



RESPONSE OF RABI MAIZE CROP TO SEED INVIGORATION WITH MAGNESIUM NITRATE AND DISTILLED WATER

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SUMMARY

Seed invigoration treatment with $Mg(NO_3)_2$ and distilled water in maize varieties KHI-536, CM-211 and CM-119 significantly improved seedling emergence in field conditions, vegetative growth (plant height, length of roots and shoots, no. of leaves, leaf area plant⁻¹, fresh and dry weights of root and shoot) relative water content of shoot and root, circumference of shoot and nitrate reductase activity (in leaves at or up to 54 DAS) and yield attributes (like length of cobs, circumference of cob, No. of cobs per plant, No. of grains per cob, yield plant⁻¹, yield ha⁻¹ and test weight). Seed treatment with $Mg(NO_3)_2$ was most effective followed by distilled water treated and directly field sown untreated control seeds. Further, the grain nitrogen was found to improve with $Mg(NO_3)_2$ treatment over distilled water and control.

Key words: LAI, magnesium nitrate, nitrate reductase, nitrogen content, seed invigoration, yield attributes

INTRODUCTION

Maize is one of the most important cereals of the world after wheat and rice. In order to increase crop productivity, seed invigoration/ priming can be useful as it reduces the germination time, improve germination rate and seedling stand. Earlier studies of Kidd and West (1918) have indicated that factors which influence the plant during the early stages of development may also profoundly influence the subsequent life history and ultimately increase the yield of crop also. Priming has improved seedling establishment in horticultural (Khan 1992, Jett *et al.* 1996) and field crops like wheat, maize and rice (Chawdhary and Baset 1994, Basra *et al.* 2002 a and b, Farooq *et al.* 2004) respectively. Seed invigoration is also useful under salinity (Muhyaddin and Weibe, 1989), high and low temperature (Bradford *et al.* 1990) and high (Lee *et*

al. 1998, Ruan *et al.* 2002) and low soil moisture contents (Du and Tuong 2002).

Osmopriming / soaking has been done by using distilled water (Bradford 1986) or some chemicals (Ruan *et al.* 2002) which improves seedling vigor index, seedling establishment, yield (Du and Tuong 2002) and grain quality. Kiss (1979) reported that maize seed treatment with $MgSO_4$ and magnesium citrate improved germination via activating various enzymes of respiratory cycle and nitrogen metabolism. While, Fecenko and Franeakova (1980) observed that $Mg(NO_3)_2$ when applied to spring barley decreased the soluble nitrogen of grain. Further, Bose and Tandon (1991) also reported that pre-sowing soaking (osmopriming) with $Mg(NO_3)_2$ promote germination of maize seeds. Bose and Mishra (1992) observed that osmopriming with $Mg(NO_3)_2$ improved the fresh and dry weights, total nitrogen content and nitrate

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reductase activity of root and shoot and also the plant height in wheat genotypes. The present study was therefore, aimed to see the performance of maize varieties by invigorating its seeds with $Mg(NO_3)_2$ and distilled water.

MATERIALS AND METHODS

In the present investigation the maize (*Zea mays* L. varieties; V_1 = KHI-536, V_2 = CM-211, V_3 = CM-119) seeds were sown in *rabi* season 2004 in a randomized block design (R.B.D. factorial) with three replications according to recommended practices. Nitrogen fertilizer was given @ 150 kg N/ha, half dose of nitrogen at knee-high stage and remaining half of the N at tasseling stage. P and K were applied @ 60 kg P_2O_5 / ha and 40 kg K_2O /ha as basal. Before sowing, seeds were surface sterilized with 0.1% $HgCl_2$ (Mercuric chloride) solution for two minutes and then thoroughly washed with distilled water for 5 to 6 times. Seeds of the three varieties were treated with $Mg(NO_3)_2$ (7.5 mM) and distilled water (DW) respectively for 20 hours and the untreated seeds were used as control and sown in the field after surface sterilization without any soaking treatment. $Mg(NO_3)_2$ and DW treated seeds were kept for another four hours in shade for priming treatment.

The physio-morphological observations and yield attributes were measured at 9, 11, 13 and 54 Days after sowing (DAS) and at harvest. Seedling emergence in field was estimated from thirty six seeds sown in each

row. Seedling emergence was recorded at 9, 11 and 13 DAS; and percent emergence was calculated as follows:

$$\text{Seedling emergence (\%)} = \frac{\text{No. of seeds emerged}}{\text{Total seeds used for sowing}} \times 100$$

Root length of the longest root was measured from its physiological base to tip by using scale after proper washing of roots. Circumference of stem, present near the soil surface was measured with thread. Leaf area was measured using leaf area meter (Model – Systronic Leaf Area Meter 211). Dry weight of roots and shoots was obtained by drying at 60 to 70°C till constant weight was achieved. Nitrate reductase activity of leaves, protein and nitrogen contents in grains were measured by using the method of Srivastava (1974), Lowry *et al* (1951) and Lang (1958) respectively.

