The Effects of Different Seed Priming Chemicals on Germination and Seedling Growth Rate of Maize (*Zea mays L.*) in Lesotho

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***Abstract*—** *Maize is grown widely in Lesotho as a staple crop for the nation and is accepted in cultural dishes. Its productivity is low necessitating importation from neighboring South Africa. Low productivity is attributed to low germination rate and poor stand in the field. The objective of the study is to identify the most potent chemical compounds that enhance high germination and seedling growth rate of maize. The study was conducted at the National University of Lesotho domiciled in Maseru, Lesotho. The experiment was performed in the laboratory of Department of Crop Science. Complete Randomized Design with PANNAR Seed Company maize cultivar of PAN 12 and four priming chemical compounds varied in amounts and duration immersed in the solutions. Chemical compounds were Indole Butyric Acid, Calcium chloride, Sodium chloride and Copper sulphate, while distilled water was control. Seed germination and seedlings parameters measured were germination rate, germination percentage, germination index, radical length, plumule length, plumule fresh weight and dry weight, radical fresh weight and dry weight, and coleoptile length. Data from parameters were subjected to perform Analysis of Variance and least significant differences. Results showed no significant difference among concentrations of Indole Butyric Acid on all parameters. Three other chemical compounds revealed significant to highly significant differences. Priming maize seed with Calcium chloride for a duration of 18hrs to 24hrs increased seed germination and seedling growth rate significantly. Similarly, varying concentrations of Calcium chloride compound used showed significantly different responses on measured parameters of maize seed. Moreover, results on copper sulphate indicated that the higher the concentration of copper sulphate, the lower the maize seed germination and seedling growth rate. In conclusion, maize seed primed with water generated better results compared Sodium chloride, Calcium chloride and Copper sulphate based on sequence of potency.*

***Keywords*— Maize, PAN 12, seed germination, seedling growth rate, seed priming, Lesotho.**

I. INTRODUCTION

Lesotho is among the nations with inhabitants consuming maize as a staple food prepared in various dishes. Almost all farming households grow maize for both home consumption and animal feeding. Morojele and Sekoli (2016) [1] state that maize is a major staple crop in Lesotho as evidenced by number of farmers (195,958) involved in its production, proportion of area under which it is grown (146,313 ha) and the rate at which it is consumed (266,755 metric tons) [2]. Maize ranks first among cereal crops grown in Lesotho, followed by sorghum, wheat and beans [3]. It is cultivated across all agro-ecological zones of Lesotho, namely; low-lands, foot-hills, mountains and Orange River valley. Among the four ecological zones of Lesotho, lowlands account for the highest maize production reaching 15, 800 tons on 118 586 hectares. The lowest production is in the Orange River Valley where 1,475 tons is achieved on 2,757 hectares (2021). Foothills and mountain zones are at par. In the lowlands, arable area put under maize is larger than in the other zones because of both suitable climatic and edaphic conditions prevailing and a long growing season, from October to December. In the foothills and mountain zones, planting can only commence in September and terminate in November due to early chilling and freezing injuries that the crop suffers [3]. The Orange River Valley is prone to drought and is very hot and dry in summer resulting in maize crops being adversely affected in terms of growth, development and grain yield [1], [4].

The Basotho nation perceives maize as one of the crops contributing significantly to the household economy, particularly when all farmers consume it and sell the surplus to community members in the neighborhood generating income for purchasing other

household needs [5], [6]. The importance of maize to the Basotho nation cannot be over-emphasized as a main source of nutrients particularly energy and other elements. Nutritionally, carbohydrates (70-87 %), proteins (6-13 %), fiber (7%), oil (2-6 %), vitamin B and minerals constitute maize grain [7], [8]. For maize to be a balanced diet, it is complemented by the common bean, which has essential amino acids devoid in maize such as lysine. Lysine plays a critical role in post-translational modifications facilitated by enzymes Lysol hydroxylase and Lysol oxidase, which are directly involved in the synthesis and maturation of collagens [9]. Farmers cook and prepare maize with various forms of relish such as immature pods of beans and peas, pumpkin, indigenous and exotic vegetables. Besides maize being consumed by Basotho, it is also used to feed domestic animals as grains or plant residues during the winter, when feed resources are very scarce [1]. The economic importance of maize in Lesotho cannot be over-emphasized as afore-mentioned necessitating a boast in productivity, which will translate into increased national production. It is therefore imperative to identify factors that determine the optimum growth rate, good standability in the field, high grain yield and quality of maize crops in Lesotho.

