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# Bio-physical and physiological changes associated with seed enhancement treatments in speciality maize (*Zea mays*)

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ABSTRACT

Efficacy of seed enhancement treatments were evaluated on four maize (*Zea mays* L.) varieties; HQPM-1, VL Amber pop corn, Win orange sweet corn and Navjot. Seeds were subjected to hydropriming (17 h/20°C), halo priming ($KNO_3$: 0.3%/17 h/ 20°C) and magneto priming (1000G/2h) and changes in emergence percentage, its speed, seedling vigour, seedling root growth, seed absorption-desorption patterns and water activity were studied. Seed enhancement treatments significantly increased seedling emergence (23.9-27.7%); speed of emergence (31.1-39.6%); seedling vigour (33.5- 44.5%) and root growth with respect to total surface area, length and volume. These treatments also modified water absorption and desorption patterns of the seed and increased seed water activity compared to control. The most effective treatment was magneto priming, followed by halo and hydro priming. Quality protein maize HQPM 1 showed highest enhancement in different traits among genotypes compared in the study.

**Key words:** Absorption-desorption pattern, Maize, Root growth, Seed enhancement treatment, Vigour, Water activity

Physiological constraints along with abiotic and biotic stresses result in poor germination and crop stand in maize (*Zea mays* L.). Pre sowing seed enhancement treatments like seed priming, chemical and physical seed treatments are widely adopted to enhance the rate and uniformity of germination, plant stand, early vegetative growth and seed yield (Bennett and Waters 1987, Fujikura *et al*. 1993, Sung and Chang 1993). Among priming treatments, hydro, halo, osmo and matrix priming are commonly used as pre sowing seed enhancement treatments in maize. Harris *et al*. (1999) reported that hydro priming increased field emergence, seedling establishment, field stand, vegetative growth and yield in maize under rainfed conditions. Hydro (distilled water) and matrix priming (vermiculite) in sweet corn improved field emergence, early vegetative growth (2-4 leaf stage) and ensured better survival of seedlings both under optimum and sub optimum conditions (Bennett and Waters 1987, Fujikura *et al*. 1993, Basu 1999, Thasni 2003, Mir 2010). Sung and Chang (1993) concluded that hydropriming being more effective in reducing mean emergence time and emergence percentage than osmo priming in Shrunken 2 corn under sub-optimal temperatures (10, 15 and 20°C). Among physical enhancement treatments, magneto priming is reported to enhance germination, speed of germination, seedling vigour, root growth and crop performance *per se* (Galland and Pazur 2005, Vashisth and Nagarajan 2007, 2008).

Water is an important substrate in many reactions and the physical state of water during imbibition strongly influences germination under varying environmental conditions and its storage behaviour. Enhanced germination and vigour in primed seeds are the expression of better seed water relations, water binding properties, increased membrane integrity, protein and nucleic acid synthesis, enzymatic activities and better free radical quenching mechanism (Nagarajan *et al*. 2005, Vashisth and Nagarajan 2009).

Chemical composition of seed influence its storage behaviour and response to different seed enhancement treatments. Maize genotypes are available in different quality categories, viz. sweet corn (sugar rich), popcorn (tough endosperm, popping type) and quality protein maize (high lysine and tryptophan), which vary in their genetic and chemical composition from the normal grain maize. Reports suggested that sweet corn varieties are prone to low emergence and early seedling mortality (Anonymous 2001) whereas high lysine maize have poor storability (Thasni 2003, Sanghmitra 2006). Much information is not available on response of different compositional group to seed

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enhancement treatments. Thus, the present study was undertaken on maize varieties belonging to different quality groups to elucidate the effect of seed enhancement treatments on different physiological and bio-physical parameters in speciality maize.

## MATERIALS AND METHODS

Seeds of speciality maize varieties, i e HQPM 1 (Quality protein maize, single cross), VL Amber pop corn (Pop Corn, Composite), Win orange sweet corn (Sweet Corn, Composite)] and Navjot (common maize, Composite) were procured from the Directorate of Maize Research (DMR), New Delhi; VPKAS, Almora; DMR, Winter Nursery, Hyderabad and DMR, New Delhi, respectively. The initial germination was 91, 96, 86 and 85% respectively with seed moisture ranging from 8-9%. Seeds were subjected to hydro and halo priming by keeping the seeds over hydrated (distill water) and 0.3% $KNO_3$ soaked filter paper respectively in petri dishes for 17h at 20°C. The hydrated seeds were surface dried, followed by air-drying at ambient temperature. For magnetic treatment, 100 seeds were placed in a cylindrical sample holder of 42 $cm^3$ capacity. The sample holder was placed in between the poles of an electromagnet having uniform magnetic field. The seeds were exposed to 1000 G for 2 h (Vashisth and Nagarajan 2009).