RESULTS AND DISCUSSION

Seedling emergence percentage in the field of all the three studied varieties i.e. KHI-536 (V_1), CM-211 (V_2) and CM-119 (V_3) improved in the treated seeds in respect to untreated one (control) (Table 1). Seeds treated with $Mg(NO_3)_2$ showed maximum seedling emergence percentage than control at 9, 11 and 13 DAS. The morphological parameters like plant height, length of longest root, circumference of shoot, number of leaves, leaf area (LA), shoot and root weight and their relative water content (RWC) at 54 DAS are presented in table 1, 2 and 3 and fig.1 and 2. All these parameters

Table 1. Effect of pre-sowing soaking treatment with distilled water and magnesium nitrate to the seeds on seedling emergence percentage (germination %) and height per plant up to collar (cm) of maize varieties.

Parameters	Seedling emergence percentage									54 (DAS)		
	9 DAS			11 DAS			13 DAS			Plant height (cm)		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
Control (T_1)	85.18	80.55	86.11	92.59	86.72	84.25	87.83	87.03	86.10	6.52	7.33	6.11
Distilled water (T_2)	88.88	82.40	88.88	90.12	88.51	89.19	87.77	87.96	90.74	7.92	7.71	7.50
$Mg(NO_3)_2$ (T_3)	91.66	95.00	92.58	91.35	93.51	93.51	95.37	94.44	95.37	8.61	8.25	9.36
SEm±	2.58	2.58	4.47	1.91	1.91	3.31	2.13	2.13	3.69	0.46	0.46	0.79
C. D. at 5%	5.45	5.45	9.44	4.04	4.04	7.00	4.49	4.49	7.78	0.96	0.96	1.67

V_1 = KHI-536, V_2 = CM-211, V_3 = CM-119

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Table 2. Effect of pre-sowing soaking treatment with distilled water and magnesium nitrate to the seeds on length of root per plant (cm), circumference of shoot (cm), no. of leaves per plant and leaf area per plant (cm²) of maize varieties 54 DAS

Parameters	Length of root per plant (cm)			Circumference of root (cm)			No. of leaves per plant			Leaf area per plant (cm ²)		
	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃
Control (T ₁)	10.66	10.66	9.10	2.64	3.28	2.73	6.27	6.3	6.61	47.36	93.06	159.36
Distilled water (T ₂)	15.66	15.66	13.00	3.07	3.29	3.28	6.44	6.77	6.72	160.76	189.96	175.16
Mg(NO ₃) ₂ (T ₃)	17.16	17.16	17.16	3.27	3.37	3.41	7.16	7.61	7.33	282.76	228.00	220.10
SEm±	1.40	1.40	2.43	0.10	0.10	0.17	0.28	0.28	0.50	28.79	28.79	49.88
C. D. at 5%	2.96	2.96	5.13	0.21	0.21	0.36	0.61	0.61	1.05	60.76	60.76	105.25

Table 3. Effect of pre-sowing soaking treatment with distilled water and magnesium nitrate to the seeds on shoot fresh weight(g), root fresh weight(g), shoot dry weight (g), root dry weight (g) of maize varieties 54 DAS

Parameters	Shoot fresh weight (g)			Root fresh weight			Shoot dry weight (g)			Root dry weight (g)		
	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃
Control (T ₁)	2.353	3.303	4.477	0.853	1.207	1.303	0.18	0.43	0.46	0.10	0.16	0.16
Distilled water (T ₂)	5.040	7.217	6.420	1.763	1.657	1.607	0.50	0.84	0.60	0.20	0.19	0.19
Mg(NO ₃) ₂ (T ₃)	14.003	9.553	10.503	2.753	2.097	2.253	1.41	0.86	0.91	0.31	0.22	0.23
SEm±	0.108	0.108	0.187	0.046	0.046	0.079	0.22	0.22	0.38	0.04	0.04	0.07
C.D. at 5%	0.313	0.313	0.542	0.097	0.097	0.167	0.46	0.46	0.80	0.09	0.09	0.16