These factors when applied accordingly will enable Lesotho to meet its requirement for maize and export surplus elsewhere. According to Anazco *et al.*, (2023) [9], the primary causes of low productivity and poor standability are low seed germination rate and emergence of weak seedling above the soil surface. Reed *et al.,* (2022) highlighted that seed germination and quality tests are performed in the laboratory before the seed is released to the farmers for sale with a germination percentage of 85%, which must be declared officially on the label. In Lesotho, such seeds with declared germination percentages result in low germination rates and weak seedling emergence above the soil surface in the field. The low germination emergence rate is attributed to the time elapsed from planting to emergence above the soil surface. Longer elapsed period results in low germination, which in turn culminate into poor crop stand. It is only through seed priming that germination rate and period can be enhanced, which triggers germination mechanism and processes [10], [11]. Seed priming is crucial as the main source of water for germinating seed and producing stronger seedlings where soil moisture is inadequate to initiate a germination process [12]. Insufficient soil moisture can contribute to delay or uneven germination, resulting in poor seedling establishment and crop yield [13]. Several studies validate the notion that when maize seeds are soaked in water before sowing, germination is enhanced, thus such practice increases the chances of growing faster than when such a method is not applied at all [14], [15]. Besides, many researchers discovered that certain chemical compounds are more potent in enhancing germination than pure distilled water when proper procedure is followed and modified accordingly [16], [17]. The seed priming methods such as hydro-priming, halo-priming, osmo-priming and solid matrix priming were introduced and adopted to enhance seed germination elsewhere [18], [19]. Hence, the study explored the effects of different seed priming chemicals on the germination and seedling growth rate of maize (*Zea Mays L.*). Specific objective of the study was to (i) identify the most potent chemical compounds that enhance high germination and seedling growth rate of maize.

II. MATERIALS AND METHODS

2.1 Study Area:

The study was conducted in the National University of Lesotho, Faculty of Agriculture, in the Department of Crop Science at the Roma Valley. The National University of Lesotho is domiciled approximately 34km south east of Maseru, the capital town of Lesotho. The coordinates of the University are 29^0 26’ 48 South latitude and 27^0 42’ 29 East longitudes with an altitude of 1,610m above sea level. The experiment was undertaken in the laboratory thereof.

2.2 Experimental Design:

Maize seed cultivar of PAN 12 bred by PANNAR Seed Company was obtained in the Department of Crop Science at the National University of Lesotho. This cultivar was the only one used for an experiment. Completely Randomized Design with three replications of four treatments was applied. Four seed-priming chemical compounds (treatments) were used to determine their potential to enhance seed germination, each tested at different concentration levels. The compounds were Indole butyric acid (IBA), 1% Calcium chloride ($CaCl_2$), Sodium chloride (NaCl) and copper sulphate ($CuSO_4$) having different volumes of distilled water such as 100ml and 250ml respectively, and distilled water was used as a control. Healthy maize seeds were collected and sterilized for 5 minutes using 2% sodium hypochlorite and washed thoroughly with distilled water. A total number of 570 seeds of maize were placed in 57 Petri dishes, each bowl containing 10 maize seeds. PAN 12 cultivar of maize seeds commonly used by farmers was used for this study. Three replications were used for priming chemical compounds. Several methods mentioned were applied below following procedures by respective authorities.

2.3 Priming with Distilled Water (H2O) (Hydro-priming):

2.3.1 Procedure:

The procedure described by Forti *et al*., (2020) and Heydecker (1973) [20], [21] for seed priming with distilled water was adopted in this study. The total number of 570 seeds were soaked with distilled water for 24 hours, after which were dried with a paper towel and placed in petri dishes. Within each petri dish, 10 maize seeds were placed and transferred to the growth chamber set at 24^0C. The light intensity of 61.2 lux was provided both day and night to provide consistency; particularly where seeds require light to trigger germination through phytochromes, with 70-80% relative humidity. Distilled water was applied regularly to the seeds until the seeds displayed sprouting. After 14 days, all parameters such as germination percentage, germination index, coleoptile, plumule length, radicle length, plumule fresh weight, radicle fresh weight, plumule dry weight, and radicle dry weight measurements were recorded.