Three replicates of 25 maize seeds (treated and control seeds) were sown in sterilised sand in the pots kept in a glass house maintained at 25°C and RH-70%, to study the seedling emergence, speed of emergence, seedling vigour and root growth. Seedling emergence percentage and vigour was recorded 14 days after sowing. Speed of emergence was computed by counting number of seedlings emerged each day and speed of emergence was estimated as per Maguire (1962).

Speed of emergence $=\Sigma n/t$, where n is number of seeds newly germinated at time t and t is days from sowing.

Root growth of seedlings was analyzed by WINRHIZO™ system wherein 21 days old seedlings were placed on desktop optical scanner for root scanning and root growth was measured in terms of root length (cm), surface area ($cm^2$) and volume ($cm^3$) along with number of forks in the root. Ten normal seedlings from each replication were selected randomly 14 days after sowing and their root and shoot length was measured. Seedlings were dried overnight in oven at 80 $\pm$ 1°C for seedling dry weight. Seedling vigour was calculated following formula suggested by Abdul-Baki and Anderson (1973) as

Vigour Index I = Germination (%) × Seedling length (Root + Shoot) (cm)

Vigour Index II= Germination (%) × Seedling dry weight (g)

The treated and control seeds were conditioned to the same moisture content (10%) by placing seeds over anhydrous calcium chloride in a desiccators at 25°C in nylon wire-mesh bags. Three replications of 20 seeds each of treated and control seeds were weighed separately and hydrated in closed desiccators at 25°C and 100% RH for absorption of water by the seeds. The increase in weight was recorded at 2h interval up to 48h. The hydrated seeds were then kept in an open petri plate and dried at 25°C and 60 ± 2% RH. The decrease in weight was also recorded at 2h interval up to 48h for dehydration cycle. Water activity, which characterizes the free available water in the seed, was measured by water activity meter (Rotronic, Switzerland) on the same seeds used for studying the water absorption pattern.

## RESULTS AND DISCUSSION

### *Emergence and seedling growth*

In the study, all the seed enhancement treatments significantly increased the seedling emergence percentage, speed of emergence and seedling vigour under glass house conditions. (Table 1). The response of different treatments varied within a genotype and also different genotypes responded differently to treatments. These enhancement treatments increased seedling emergence by 23.9 to 27.7% and speed of emergence by 31.1-39.6% in treated seeds over control. Magnetically treated seeds showed highest response in improvement of total seedling emergence and its speed for all the genotypes. Among genotypes, maximum gain in these traits was observed in HQPM-1 followed by Navjot and least in VL Amber popcorn and Win sweet corn (Table 1). Seed vigour measured in terms of vigour index I and II indices showed a gain of 44.5 and 50.5% with magnetic treatment, 40.8 and 42.4% with halo priming and 34.1 and 33.5% by hydro priming respectively. Among the treatments, magnetic treatment and halo priming were more effective in improving vigour traits followed by hydro priming as compared to unprimed seeds (Fig 1). Afzal *et al.* (2008) also reported rapid and uniform seedling emergence, speed of emergence and vigour in primed maize seeds. Thansi (2003), Basu *et al.* (2005) and Vashisth and Nagarajan (2009) showed similar improvement in field performance and early vigour under optimum and suboptimum temperature regimes in maize.

