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Effect of hardening on germination and seedling characters of maize *(Zea mays L)*

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ABSTRACT

The ideal temperature is necessary for the maize crop to provide the highest harvest yield. Environmental stress elements such as abiotic and biotic stress factors are expected to intensify and become more widespread as a result of climate change. Drought, temperature, and salinity are the key factors affecting maize output globally. Various management practices may help in contributing tolerance to the plants against adverse environmental impact, and seed hardening is one among them. The experiment was conducted in the laboratory of Seed science and Technology, Department of Agriculture, Kalasalingam School of Agriculture and Horticulture, Krishnankoil, Tamil Nadu to study the effect of various hardening treatments in maize seeds. Maize seeds were hardened with the following chemicals at varying concentrations for 12 hours viz., T_0 - Control, T_1 - Distilled water, T_2 - Boric acid (0.5%), T_3 - Boric acid (1.0%), T_4 - Boric acid (1.5%), T_5 - KNO_3 (0.5%), T_6 - KNO_3 (1.0%), T_7 - KNO_3 (1.5%), T_8 - KH_2PO_4 (0.5%), T_9 - KH_2PO_4 (1.0%) and T_{10} - KH_2PO_4 (1.5%). Significant differences were found between control and hardening treatments. Maximum germination percentage, shoot, and root length, seedling length, fresh and dry weight of the seedling vigor index were observed for the seeds treated with 1.5% KNO_3. This experiment also showed the positive influence of KH_2PO_4 (1.5%) in various seedling characters followed by 1.5% KNO_3. This study might help to improve the seedling character with the help of seed-hardening treatments to withstand adverse abiotic stress situations.

Keywords: *Maize, Abiotic stress, Hardening, Germination, Seedling characters, Vigor*

Introduction

The primarily grown crop on earth is maize (*Zea mays* L.), a domesticated cereal grain from Central America that is the leading crop in the globe. One of the most adaptable developing crops, it has a wide range of uses. Due to its maximum genetic production potential, maize is referred to as the "queen of cereals" universally. Abiotic pressures, such as nutrient restrictions and drought, are rising to the top of the list of constraints, which is causing the global decline in grain output of annual crops to accelerate. When it comes to the impacts of climate change on agriculture, maize appears to be the most vulnerable crop[1]. It is well established that critical environmental conditions such as drought, extreme heat, salt, and nutritional deficit reduce maize productivity around the globe [2].

Around 42% of the entire amount of food grains produced in India are grown on roughly 70% of the country's arable land. Low and unpredictable rainfall, the use of poor quality seeds, a soil moisture deficit, and incorrect crop management are all factors in the low productivity under rainfed conditions. Along with an enhanced set of techniques, high-quality seeds are crucial for increasing yield. To increase the crop's production potential in rainfed conditions, several management measures are used. One of these seed management strategies is seed hardening, which involves hydrating and then drying seeds to their original moisture content to withstand stressful field conditions. According to reports, physiological seed treatments that improve seed performance essentially depend on the hydration and dehydration of the seed [3]. To improve the rate and uniformity of germination, seed priming/hardening is a frequent method [4]. Hardened crops also had better establishment, developed faster, bloomed earlier, and produced more [5].

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Materials and Methods

The present study entitled "Effect of hardening on germination and seedling characters of maize (*Zea mays* L)" was conducted during Kharif season 2023, in the laboratory of Seed science and Technology, Department of Agriculture, Kalasalingam School of Agriculture and Horticulture, Krishnankoil, Tamil Nadu. For hardening, various treatments were applied at various concentrations of T_0 - Control, T_1 - Distilled water, T_2 - Boric acid (0.5%), T_3 - Boric acid (1.0%), T_4 - Boric acid (1.5%), T_5 - KNO_3 (0.5%), T_6 - KNO_3 (1.0%), T_7 - KNO_3 (1.5%), T_8 - KH_2PO_4 (0.5%), T_9 - KH_2PO_4 (1.0%) and T_{10} - KH_2PO_4 (1.5%).