2.4 Priming with Indole butyric acid:

2.4.1 Procedure:

The procedure outlined by Banerjee and Roychoudhury (2018) [22] for seed priming with indole butyric acid was adopted in this study. Indole Butyric Acid of the following magnitudes were weighed; 0, 37.5mg, 75mg and 112,5mg, and after which they were transferred to individual 1000ml volumetric flasks. An amount of 200ml distilled water was added to each flask and mixed thoroughly. A magnetic sterilizer was used to mix butyric acid until dissolved, and then distilled water was added to the top mark of a volumetric flask [23]. Seeds were then placed in Petri dishes according to the sample size (10 seeds per petri dish), four concentrations, and three replications of each concentration. A set of 12 petri dishes containing 10 seeds were soaked with different concentrations of Indole Butyric Acid (0, 37.5mg, 75mg, and 112,5mg) for 24 hours. After which they were removed, dried and put back to their respective petri dishes. The petri dishes were transferred to the growth chamber set at 25ºC with a relative humidity of 70-80% and the light intensity was 61.2 lux. The seeds were watered with the distilled water every day until day 7. The seed germination was recorded daily at a certain time for 7 days. After 7 days, the coleoptile length of all germinated seeds was measured followed by other parameters [23].

2.5 Priming with Calcium Chloride (CaCl2) (Osmo-priming):

2.5.1 Procedure:

The method adopted followed that of Di Girolamo and Barbanti (2019) [24] for seed priming with Calcium chloride whereby 1% calcium solution and 10g calcium salt were placed in a measuring flask with a volume made up to 1000ml with distilled water. Distilled water was utilized to wash selected seeds, while subsequently dipping them into sodium hypochlorite 0.05% solution for 5 minutes for surface sterilization. Seeds were then dried at room temperature up to moisture content <10% on a dry weight basis of the seeds following standard conditions for seed storage [25]. Seeds were immersed in distilled water to regulate hydro priming and halo priming (1% $CaCl_2$) each for 12, 18, 24 and 30hrs respectively, as per treatments put separately at room temperature. Ten seeds were placed in petri dishes of double layers of Whatman no.5 filter paper, moistened with 5ml distilled water for up to 7 days. Each priming treatment was replicated three times in a completely randomized design (CRD). Then petri dishes were transferred into the growth chamber under controlled conditions set at 25^0 C with 60% relative humidity and 61.2 lux as light intensity. Upon germination, seedlings were counted for two weeks. The number of normal seedlings was recorded according to the international seed testing agency [26]. Other parameters such as germination percentage, germination index, radical and plumule length, fresh and dry weight of radical and plumule finally the Coleoptile were recorded.

2.6 Priming with Sodium Chloride (NaCl) (Osmo-Priming):

2.6.1 Procedure:

The procedure developed by Rajpar *et al.* (2006) and Toklu *et al*. (2015) [27], [28] for seed priming using sodium chloride was also adopted in this study. The following amounts of Sodium chloride were weighed (2, 5, 10, and 15g) to prepare different concentrations. Each concentration was placed into a measuring flask and the volume was made up to 1000ml with distilled water. Seeds were then sterilized by dipping maize seeds into sodium hypochlorite 0.05% solution for 5min, removed, and rinsed thoroughly in distilled water. Seeds were soaked in 200ml of each of the concentrations for 24 hours, removed and rinsed with distilled water. The sample size of 10 seeds was planted on a moistened filter paper in each of the already labeled petri dishes. Each treatment was replicated three times and then transferred into a growth chamber at 25^0C temperature with 80% relative humidity and a light intensity of 61.2 lux. The germination count was taken daily for five days, while other

parameters were germination percentage, germination index, radical and plumule length, fresh and dry weight of radical and plumule finally the Coleoptile were also recorded.