showed improvement in Mg(NO₃)₂ invigorated seeds followed by DW treated one; control was always found poor in this respect. Maximum number of leaves per plant was found in variety CM-119; but the treated sets improved the number of leaves over control in each and every variety; however, maximum response was represented by variety CM-211 in respect to Mg(NO₃)₂ treated sets followed by distilled water. Maximum leaf area (LA) per plant was found in variety CM-119 followed by CM-211 and KHI-536; plants raised from seeds invigorated with Mg(NO₃)₂ showed an enormous hike in LA improvement over DW treatment and control. Further, the maximum increment in LA was noted in variety KHI-536 in comparison to varieties CM-211 and CM-119. Fresh and dry weights of shoots and roots also increased maximum with Mg(NO₃)₂ seed invigoration and that was followed by DW treated and non-treated

control plants (Table 3). But in case of RWC of shoot (Fig. 1) of variety KHI-536, DW treated sets showed maximum value and that was slightly more than Mg(NO₃)₂ treated sets, on the other hand rest of two varieties represented higher value of RWC in Mg(NO₃)₂

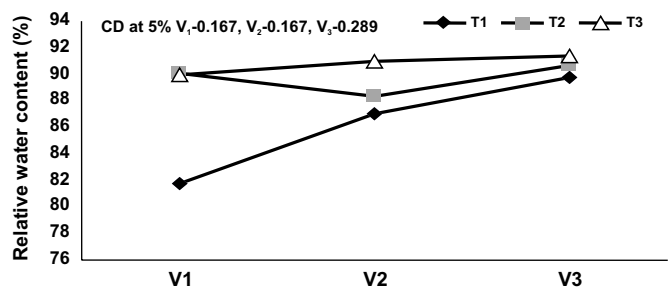


Fig. 1. Effect of presowing-soaking treatment with distilled water and magnesium nitrate on relative water content of shoot in maize plants

osmoprimed sets followed by DW and control one. Variety CM-119 performed better for both shoots and roots regarding RWC (Fig. 1 & 2).

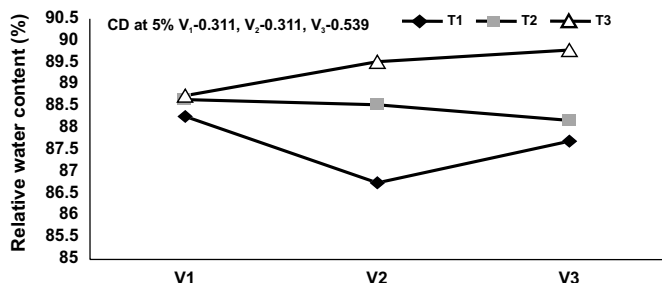


Fig. 2. Effect of presowing-soaking treatment with distilled water and magnesium nitrate on relative water content of root in maize plants

Nitrate reductase activities (NRA) of the leaves were measured at 18, 36 and 54 DAS (Fig. 3). The NRA was found maximum in Mg(NO₃)₂ treated sets in respect to DW treatment (hydropriming) and control one; however, up to 36 DAS period the difference was not very prominent but at 54 DAS in KHI-536 and CM-119 Mg(NO₃)₂ invigorated seeds showed a promising enhancement in NRA over DW treatment where as the control plants showed always an inferior performance than both the former mentioned treatments (Fig. 3).

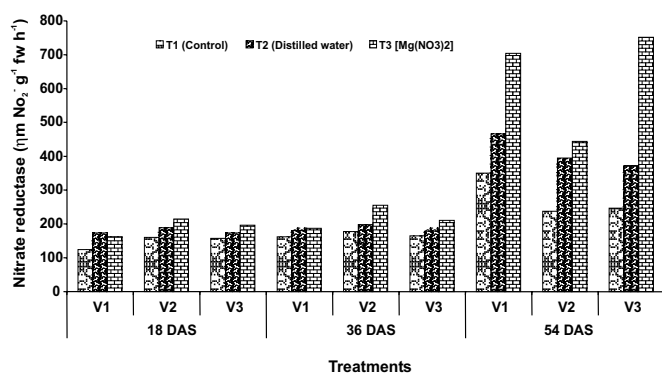


Fig. 3. Effect of pre-sowing seed soaking treatment with distilled water and magnesium nitrate on nitrate reductase activity in the leaves of maize varieties. (CD at 5% : 18 DAS: V1- 48.45, V2- 24.53 and V3- 83.93; 36 DAS: V1- 24.53, V2- 48.45 and V3- 42.49; 54 DAS:V1- 118.37, V2-118.37 and V3- 205.02)

