100 ppm (T_{10}), $ZnSO_4$ 0.5 percent (T_{11}), BAP 20 ppm (T_{12})and normal non hardened seeds as control (T_1.) The field experiment was conducted in plot number 178 at University of Agricultural Sciences, Raichur in Randomized block design (RBD) and was replicated thrice. The crop was raised by adopting the recommended package of practices during *kharif* 2014. The observations namely plant height, number of leaves, leaf area by disc method (Vivekanadan *et al.*, 1972) [11], total dry matter accumulation and its distribution in different parts was recorded in five randomly selected plants in a plot of each treatment. Yield components were derived from the mean observations of five plants and plot yield was converted to yield per hectare.

Results and Discussion

In the present study, significantly higher grain yield (53.60 q $ha^{-1)}$ was recorded in seeds hardened with $CaCl_2$ 2 percent over control ((42.84 q $ha^{-1)}$ followed by $ZnSO_4$ 0.5% **(**52.71q ha^{-1}) and cycocel 100 ppm. **(**51.39q ha^{-1}). 25 percent improvement in grain yield was noticed in seeds hardened with $CaCl_2$ 2 percent over control. This may be attributed to significant improvement in the sink capacity of the plant and was expressed in terms of bigger cobs with bold seeds. It was evident from increased yield traits *viz.* increased cob length (8%) and cob thickness (28%), test weight (21%) and grains per plant (25%) over control. This is in conformity with the findings of earlier research workers that pre-sowing seed hardening with $CaCl_2$ 2 percent recorded significantly higher yield per ha in sunflower (Pawar *et al.*, 2003) [10]. Seed hardening with -1.5 MPa $CaCl_2$ in rice recorded significantly more straw yield, kernel yield and 1000 seed weight (Farooq *et al.*, 2007) [7]. Further Afzal *et al.* (2013) [1] who reported 66 percent increase in grain yield and 72 percent stover yield in maize seeds primed with 1.5 percent $ZnSO_4$

In generally yield and yield traits intern largely influenced by morphological and growth parameters. Interestingly, In the present study morphological parameters like plant height and number of leaves per plant were not influenced by any of the seed hardening treatments. This may be due to the fact that, these parameters are genetically inherited characters and there may not be any limiting factor for the complete expression However, significant differences among pre-sowing seed hardening treatments was observed with growth parameters.viz; Leaf area, total dry matter accumulation and its partition into stem, leaf and reproductive parts. Significantly higher leaf area (27%) and leaf dry matter (57%), was associated with treatment receiving $CaCl_2$ @ 2% seed hardening as compare to control. Thus, it indicates that Photosynthatic source of the plant was improved and was evident from the improved leaf area ie photosynthetic apparatus and leaf dry matter. The increase in leaf area due hardening may be attributed to redistribution of nutrient reserves leading to cell enlargement and increase in normal cell division. The findings are in accordance with the reports of Gurmani *et al.* (2006) [5] in rice who reported the application of BA and CCC increased leaf area and in wheat, seeds primed with KNO_3 and KH_2PO_4 observed significantly increased leaf area by Hamidi *et al.* (2013) [6].

Dry matter production and its distribution in different plant parts is an important parameter that determines yield. The positive effect CaCl2 2% seed hardening documented its influence on dry matter production and the way in which it is partitioned into different parts of the plant. It is characterised by better source-sink relationship due to higher rate of CO_2 fixation and RuBP carboxylase activity and effective sink size. The increased total dry matter accumulation (32%), and its increased partition into leaf dry matter (57%), stem dry matter (45%) and reproductive parts. (20%) as compare to control, was observed with seed hardening with CaCl2 2% treatment. Thus results indicate that Dry matter production and distribution is an important parameter in boosting the source-sink relationship and yield potential. Similar observations were made by Nam *et al.* (1998) [8] and Katti *et al.* (1999) [7] in pigeonpea. The results were in occurrence with Pawar *et al.* (2003) [10] in sunflower seeds hardened with $CaCl_2$ 2 percent which recorded higher TDM at harvest and 50 percent flowering stage. These results are in agreement with Dastborhan *et al.* (2013) [3] who revealed that borage seeds primed with KNO_3 @ 1.0 percent and KH_2PO_4 recorded higher stem dry weight, leaves dry weight over hydro priming and unprimed seeds. In this study, interestingly more positive effect of Ca on plant growth and development was evident when supplied through hardening process. It is well established fact that Ca in the form of Calcium pectate, is responsible for holding together the cell walls of plants and regulates new tissue formation viz; root tips, young leaves, and shoot tips avoides distorted growth from improper cell wall formation. Further, Calcium ion (Ca^{2+}) is a ubiquitous intracellular second messenger and is involved in the regulation of cell cycle and gene expression through activation of many calcium dependent protein kinases which is crucial for plant growth and development and is more so against stresses (Narendra Tuteja and Shilpi Mahajan, 2007) [9].