2.7 Priming with Copper sulphate (CuSo4) (Osmo-priming):

2.7.1 Procedure:

The method followed was explained by Rajpar *et al*. (2006) and Toklu *et al*. (2015) [27], [28] for priming maize seeds using Copper sulphate. The following amounts of copper sulphate were prepared to develop different concentrations (20, 40, 60, and 80g). Each concentration was placed into a measuring flask and volume was made up to 100ml with distilled water. Seeds were then sterilized by dipping maize seeds into sodium hypochlorite 0.05% solution for (5min), removed and rinsed thoroughly in distilled water. Seeds were soaked in each concentration for 24 hours, removed and rinsed with distilled water. The sample size of 10 seeds was planted on a moistened filter paper in each of the already labeled petri dishes. Each concentration was replicated three times and then transferred into a growth chamber set at 25^0C temperature with 70-80% relative humidity and a light intensity of 61.2 lux. The germination count was taken daily for five days, while other parameters as afore-mentioned were measured for five days after the germination.

2.8 Data collection:

The following seed germination and seedlings parameters were measured; germination rate was measured from day 1 after planting until day 14. Other parameters such as germination percentage, germination index, radical length, plumule length, plumule fresh weight, dry weight, radical fresh weight, dry weight, and Coleoptile length depended on different methods adopted.

2.9 Data Analysis:

Data collected from the four procedures were separately analyzed using SPSS software (version 21) and subjected to ANOVA to establish the differences among the seed priming chemical compounds, after which mean separation using the least significant difference was performed at P<0.01 and P<0.05.

III. RESULTS AND DISCUSSIONS

3.1 Calcium Chloride as a Seed Primer:

Analysis of variance depicted in Table 1 showed a highly significant difference (P<0.01) among Calcium chloride priming durations on maize cultivar and the reaction of maize (PAN 12) evaluated for germination percentage, plumule fresh weight and radical fresh weight. A significant difference (P<0.05) was observed for germination index and radical dry weight. No significant difference was obtained for coleoptile length, plumule length and plumule dry weight.

TABLE 1
SUMMARIZED ANALYSIS OF VARIANCE FOR SEED GERMINATION PARAMETERS PRIMED WITH $CaCl_2$

Source of Variation	Df	Mean Square								
		Germination %	Germination index	Coleoptile length	Plumule length	Radicle length	Plumule fresh weight	Radicle fresh weight	Plumule dry weight	Radicle dry weight
Treatment	7	703.14**	7.54*	909.99	14149.91**	1604.95	2.35**	1.34**	0.51	0.01*
Error	16	126.83	1.50	555.42	3512.29	1011.29	0.58	0.10	0.01	0.03
Total	23	6951.33	76.81	15256.63	155246.00	2741.33	25.67	10.96	0.58	0.12

*****High Significant (P<0.01), *Significant (P<0.05)***

Table 2 showed that the highest germination percentages were 96% and 93% obtained from control (distilled water) at 24hrs and 18hrs durations, respectively. The germination percentage of 93% at 18hrs was the same as calcium chloride primed for 12hrs. The lowest germination percentage was 50% found on a control where seeds were soaked for 30 hours. The highest germination index of 7.9333 was expressed by control where seeds were primed for 24hrs, while the lowest germination seed index was 2.7333 found at 30hrs on a control. The germination index showed a grand mean of 4.9167. Coleoptile measured the longest length of 102.333mm, followed by 85mm when immersed in $Cacl_2$ for 18 hours. The shortest coleoptile length was

49.333mm on control soaked for 30hrs. The grand mean of coleoptile length stood at 72.1250mm. The longest plumule length was 334.6667mm where seeds were placed in $Cacl_2$ for 24 hours, while the shortest length was 139.3333mm obtained from control soaked for 12 hours. The grand mean for plumule length was 207mm captured from a control. Radicle length revealed a grand mean of 73.6667mm. The longest radical length was 110.6667mm obtained on duration of 24hrs, while the shortest radicle length was 53.6667mm found on control in 30hrs. Plumule fresh weight for calcium chloride had a grand mean of 2.8958, with the highest weight of 4.1667g and the lowest weight of 1.8000g obtained on a control for 24hrs and at $Cacl_2$ primed for 30hrs same as 30hrs on a control, respectively. The highest radicle fresh weight was 2.2333g on a control soaked for 24 hours. The grand mean of radicle fresh weight was 0.8500g. The lower radicle fresh weight found on $Cacl_2$ soaked for 30 hours was 0.2333g. The grand mean of plumule dry weight grand mean was detected to be 0.4417g with the highest weight of 0.6667g, and the lowest weight being 0.2667g, which were all obtained from the control within 24hrs and 30hrs, respectively. Finally, the radicle dry weight grand mean was 0.1083g. At 24hrs, on a control, 0.2333g showed as the highest weight, whereas at 30hrs of 1% $Cacl_2$, the lowest weight was 0.0333g.