### *Seedling root growth*

The root growth studies done with WINRHIZO™ showed that these treatments improved root length, surface area, volume and number of forks in all genotypes implicating better establishment capacity of seedlings under abiotic stress under field conditions. Maximum increase in root growth was recorded in Win orange sweet corn followed by VL Amber popcorn (Table 2) (Fig 1). Among treatments, magnetic treatment was most effective followed by halo and hydro priming in improving seedling root traits. As root plays vital role in plant establishment, anchorage and growth, the stimulatory effect of seed enhancement treatments on root growth especially on its length, surface area, volume and number of secondary roots (forks), would ensure better seedling establishment and growth under abiotic stresses where seedling establishment is very critical for crop sustenance. Similar increase in root growth in magneto

Table 2 Effect of seed enhancement treatments on seedling root growth of maize under glass house conditions

| Genotype | Length (cm) | | | | | Surface area (cm ) | | | | | Volume (cm ) | | | | | Forks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean |
| HQPM 1 | 197 | 220 | 236.4 | 250.9 | 226.1 | 53.76 | 60.46 | 57.19 | 61.55 | 58.24 | 0.85 | 0.97 | 1.1 | 1.21 | 1.03 | 410 | 442.5 | 776.5 | 862 | 622.7 |
| VLAPC | 222.9 | 244.9 | 302.2 | 322.2 | 273.1 | 49.14 | 50.01 | 68.21 | 59.53 | 56.72 | 0.86 | 0.86 | 1.25 | 1.1 | 1.01 | 835.5 | 853 | 1017 | 904 | 902.3 |
| WOSC | 198.7 | 268.0 | 246.5 | 304.4 | 254.4 | 52.3 | 70.39 | 67.55 | 75.09 | 66.33 | 1.1 | 1.47 | 1.49 | 1.47 | 1.38 | 714.5 | 1018 | 999 | 1096 | 956.8 |
| Navjot | 295.4 | 327.0 | 325.3 | 282.5 | 307.5 | 62.14 | 69.86 | 69.57 | 68.68 | 67.56 | 1.05 | 1.12 | 1.18 | 1.16 | 1.12 | 786.5 | 822.5 | 1031.5 | 1069.5 | |
| Mean | 295.4 | 327.0 | 325.3 | 282.5 | | 62.14 | 69.86 | 69.57 | 68.68 | | 1.05 | 1.12 | 1.18 | 1.16 | | 786.5 | 822.5 | 1031.5 | 1069.5 | |
| CD (P=0.05) | Var | 58.2 | | | | 6.92 | | | | | 0.21 | | | | | 229 | | | | |
| | Treat | 39.7 | | | | 4.65 | | | | | 0.14 | | | | | 199.2 | | | | |
| | Inter. | 75.2 | | | | 8.95 | | | | | 0.32 | | | | | 305.2 | | | | |

Table 1 Effect of seed enhancement treatments on emergence, its speed and seedling vigour indices in maize under glass house conditions

| Genotype | Emergence (%) | | | | | Speed of emergence | | | | | Vigour Index I | | | | | Vigour Index II | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean | T1 | T2 | T3 | T4 | Mean |
| HQPM 1 | 73.3 (58.9) | 97.3 (82.3) | 100.0 (90.0) | 100.0 (90.0) | 92.6 (74.2) | 2.59 | 3.24 | 3.78 | 3.56 | 3.29 | 2583.3 | 3617.9 | 3913.6 | 3927.0 | 3510.4 | 52.4 | 74.4 | 82.1 | 96.4 | 76.3 |
| VLAPC | 72.0 (58.1) | 98.6 (80.9) | 93.34 (75.3) | 86.6 (68.6) | 87.6 (69.4) | 2.82 | 3.94 | 3.52 | 3.21 | 3.37 | 2492.3 | 3798.7 | 3560.6 | 3321.9 | 3293.3 | 34.8 | 55.8 | 48.7 | 44.1 | 45.8 |
| WOSC | 72.0 (58.1) | 78.6 (62.5) | 82.6 (65.4) | 84.0 (67.5) | 79.3 (62.9) | 1.92 | 2.74 | 2.77 | 2.82 | 2.56 | 2470.2 | 2738.3 | 2782.5 | 3030.6 | 2755.4 | 33.2 | 36.8 | 41.8 | 43.0 | 38.7 |
| Navjot | 66.6 (54.7) | 77.3 (61.6) | 86.6 (68.9) | 90.6 (72.2) | 80.3 (63.6) | 2.07 | 2.43 | 3.06 | 3.27 | 2.70 | 2015.7 | 2675.7 | 3205.7 | 3536.0 | 2858.2 | 42.1 | 4.4 | 58.8 | 60.9 | 52.9 |
| Mean | 70.9 (57.4) | 87.9 (69.3) | 90.6 (72.2) | 90.3 (72.1) | | 2.35 | 3.08 | 3.28 | 3.21 | | 2390.3 | 3207.6 | 3365.6 | 3453.8 | | 40.6 | 54.2 | 57.8 | 61.1 | |
| CD (P=0.05) | Var | (1.98) | | | | 0.09 | | | | | 100.89 | | | | | 2.56 | | | | |
| | Treat | (1.98) | | | | 0.09 | | | | | 100.89 | | | | | 2.56 | | | | |
| | Inter. | (5.26) | | | | 0.22 | | | | | 266.92 | | | | | 6.78 | | | | |