Plants raised from treated seeds showed an improvement in length as well as circumference of cob and major improvement was noted with Mg(NO₃)₂

treatment (Table 4). Seed yield plant⁻¹, No. of grains plant⁻¹, No. of cobs plant⁻¹, yield ha⁻¹ and test weight enhanced with seed invigoration treatment with Mg(NO₃)₂ followed by DW over control. Also, the Mg(NO₃)₂ treated plants had one cob (filled with seeds) and majority of these plants showed the formation of two cobs (Table 5) but the cob present at lower portion of the plant was without grain. Variety CM-211 represented more yield (38.19%) increment than the other two varieties KHI-536 (26.26%), and CM-119 (16.54%) while the seeds were invigorated with Mg(NO₃)₂ in respect to control. The control plants showed poor performance with all the above mentioned parameters of yield as well as contained only one cob per plant (Table 5). The grains from treated seeds had more nitrogen and protein contents compared to untreated control (Fig. 4 and 5). Among the treatments Mg(NO₃)₂ treatment showed better performance and that was followed by DW treated and control sets.

Table 4. Effect of pre-sowing soaking treatment with distilled water and magnesium nitrate to the seeds on length (cm) and circumference of cobs (cm) of maize varieties.

Parameters	Length of cob (cm)			Circumference of cob (cm)		
	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃
Control (T ₁)	13.99	13.22	14.14	13.68	12.89	13.37
Distilled water (T ₂)	14.58	13.83	14.53	14.25	14.00	13.79
Mg(NO ₃) ₂ (T ₃)	16.36	14.75	15.44	14.89	14.58	14.66
SEM±	0.41	0.41	0.72	0.31	0.31	0.54
C. D. at 5%	0.87	0.87	1.52	0.66	0.66	1.14

The result of present investigation suggests that seed invigoration with Mg(NO₃)₂ and DW showed an improvement in the germination hence increases the seedling emergence percentage in field in all the three studied varieties of maize. Bose and Tandon (1991) also showed that seed invigoration with Mg(NO₃)₂ improved germination percentage and nitrogen content in growing seedlings, however the response depends on the variety also. Further, the result of present investigation showed an increase in vegetative growth (height of plant, circumference of shoot and length of root) in treated sets

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Table 5. Effect of pre-sowing soaking treatment with distilled water and magnesium nitrate to the seeds on seed yield plant⁻¹ (g), no. of grain cob⁻¹, no. of cob plant⁻¹, yield /ha (q) and test weight (g) of maize varieties at maturity

Parameters	Seed yield plant ⁻¹ (g)			No. of grain cob ⁻¹			No. of cob plant ⁻¹			Test weight (g)			Yield ha ⁻¹ (Q)		
	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃	V ₁	V ₂	V ₃
Control (T1)	90.83	70.65	93.66	354.89	310.58	399.39	1	1	1	60.55	47.10	62.44	255.94	227.48	234.51
Distilled water (T2)	112.50	74.24	97.22	422.09	313.66	396.59	1	1	1	75.00	49.49	64.81	266.52	236.69	245.14
Mg(NO ₃) ₂ (T3)	114.68	97.64	109.16	425.78	395.50	436.94	1+0.89*	1+0.61*	1+0.94*	76.45	65.09	72.77	269.34	246.98	249.83
SEm±	6.166	6.166	10.680	2.276	2.276	3.943	0.068	0.068	0.118	1.176	1.176	2.036	9.95	9.95	17.23
C. D. at 5%	13.01	13.01	22.53	4.803	4.803	8.319	0.143	0.143	0.248	2.480	2.480	4.296	20.99	20.99	36.36

*Cob without grains

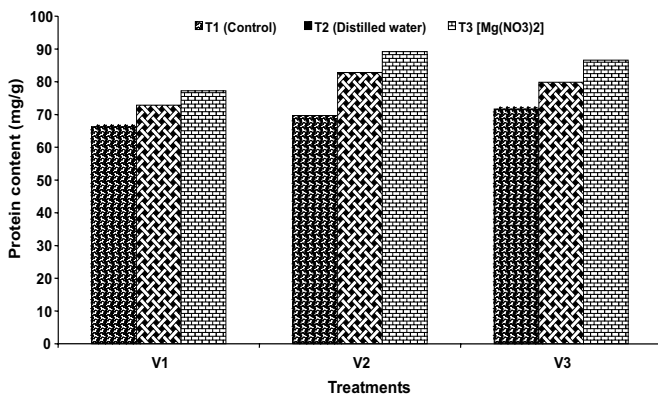


Fig. 4. Effect of pre-sowing seed soaking treatment with distilled water and magnesium nitrate on protein content (mg/g) in seeds of maize varieties. (CD at 5% = V1-6.82, V2-6.82 and V3-11.81)