TABLE 2
MEANS FOR $CaCl_2$ DURATIONS

Duration	Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
12hrs	93.33	5.37	67.00	205.00	66.33	3.70	.63	.57	.10
18hrs	86.67	5.37	85.00	277.67	103.00	3.40	.70	.50	.10
24hrs	76.67	5.77	83.00	214.00	66.00	3.23	.77	.43	.10
30hrs	76.00	3.27	73.00	148.00	46.67	1.80	.23	.30	.03
0.12hrs	90.00	4.73	61.67	139.33	60.00	2.23	.43	.40	.10
0.18hrs	93.33	4.83	55.67	187.00	83.00	2.83	1.43	.40	.13
0.24hrs	96.66	7.93	102.33	334.67	110.67	4.17	2.23	.67	.23
0.30hrs	50.00	2.73	49.33	150.33	53.67	1.80	.37	.27	.07
Grand mean	82.83	4.92	72.13	207.00	73.67	2.8958	.85	.44	.11
CV	13.60	24.91	32.68	28.63	43.17	26.25	37.28	25.73	49.85
LSD	19.49	2.12	40.79	102.58	55.04	1.32	0.55	0.19	0.09

Priming seeds for approximately 24 hours with distilled water improved the germination parameters. This implied that the absence of inhibiting factors can be observed because the seeds absorbed more water which assisted in speeding up the enzyme activities. When the enzyme activities were activated, they easily hydrolyzed starch, protein and lipids into simplex compounds to provide energy for the growing embryo. The above experimental results correlated with Shrestha *et al*. (2019) [29] who revealed that water was necessary for enzymatic reactions and the mobilization of seed storage reserves, including lipids, carbohydrates, and proteins. Similarly, Chen *et al*., (2022) [30] induced germination in sorghum using $Cacl_2$. As shown in Table 2 above, the following germination parameters: 1) plumule length, 2) radicle length, 3) plumule fresh weight, 4) radicle fresh weight, 5) plumule dry weight, and 6) radicle dry weight showed different germination increases, for instance, $CaCl_2$ for 12hrs, 18hrs, and 24hrs. This result conformed to Yousof (2013) [31] who reported the significance of halo priming between 12hrs and 24hrs, while water uptake was increased when the priming time was prolonged for 24hrs. When priming time for 36 hours, the osmotic potential to (-1.25mpa) water uptake decreased. Generally, $CaCl_2$ induced the germination processes it helped in killing or neutralizing toxic substances found in the soil [32].

3.2 Sodium Chloride as a Seed Primer:

Table 3 below indicated analysis of variances where there was a highly significant difference (P<0.01) among sodium chloride concentrations on maize cultivar and the reaction of maize (PAN 12) evaluated for germination percentage, germination index, coleoptile, plumule length, radicle length, plumule fresh weight and radicle dry weight. No significant difference (P<0.05) was observed for plumule dry weight.

TABLE 3
SUMMARIZED ANALYSIS OF VARIANCE FOR SEED GERMINATION PARAMETERS PRIMED WITH NaCl.

Source of Variation	Df	Mean Square								
		Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
Treatment	4	1140.00**	1.37**	255.93**	474.17	1688.90**	.42**	.18**	.001	.003**
Error	10	80.00	.119	47.097	513.93	94.33	.099	.23	.003	.001
Total	14	5360.00	6.696	1494.40	7036.00	7698.93	2.66	.93	.036	.017