$T_1$: Control; $T_2$: Hydropriming (17h at 20°C); $T_3$: Halo priming (0.3%, 17h at 20°C); $T_4$: Magneto priming (1000G/2h). Values in parenthesis are arc sine converted values primed maize seeds have been reported by Vashisth and Nagarajan (2007).

*Absorption and desorption pattern and water activity*

Water is an important component of seed essential for its physiological activities, biochemical pathways, and macromolecular structures sustaining permeability. The pattern of absorption and desorption was monitored at 100% RH, from 2h to 48h at 25 $\pm$ 1$^0$C. The seed water absorption curve showed a steady increase in water uptake per cent which increased from 2.2 to 48.9% in different cultivars, up to 48h of absorption. The gain in moisture content was higher up to 30h of absorption than between 30-48h. The desorption pattern also showed same trend, with a steady decline in seed moisture content which ranged from 40.5 to 3.3% in different cultivars up to 48h of desorption and steep reduction in moisture per cent was observed up to 30h of desorption (Fig 2). Desorption rates were lower for primed seeds compared to unprimed control. Intra-varietal treatment effects on the absorption pattern were evident in all cultivars. The rate of absorption after 48h of equilibration was significantly higher in the treated seeds than control. Among priming treatments, magneto primed seeds showed greater absorption and slower desorption rates. Hydro and halo primed seeds showed a similar pattern of water absorption-desorption compared to unprimed control seeds. Studies