Table 1: Yield and yield parameters as influenced by seed hardening in maize

Treatments	Cob length (cm)	Cob diameter (cm)	Shelling (%)	Number of cobs $plant^{-1}$	Test weight (g)	Grain weight (g $plant^{-1}$)	Grain yield (q ha^{-1})
T_1: Control	14.3	3.9	76.87	1.28	25.85	77.11	42.84
T_2: Water	14.7	4.0	77.15	1.29	26.80	78.96	43.87
T_3: $CaCl_2$ (2%)	18.0	5.0	86.91	1.43	31.53	96.47	53.60
T_4: KH_2PO_4 (1%)	15.4	4.5	78.64	1.32	28.86	86.26	47.92
T_5: KCl (2%)	15.1	4.3	78.42	1.31	28.70	86.71	48.17
T_6: KNO_3 (1%)	16.4	4.5	82.16	1.37	29.80	89.42	49.68
T_7: Cycocel (1000 ppm)	16.7	4.8	84.30	1.38	30.59	92.49	51.39
T_8: Ascorbic acid (20 ppm)	15.2	4.4	78.98	1.32	29.14	82.05	45.59
T_9: PEG 6000 (10%)	15.1	4.3	79.67	1.33	27.87	81.32	45.18
T_{10}: GA_3 (100 ppm)	15.0	4.1	78.96	1.31	27.23	79.59	44.21
T_{11}: $ZnSO_4$ (0.5%)	17.1	4.9	85.40	1.40	31.07	94.87	52.71
T_{12}: BAP (20 ppm)	15.1	4.3	78.86	1.32	28.15	81.69	45.38
S.Em.±	0.7	0.2	3.74	0.06	1.16	4.05	2.25
C.D. at 5%	2.1	0.6	NS	NS	3.40	11.89	6.61

Note: PEG – Polyethylene glycol 6000, BAP-Benzyl amino purine
NS – Non significant

Table 2: Physiological growth parameters as influenced by seed hardening in maize

Treatment	Plant height (cm)	Number of Leaves plant^{-1}	Leaf area (dm^2 plant^{-1})	TDM (g plant^{-1})	Leaf dry matter (g plant^{-1})	Stem Dry matter (g plant^{-1}	Dry matter accumulation in reproductive parts (g plant^{-1})
T_1: Control	190.73	8.20	40.20	235.91	28.62	64.02	143.27
T_2: Water	192.33	8.43	41.66	241.82	30.13	66.16	145.52
T_3: $CaCl_2$ (2%)	206.30	9.87	51.41	310.49	45.05	93.01	172.43
T_4: KH_2PO_4 (1%)	196.30	8.93	45.93	268.64	34.83	75.63	158.19
T_5: KCl (2%)	195.60	8.60	45.72	267.53	33.31	76.77	157.45
T_6: KNO_3 (1%)	200.37	9.26	46.73	284.42	37.70	82.52	164.19
T_7: Cycocel (1000 ppm)	188.60	9.60	48.49	294.34	40.86	88.11	165.37
T_8: Ascorbic acid (20 ppm)	197.20	9.03	45.87	266.16	34.96	76.83	154.04
T_9: PEG 6000 (10%)	196.57	8.97	43.21	255.07	32.62	71.62	150.83
T_{10}: GA_3 (100 ppm)	197.97	7.93	43.19	249.03	31.60	68.52	148.91
T_{11}: $ZnSO_4$ (0.5%)	202.33	9.78	49.46	300.57	41.54	89.52	169.50
T_{12}: BAP (20 ppm)	198.43	9.13	44.13	257.59	34.23	72.78	150.92
S.Em.±	9.14	0.58	2.11	12.41	2.21	4.40	6.30
C.D. at 5%	NS	NS	6.19	36.40	6.48	12.91	18.47

Note: PEG – Polyethylene glycol 6000, BAP-Benzyl amino purine Total dry matter accumulation (TDM) NS – Non significant

Conclusion

The results of the present investigations indicates that seed hardening with 2.0% $CaCl_2$ played an effective role in improving growth -physiological and yield attributing characters in Maize. Improvement of seed physiological aspects by seed hardening with 2.0% $CaCl_2$ is a simple and easy method to enhance the seed performance and agricultural productivity of a particular crop especially in the dry land and marginal lands of resource poor end users.

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