*****High Significant (P<0.01), *Significant (P<0.05)***

Table 4 below revealed that the highest germination percentages (83% and 60%) were obtained from 15g and 10g concentrations of sodium chloride, respectively. The lowest germination percentage was 33% found on 2g concentration of sodium chloride. The highest germination index of 3.03 was observed where the seed was soaked with 15g sodium chloride solution. Moreover, the lowest germination seed index was 1.36 in a 2g concentration of sodium chloride. The germination index showed a grand mean of 2.1600. Coleoptile measured the longest length of 43.67mm where seeds were soaked in 5g sodium chloride solution, while the shortest length was 23.33mm obtained from a control. The grand mean of coleoptile length stood at 33.80mm. The longest plumule length was 85.00mm found on the concentration of 10g sodium chloride, while the shortest length was 54.00mm obtained from a 2g concentration of sodium chloride. The grand mean for plumule length was 69.00mm. Radicle length revealed a grand mean of 72.26mm. The longest radicle length was 97.33mm followed by 87.67mm obtained from 15g sodium chloride concentration and on a control respectively. The shortest radicle length was 38.33mm found on where seeds were soaked with 2g sodium chloride solution. The plumule fresh weight had a grand mean of 0.820g, with the highest weight of 1.20g found on 15g of sodium chloride concentration solution, and the lowest weight of 0.23g was obtained from 2g sodium chloride concentration. The highest radicle fresh weight was 0.80g obtained from where the seed was soaked with 10g sodium chloride solution with the lowest weight of 0.20g found on 2g concentration of sodium chloride solution. The grand mean of radicle fresh weight was 0.566g. The grand mean for plumule dry weight was 0.160g, with the highest weight of 0.167g obtained on a control, 2g, 5g, and 15g of NaCl concentration solution. The lowest plumule fresh weight was 0.133g found on 10g NaCl solution. Finally, the radicle dry weight grand mean was 0.113g. The highest radicle dry weight was 0.167g obtained on control, with the lowest weight of 0.100g found on all four concentrations of NaCl solution.

TABLE 4
MEANS FOR NaCl CONCENTRATION

Concentration of NaCl	Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
0	53.3333	2.2000	23.3333	60.3333	87.6667	1.0667	.5667	.1667	.1667
2g	33.3333	1.3667	24.6667	54.0000	38.3333	.2333	.2000	.1667	.1000
5g	40.0000	1.6333	43.6667	77.6667	58.6667	.7333	.5000	.1667	.1000
10g	60.0000	2.5667	40.0000	85.0000	79.3333	.8667	.8000	.1333	.1000
15g	83.3333	3.0333	37.3333	68.0000	97.3333	1.2000	.7667	.1667	.1000
Grand mean	54.0000	2.1600	33.8000	50.47	69.00	.8200	.5667	.1600	.1133
CV	16.56	15.95	20.30	30.32	32.86	38.31	26.96	36.08	22.78
LSD	16.27	0.63	12.48	27.84	31.24	0.57	0.28	0.11	0.05

The above table highlights that there was a significant difference in the germination process, which showed an impact on germination parameters such as 1) germination percentage, 2) germination index, 3) radicle length, 4) plumule fresh weight, 5) plumule dry weight and 6) radicle dry weights where seeds were primed with 15g concentration of sodium chloride solution. Also, in a 10g concentration solution, there was a significant difference in coleoptile, plumule length and radicle fresh weight. However, the results of this study revealed that no was significant reaction of sodium chloride as it did not show any negative impact on metabolic processes within the seed, implying no observation of osmotic stress. Instead, more water was absorbed which initiated the enzyme activity to resume. These results are in line with Marthandan *et al*. (2020) [33]and Gebreegziabher (2017) [34] who highlighted that pre-sowing treatment of maize seeds with sodium salt can initiate various reactions, which included an early metabolic process, activated various enzymes, and enhanced physiological activities inside the seed. Moreover, Naim *et al.* (2012) [35] reported that seed germination percentage was likely to be increased by a low level of salinity. In general, this study showed that salt stress at 2g, enhanced germination percentage, and all the parameters were salt sensitive at 5g, 10g, and 15g. Pannar cultivar had germinated well under salt stress. This meant that the Pannar 12 cultivar, which was used in this study was salt tolerant during the germination process as per se the result. This result was consistent with Naim *et al*. (2012) [35] who revealed that crop cultivars germinated effectively under salt stress.

3.3 Copper Sulphate as a Seed Primer:

Table 5 revealed a highly significant difference ($P<0.01$) among copper sulphate concentration on maize cultivar and the reaction of maize (PAN 12) evaluated for germination percentage, germination index, coleoptile, plumule length, plumule fresh weight, and radicle fresh weight. A significant difference ($P<0.05$) was observed only for radicle length. No significant difference was found between plumule dry weight and radicle dry weight.