For the preparation of KNO3 solution (KNO3- 0.5%, 1%, and 1.5%) 0.5gm, 1gm, and 1.5gm of potassium nitrate were taken and mixed with 100 ml of distilled water to prepare 0.5%, 1% and 1.5% solution, respectively. For the preparation of Boric acid(H_3BO_3- 0.5%, 1%, and 1.5%) solution 0.5gm, 1gm, and 1.5gm of boric acid was taken in a beaker and mixed with 100 ml of distilled water to prepare 0.5%, 1% and 1.5% solution, respectively, while for (KH_2PO_4- 0.5%, 1%, and 1.5%) Potassium dihydrogen Orthophosphate (KH_2PO_4)solution, 0.5gm, 1gm, 1.5gm of boric acid was taken in a beaker and mixed with 100 ml of distilled water to prepare 0.5%, 1% and 1.5% solution, respectively. To prevent contamination, muslin material was placed over the flasks containing the chemicals.

Maize seeds were soaked in the necessary solution for 12 hours at a temperature of 25°C following the preparation of the potassium nitrate, boric acid, and potassium dihydrogen orthophosphate solution (KNO_3, H_3BO_3, and KH_2PO_4). The solution was removed from the beaker after the seeds had soaked for 12 hours, and the pre-soaked seeds were then air-dried or shade dried to their original weight before being placed for germination in a laboratory under controlled conditions adopting a completely randomized design.

Germination % (ISTA 2004), Root length (cm), Shoot length (cm), Seedling length (cm), Seedling fresh weight (gm), Seedling dry weight (gm), Vigor index I, and Vigor index II [6] observations of these characteristics were noted. Analysis of range, mean, and coefficient of variation was performed on the experimental data that were recorded [7].

Result and Discussion

The results show that all examined features were influenced by the treatments, and the control group (unhardened seeds) and the hardened group significantly differed (Table 1). According to the reports [8], seed hardening is the process of alternately drying and soaking seeds. Earlier findings showed that multiple pre-sowing treatments for cowpea and black gram increased seed weight [9].

Germination percentage performance ranged from 74% to 95% on average, with a mean value of 84.50% (Table 1). Significantly, the seeds hardened with KNO_3 (1.5%) (T_7) reported the highest percentage of germination (95%), followed by those hardened with T_{10} KH_2PO_4 (1.5%) solution (94%), while the seeds hardened with distilled water (T_1) showed the lowest percentage of germination (81%). T0 seeds had a minimum germination rate of 74% when used as the unhardened control. Hardened seeds exhibited a superior germination pattern and a greater level of vigor than non-hardened seeds [10]. The fertilizing effect from the release of nutrients from damaged or degraded tissue of storage organs via hydrolysis may be the cause of the hardened seed's stimulatory effect on germination and the growth of seedlings [11]. In sorghum, [12] and rice [13], seed priming with 1% KNO3 was found to be beneficial in terms of emergence percentage, which was following our findings.

The range of the average seedling root length and shoot length was 12.49cm to 17.97cm and 13.31cm to 21.24cm, with a mean of 15.50cm and 17.49cm, respectively (Table 1). Seeds hardened with KNO_3 (1.5%) (T_7) measured the longest root and shoot length (17.97cm and 21.24cm, respectively), followed by the seeds hardened with T_{10} KH_2PO_4 (1.5%) solution. T_0 measured the shortest root length, which was 12.49 cm and 14.71cm, respectively, for unhardened seeds. Cell proliferation plays a crucial role in the development and function of plants [14]. K is also crucial for this process. It is commonly accepted that K activates and regulates ATPase in the plasma membrane to provide acid stimulation, which subsequently causes cell wall thinning and hydrolase activation, facilitating cell growth [15,16]. This might cause an increase in shoot and root length in maize seedlings when treated with KNO_3 and KH_2PO_4.

Maize seeds hardened with 1.5% KNO_3 (T_7) recorded a maximum seedling length of about 39.21cm followed by 1.5% KH_2PO_4 (T_{10}) (Table 1) with a seedling length of about 37.76cm. The range of seedling length for different treatments varies from 26.79cm to 39.21cm, while, the minimum seedling length (26.79cm) was observed in 0.5% KH_2PO_4 (T_8). Furthermore, it has been noted that exogenous KNO_3 increases the expression of genes related to N and C metabolism as well as energy synthesis [17]. Also, the combined favorable effects of K and H_2O on root and shoot growth account for the longer seedling length in KNO_3. According to some reports, seeds that are hydrated to the same level as but not higher than the lag phase of hardening can undergo early DNA replication, increased RNA and protein synthesis, increased ATP availability, faster embryo growth, repair of damaged seed parts, and less metabolite leakage than controls [18]. The length of the seedling as a whole rose as a result of all these factors increasing the length of the seed's roots and shoots.