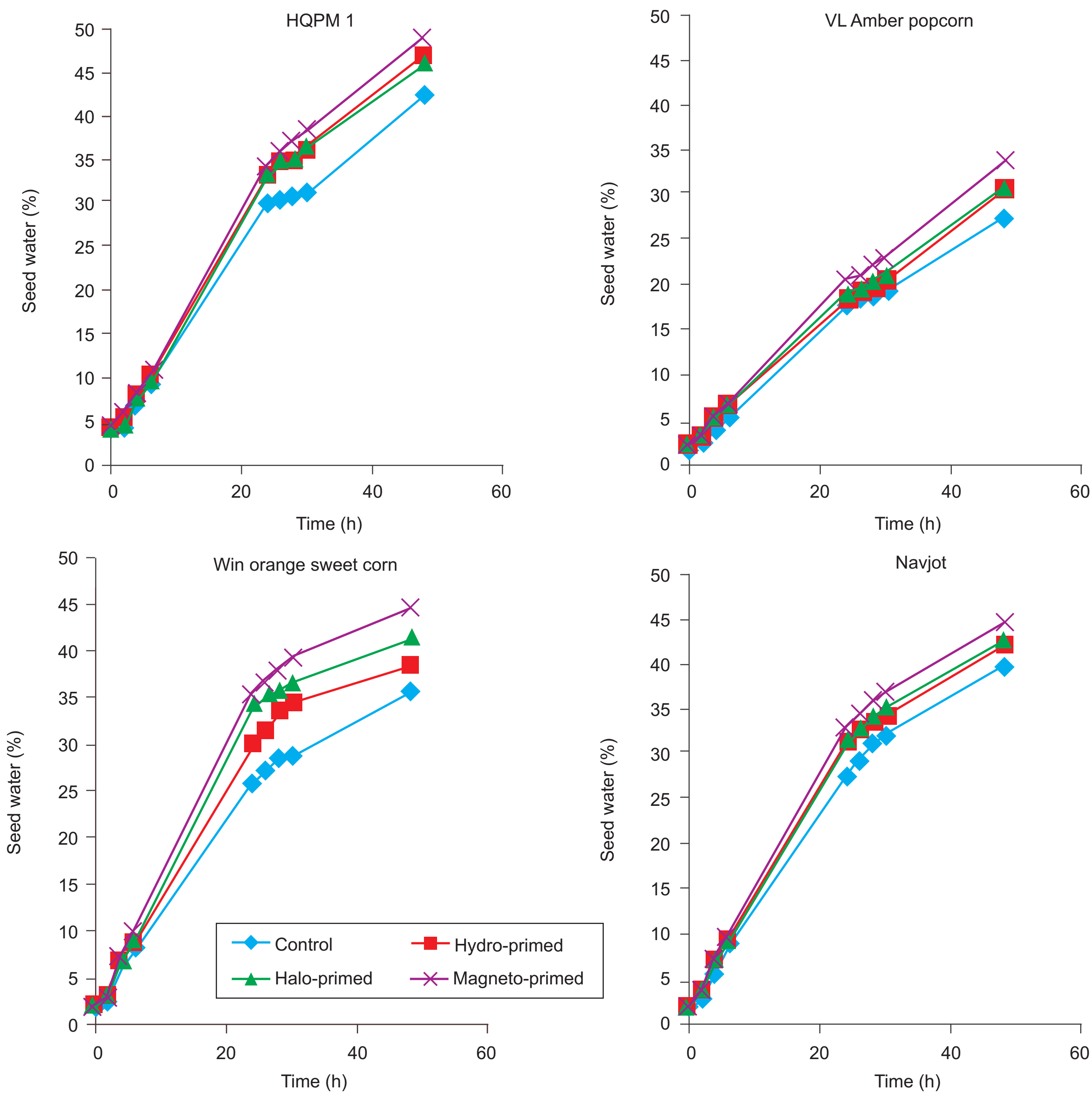


Fig 1 Effect of seed enhancement treatment on changes in water absorption pattern in different maize genotypes at 25°C. Values are means of three measurements. Bars represent ± SEM (n=3)