TABLE 5
SUMMARIZED ANALYSIS OF VARIANCE FOR SEED GERMINATION PARAMETERS PRIMED WITH $CuSO_4$

Source of Variation	Df	Mean Square								
		Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
Treatment	4	1623.33**	3.82**	570.83**	441.10**	951.23*	.097**	.199**	.004	.004
Error	10	126.67	.09	24.67	33.73	264.00	.009	.014	.002	.001
Total	14	7760.00	16.14	2530.00	2101.73	6444.93	.476	.936	.037	.029

Table 6 indicated the highest germination percentage (70%) found in a control (distilled water). The lowest germination percentage (13.3%) was recorded on 80mg of copper sulphate solution. The highest germination index was 3.167 obtained from control, while the lowest germination index was 0.400 found on 80mg with a grand mean of 1.260. The coleoptile had the longest length of 45.33mm obtained from 40mg copper sulphate and the shortest length was 10.00mm obtained from 80mg copper sulphate solution. The grand mean was 23.00. The longest plumule length was 41.00mm found on control with the shortest length of 12.66mm found on 80mg of copper sulphate. The grand mean was 27.46. The longest radicle length was 60.66mm found where distilled water was used as a control with the shortest length of 16.33mm obtained from 80mg copper sulphate solution. The grand mean was 33.93. Plumule fresh weight for copper sulphate has a grand mean of 0.360 with the highest weight of 0.566g obtained from control and the lowest weight of 0.166g found on 80mg. The highest radicle fresh weight was 0.86g on control with the lowest weight of 0.20g obtained from 80mg. The radicle fresh weight grand mean was 0.44. The plumule dry weight grand mean was 0.467g with the highest weight of 0.03g obtained on a control. The lowest weight, that is, 0.00 was attained from 20mg copper sulphate solution. Lastly, the radicle dry weight grand mean is 0.07g with the highest weight of 0.10g obtained from control and 40mg while the lowest radicle dry weight was 0.03g obtained from 80mg and 20mg copper sulphate solution.

TABLE 6
MEANS FOR $CuSO_4$ CONCENTRATIONS

Concentration of $CuSO_4$	Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
0	70.00	3.17	26.33	41.00	60.67	.57	.87	.03	.10
20g	26.67	.83	17.67	22.67	23.00	.23	.37	.00	.03
40g	43.33	1.37	45.33	39.00	42.67	.53	.47	.10	.10
60g	16.67	.53	15.67	22.00	27.00	.30	.30	.07	.10
80g	13.33	.40	10.00	12.67	16.33	.17	.20	.03	.03
Grand mean	34.00	1.27	22.87	24.87	32.80	.29	.36	.05	.07
CV	27.38	25.49	21.98	18.72	51.18	23.29	42.43	95.83	49.79
LSD	16.94	0.59	9.14	8.47	30.54	0.12	0.28	0.08	0.07

Table 6 above expressed a significant difference in the germination process where maize seed was treated with distilled water that improved most of the germination parameters as follows: 1) germination percentage, 2) germination index, 3) plumule length, 4) radicle length, 5) plumule fresh weight, 6) radicle fresh weight and 7) radicle dry weight. This improvement was because of the free osmotic potential of water. Water plays a significant role by enhancing the activities of enzymes which helped to break the stored sugars into simplest sugars to provide energy for embryo development. El-Sanatawy *et al*. (2021) [36] showed that seed priming with water enhanced seed yield in maize. There was also a significant difference in coleoptile, plumule dry weight and radicle dry weight where maize seed was primed with a 40mg of copper sulphate solution. This implied that an increase of copper sulphate slightly increased the germination process and later decreased the germination process when the concentration up-surged above 40mg. These results conformed with Akram *et al*. (2020) [37] who reported that seed priming with 40 µM of $CuSO_4$ produced exceptional results but priming with $CuSO_4$ above 40 µM started a decline in plant growth and reached the lowest point when seeds were primed with 80 µM $CuSO_4$ because at higher concentration, seedling weight was reduced due to toxic effects of copper.

3.4 Indole Butyric Acid as a Seed Primer:

Analysis of variance depicted in Table 7 showed no significant difference ($P<0.01$) among indole butyric acid on maize cultivar and the reaction of maize (PAN 12) evaluated on all parameters. A significant difference ($P<0.05$) was also not observed on all parameters.