Seedling fresh weight and dry weight performance ranged from 2.29gm to 3.38gm and 0.39gm to 0.81gm on average, with a mean value of 2.80gm and 0.59gm, respectively (Table 1). The highest seedling fresh and dry weight was observed in the treatment T7 (1.5% KNO3) with a value of 3.38gm and 0.81gm, respectively and it was followed by the treatment T_{10} (1.5% KH_2PO_4) with a value of 3.27gm (seedling fresh weight) and 0.79gm (seedling dry weight). Increased root length and shoot length might lead to attaining maximum fresh and dry weights when seeds are treated with potassium nitrate and potassium dihydrogen phosphate.

The mean performance of the seedling vigor index Ist ranges from 2012.8 to 3724.95 with an average value of 2806.66 (Table 1). Maximum seedling vigor index Ist (3724.95) was recorded by T_7 treated with 1.5% KNO3 and it was followed by T_{10} (3549.44) treated with 1.5% KH_2PO_4 and Minimum seedling vigor index Ist was recorded by T0 untreated (2012.8) in control (Unhardened seeds). The mean performance of seedling vigor index IIndranges from 30.34 to 76.95 with a mean value of 50.83. Maximum seedling vigor index IInd(76.95) was recorded byT7 primed withKNO3 1.5%and it was followed by T10(74.26) hardened with 1.5% KH_2PO_4 Minimum seedling vigor indexIInd was recorded by unhardened T0 (28.15) control. The cumulative effect of emerging seeds under a variety of biotic and abiotic conditions is seedling vigor. Seedling vigor is not a single measured item, but rather the sum of several growth indicators, including seedling length, fresh weight, and dry weight [19].

Future scope of the study

Future research can concentrate on determining how novel plant growth regulators affect other crops like pulses and oilseeds as this study only contributes to the body of knowledge on the influence of nutrients on maize crops. In the future, the mode of action of nutrients and plant growth regulators can be explored using a molecular method.

Conflict of Interest: There is no conflict of interest between the authors

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Table 1. Mean performance of seedling characters of maize under different treatments

Maize	Germination percentage (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Fresh weight of seedling (gm)	Dry weight of seedling (gm)	Seed Vigour index Ist	Seed Vigour index IInd
T_0-Control	74	12.49	14.71	27.2	2.38	0.41	2012.8	30.34
T_1-Water	81	15.89	15.63	31.52	2.53	0.46	2553.12	37.26
T_2-Boric Acid (0.5%)	82	16.29	18.61	34.9	3.09	0.72	2861.8	59.04
T_3-Boric Acid (1%)	87	16.37	17.62	33.99	2.86	0.63	2957.13	54.81
T_4-Boric Acid (1.5%)	85	15.61	17.05	32.66	2.64	0.54	2776.1	45.90
T_5-KNO_3 (0.5%)	82	14.94	16.81	31.75	2.59	0.49	2603.5	40.18
T_6-KNO_3 (1%)	83	14.27	18.67	32.94	2.78	0.6	2734.02	49.80
T_7-KNO_3 (1.5%)	95	17.97	21.24	39.21	3.38	0.81	3724.95	76.95
T_8-KH_2PO_4 (0.5%)	82	13.48	13.31	26.79	2.29	0.39	2196.78	31.98
T_9-KH_2PO_4 (1%)	85	15.83	18.33	34.16	3.02	0.69	2903.6	58.65
T_{10}-KH_2PO_4(1.5%)	94	17.39	20.37	37.76	3.27	0.79	3549.44	74.26
Grand mean	**84.5**	**15.50**	**17.49**	**32.99**	**2.80**	**0.59**	**2806.66**	**50.83**
CD (P=0.05)	3.59	1.50	1.02	0.70	0.47	0.21	110.11	5.74
SEd	1.21	0.36	0.20	0.21	0.18	0.11	50.2	2.41
Range (Maximum)	**95**	**17.97**	**21.24**	**39.21**	**3.38**	**0.81**	**3724.95**	**76.95**
Range (Minimum)	**74**	**12.49**	**13.31**	**26.79**	**2.29**	**0.39**	**2012.8**	**30.34**

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