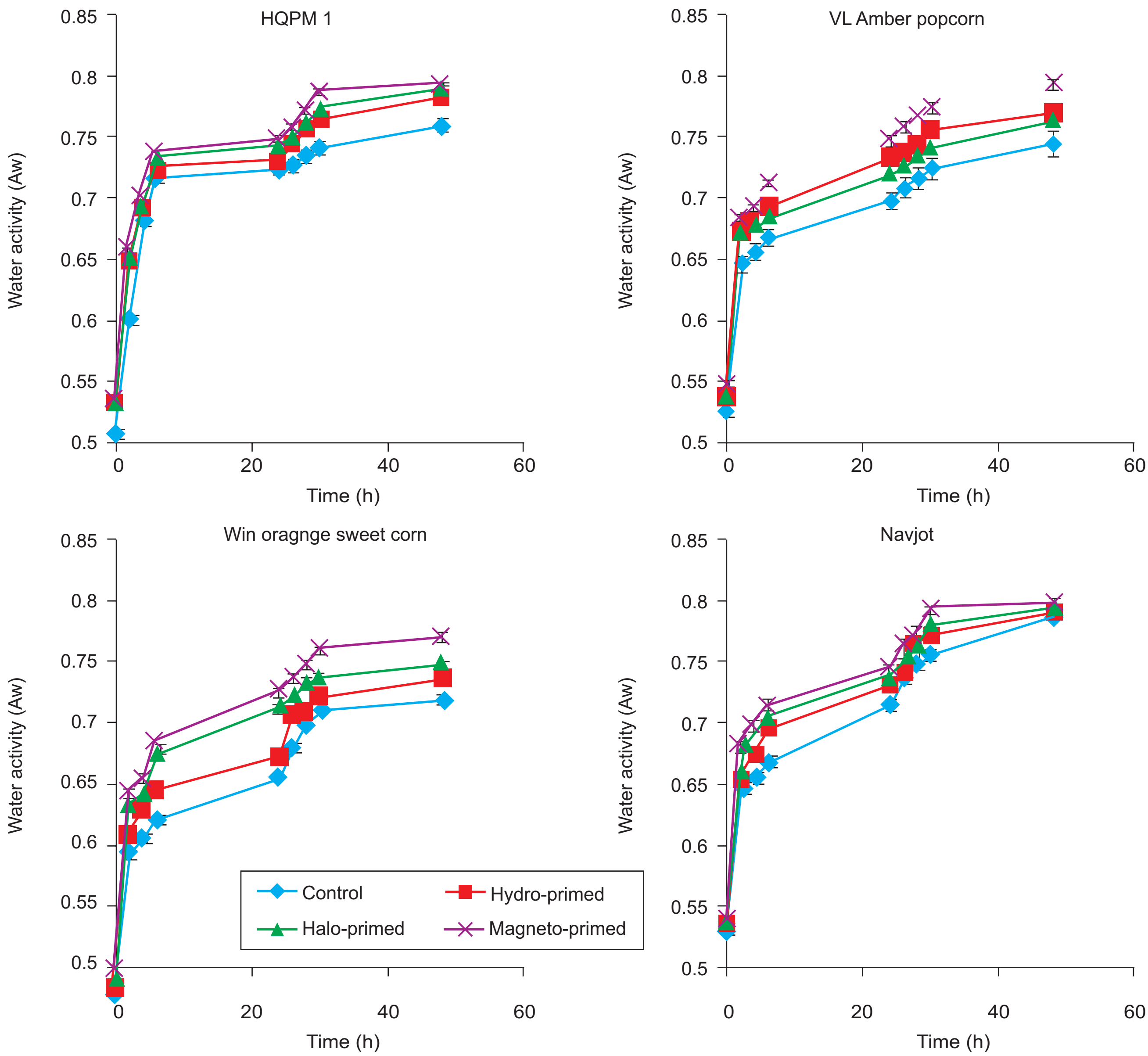


Fig 1 Effect of seed enhancement treatment on changes in water activity (Aw) pattern in different maize genotypes at 25°C. Values are means of three measurements. Bars represent ± SEM (n=3)

conducted on maize, chickpea, and sunflower on the absorption and desorption patterns showed that water is bound by weak binding sites and magnetic treatment modified the water-binding properties of seed tissue and altered the water binding sites, i e free, loosely and tightly bound water favouring higher vigour and metabolic activity (Vashisth and Nagarajan 2007, 2008, 2009). Nagarajan *et al*. (2005) and Pandita *et al*. (2007) attributed better performance of primed seeds to modification in seed water binding properties and reorganization of water during imbibition which increased the macromolecular water available for various metabolic activities related to germination (Girolamo and Barbanti 2012).

One of the measures of water status in the seed is water activity, which characterizes the state of water in the system and is measured as the ratio of vapour pressure of water in the sample to the standard vapour pressure of pure water at the same temperature. In the study, water activity significantly increased with the duration of water absorption in seeds equilibrated at 100% RH. However, the water activity values were significantly higher after seed enhancement treatments in all cultivars as compared to control. The water activity showed a steep rise after 2-8h of absorption followed by a slow gain up to 24h and a faster rise from 24-36 h in all the genotypes. Substantial intra varietal treatment effects were recorded with respect to the rate of the change in water activity. The rise in the water activity was significantly higher in the treated seeds than control. Among genotypes, HQPM 1 and magneto primed seeds recorded sharpest rise in water activity followed by halo and hydro primed and least in untreated control seeds. The primed seeds have gone through one cycle of hydration and dehydration during priming treatment, which attributed to higher rate of absorption and water activity in hydro and halo primed seeds. Similarly in magneto primed seeds, better availability of water for metabolism could be associated with availability of more weak water binding sites as magnetic treatment are reported to exchange the multi molecular and strong binding sites with weak water binding sites (Vashisth and Nagarajan 2010, Bhardwaj *et al*. 2012).

In present study, the changes induced by priming in seed water status in relation to enhanced seed performance clearly established that the moisture absorption and desorption patterns are also influenced by the chemical composition of seeds. Quality protein maize (HQPM 1) showed higher absorption, water activity and slower desorption which could be attributed to higher seed weight (1000 seed weight), carbohydrate and protein content in HQPM 1 rendering it more hydrophilic than other varieties.

The seed enhancement treatments favoured better seedling emergence, vigour, root growth and seed water relations in maize. The most effective treatments identified were magnetic treatment (1000G/2h) followed by halo priming with 0.3% $KNO_3$ and hydro priming (17h/$20^0$C). In view of the comparative advantages of a magnetic priming over other seed priming treatments, owing to the avoidance of hydration, can be adopted for seed enhancement in maize both under optimum and suboptimum conditions. It can also be concluded that the chemical composition of seeds have immense impact on their response to seed enhancement treatments.

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