TABLE 7
SUMMARIZED ANALYSIS OF VARIANCE FOR SEED GERMINATION PARAMETERS WITH IBA

Source of Variation	Df	Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
Treatment	3	319.444	.512	874.972	1312.667	1237.889	.139	.163	.002	.003
Error	8	291.667	.418	496.750	931.833	1148.250	.108	.127	.008	.003
Total	11	3291.667	4.872	6598.917	11392.667	12899.667	1.277	1.503	.067	.029

Table 8 exhibited the highest germination percentage (50%) obtained from 75g of indole butyric acid solution, with the lowest of 26.7% found at 37.5g of butyric acid concentration. The grand mean value was 40.83. The highest germination index of 1.86 was recorded on the concentration of 112.5g and 75g of indole butyric acid while the lowest was 1.00 obtained from 37,5g of butyric acid. The grand mean was 1.62. The longest coleoptile obtained from 112.5g indole was 70.33mm with the shortest length of 35mm obtained from 75g of indole butyric acid solution. The grand mean was 49.92mm. The longest plumule length was 86mm where seeds were soaked with 112.5g indole butyric acid. The current study showed the shortest plumule length (37mm) was obtained from a 75g concentration of butyric acid with a grand mean of 61.33mm. The indole butyric acid grand

mean for radicle length was 62.83mm, with the longest length of 88.33 found on a control with 45.33 as the shortest length obtained from 37.5g butyric acid solution. The plumule fresh weight of indole butyric acid has a grand mean of 0.62g. The highest weight was 0.80g obtained from 112.5g butyric acid concentration with the lowest length of 0.33 found from 37.5g indole solution. The highest radicle fresh weight was 0.70g found on the 112.5g solution of indole butyric acid and the lowest was 0.20 obtained from 37.5g of indole acid. The grand mean weight for indole acid was 0.48g. Plumule dry weight had the highest weight of 0.16g obtained from control with the lowest weight of 0.10g found from 37.5g of indole butyric acid solution and the grand mean value was 0.13g. Finally, the highest radicle dry weight where seeds were soaked with 112.5g of indole was 0.10g with the lowest value of 0.03g found on a control and 37.5g concentration while the grand mean was 0.05. Mean values are presented in Table 8 below. Contrarily, Kumari *et al*, (2017) [38] found a significant difference in seed germination and seedling vigor in maize when comparing effects of halo and hormonal priming in India. Again, Mahmood *et al*. (2016) [39] conducted a research priming seeds of maize using plant growth promoting rhizobacteria and obtained a high seed germination rate and seedling growth. In line with previous researchers, Mustafa and Khan (2015) [40] investigated effects of indole butyric acid on sugar-cane root development and found to increase root proliferation, diameter and length.

TABLE 8
MEANS FOR IBA CONCENTRATIONS

Concentration of Indole Butyric Acid	Germination %	Germination Index	Coleoptile	Plumule Length	Radicle Length	Plumule Fresh Weight	Radicle Fresh Weight	Plumule Dry Weight	Radicle Dry Weight
0	40.0000	1.7667	57.6667	69.0000	88.3333	.7667	.6333	.1667	.0333
37.5g	26.6667	1.0000	36.6667	53.0000	45.3333	.3333	.2000	.1000	.0333
75g	50.0000	1.8333	35.0000	37.3333	47.6667	.5667	.3667	.1333	.0667
112.5g	46.6667	1.8667	70.3333	86.000	70.0000	.8000	.7000	.1333	.1000
Grand Mean	40.83	1.62	49.92	61.33	62.83	.62	.48	.13	.058
CV	39.15	36.01	51.44	57.28	59.91	56.69	81.84	70.71	80.81
LSD	31.94	1.16	51.30	70.19	75.20	0.69	0.78	0.19	0.09

IV. CONCLUSION AND RECOMMENDATION

Among the four chemical compounds evaluated for potency to enhance both germination and seedling parameters, distilled water was found to be the best and is recommended. It is followed by Sodium chloride, Calcium chloride and lastly Copper sulphate. While Indole-acetic acid seemed to have no perceptible influence on all germination and seedling parameters implying that it should not be used at all to enhance germination and seedling growth in maize to be specific. The procedure developed by Forti *et al*. (2020) [20] using distilled water superseded the other three, followed by Raiparet *et al* (2006) and Toklu *et al*., (2015) [28]using sodium chloride, then Di Girolamo and Barbanti (2012) [24] with calcium chloride and lastly, copper sulphate by Baneijee and Roychoudhury (2018) [22]. Four differing concentrations of each compound were applied.

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