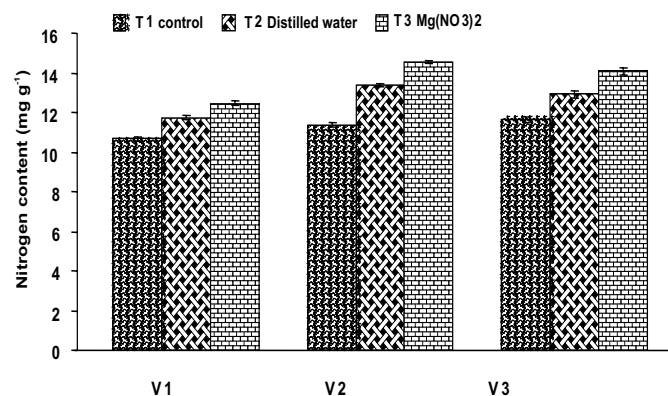


Fig. 5. Effect of presowing seed soaking treatment with distilled water and magnesium nitrate on nitrogen content (mg g⁻¹) in seeds of maize varieties

over control. Performance of mustard also improved with Mg salts used as invigoration treatment (Bose *et al.* 2007). Similarly, soaking with DW (Bradford 1986) and osmopriming with some chemicals including Ca(NO₃)₂, Mg(NO₃)₂ and KNO₃ were also found to improve seedling vigor in various crops (Ruan *et al.* 2002, Lohidas and Bose 1998 a and b, Khan 1992, Jett *et al.* 1996, Basra *et al.* 2002). In the present investigation number of leaves plant⁻¹ and leaf area plant⁻¹ were improved vigorously with application of Mg(NO₃)₂ as seed treatment. This is in accordance to the result of Bose and Pandey (2003), Bose and Mishra (2001) and Farooq *et al.* (2006) in respect to mustard and rice. where invigoration with KCl, CaCl₂, MgSO₄, Mg(NO₃)₂,

Ca(NO₃)₂ and KNO₃ improved plant height, root length, number of leaves per plant, leaf area, leaf number, chlorophyll content, nitrate reductase activity, nitrogen and amino acid contents etc. Due to high RWC in Mg(NO₃)₂ treatment plants are able to tolerate adverse conditions such as water stress, salinity, high temperature etc. Nitrate reductase activity in leaves was also found to increase in the present study (Fig. 3) and can be well correlated with an increment in nitrogen as well as protein content in grain (Fig. 4 & 5). Further, the result presents maximum increment in yield attributes in the plants raised from Mg(NO₃)₂ invigorated seeds as compared to DW treated and control sets. A number of reports related to invigoration of seeds of various crops with

inorganic chemicals and plant growth regulators suggest an improvement in yield (Basra *et al.* 2002, Pandey and Bose 2006). This might be due to the effects of Mg^{++} and NO_3^- ions which influxed in the seed during soaking and carried over from there to cause modulations in post germinative phases of plant's life. The priming of seed simply with DW also improves a number of physiological functions in plant system and consequently the yield (Bose *et al.* 2007); this might be due to elongation of root system and an increase in root volume (measured in terms of fresh weight), which improve the water status of the system and channelize nutrient uptake in a better way (Taiz and Zeiger 2004). Further, plants raised from $Mg(NO_3)_2$ invigorated seeds showed maximum improvement in the studied parameters related to vegetative (Table 1, 2, and 3) and reproductive (Table 4 & 5) growth in maize varieties due to a number of factors associated with this type of treatment. Bose and Mishra (1999) and Bose and Pandey (2003) observed an increment in the influx of Mg^{++} and NO_3^- during the soaking of seeds of mustard and okra in $Mg(NO_3)_2$ solution. They have suggested that these influxed ions showed their specific roles as per their chemical nature and that may be, where Mg^{++} plays via activating the various respiratory enzymes as a results more ATP molecules generate which may act as source of energy for various metabolic functions (Kiss 1979). On the other hand, NO_3^- ions may induce the activity of nitrate reductase enzyme which may be instrumental in increasing nitrogen metabolism in the plant (Bose and Pandey 2003); these cumulatively improve the vegetative growth followed by yield and yield attributes of the tested crops and found in the present study also (Pandey and Bose 2006). On the basis of present findings it can be concluded that seed invigoration treatment with $Mg(NO_3)_2$ improved seedling establishment, vegetative growth yield and yield attributes of maize and this practice is easy to handle and ecofriendly (Bose and Sharma 2000).

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