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Full Length Research Paper

Changes in germination behavior of wheat seeds exposed to magnetic field and magnetically structured water

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To study the invigoration impact of magnetized seed and water on germination, wheat seeds with low viability (45%) were subjected to magnetization treatments. Seed and water was passed through specifically designed magnetic funnels. Comparison was made between treatments and control for seed germination (%), shoot and root length (cm) and their fresh and dry weight (g). Seed germination index (SGI) was also calculated and compared. Magnetized water (structured water) was more invigorative to seed germination with linearity to number of passing as compared to seed magnetization. A 13.3% increase in germination was observed as compared to control using magnetized water, whereas increase in germination was insignificant with the seed magnetization. The interaction exhibited no effect on germination. It was concluded that wheat seeds with low vigor can be invigorated with the use of magnetized water; whereas, the potential to use magnetized seed remain to be extensively studied on larger groups of crops/samples.

Key words: Wheat, magnetized water, germination behavior, biomagnetism, presowing magnetic biostimulation.

INTRODUCTION

Wheat is the major staple food at global level, and with the increase in population, it has presented a persistent challenge to enhance its productivity (Fujisaka et al., 1994). Efficient crop yield is generally associated with efficient seed germination (Ghafoor and McPhee, 2012; Nisar et al., 2011). The vigorous seed ensures vigorous seedling that leads to high grain yield of wheat (Gholami and Sharafi, 2010). However, the availability of seed with good germination and high vigour has been a major concern in the farming community (Ghafoor and Arshad, 2011). High tem-perature and/or high seed moisture contents are the two major factors that affect the seed germination (Siddiqui et al., 2008). Due to ageing process, even under ideal storage conditions, seed tends to loose germination (Jatoi et al., 2001). Diverse efforts have been made from time to time to address this issue (to invigorate the seed with low germination/enhance the germination) using multidimensional approaches. The improvement in seed germination have been achieved by different pre-sowing treatments including various physical factors such as the electric field, magnetic field, laser radiation and microwave radiation (Pietruszewski and Kania, 2010). Pre-sowing chilling treatments are being used effectively alone or with other invigoration techniques to shorten the period between planting and emergence (Basra et al., 2002).

Application of kinetin and gibberellins on de-husked seeds has stimulatory effects on the germination of indica and japonica rice under aerobic and anaerobic conditions (Miyoshi and Sato, 1997). Ethanol has been reported to

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Abbreviations: SGI, Seed germination index; **WP,** water passing.

have stimulatory effects on the germination of seeds of many plant species (Taylorson and Hendricks, 1979; Bewley and Black, 1982). Gibberellic acid treatment increased emergence index, speed of germination and co-efficient of germination while oxygenated peptone enhanced root length, shoot/root ratio, biomass and vigour index (Thakare et al., 2011). Seed priming with oxygenated peptone has also accelerated the germination processes in tomato, brinjal and chilli (Patil et al., 2008). Gibberellic acid is the most important growth regulator, which speeds germination by promoting seedling elongation growth of cereal seeds (Rood et al., 1990; Kaur et al., 1998; Lee et al., 1999). Moreover, ionized rays have stimulatory effect on seed germination, and in a study it has increased seed germination in carrot by 9 to 20% (Sirtautaite, 1996; Frolova, 1983; Borisov, 1994). Experimental evidence indicated that the content of energy conveyed to seed depends on the strength of the electrical field and electrical properties of seed (Lynikiene and Pozeliene, 2003). Ultrasonic waves have also been effective in improving germination (Yaldagard et al., 2008).

Magnetic field application on water had stimulatory effect with respect to increase in seed germination because the hydrogen bond in liquid water is highly influenced by electrical and magnetic fields. Therefore magnetized water (water passed through magnetic field) bears different chemical and physical properties than ordinary water. Pre-sowing magnetic treatment of seeds has been shown to increase 30 to 50% germination rate of seeds (Wojcik, 1995). The magnetic stimulation of the wheat seeds resulted in acceleration of the process of germination., Although magnetic fields speed up seed germination and plant growth, the intensity of the applied magnetic fields and the time of seed exposure, however, vary greatly (Pietruszewski and Kania, 2010). Electromagnetic irradiation applied as pre-sowing treatment increases corn seed vigour through emergence rate, establishment percentage, and dry mass of seedling aerial part, according to the combination of radiation intensity, time and the genotype (Zepeda-Bautista et al., 2010). The influence of magnetic field treatment on tobacco seeds germination has been found to be dependent upon strength of magnetic field and exposure time (Aladjadjiyan and Ylieva, 2003). Studies showed that the influence of the stationary magnetic field on the seeds increased the germination of non-standard seeds and improved their quality (Galland and Pazur, 2005).

Recently some magnetic devices have been developed by Magnetic Technologies L.L.C., Russia, with the claim that after passing seed or water through these devices, they get bio-stimulated and structured, respectively. This magnetized seed or water exhibits better results in terms of germination and plant growth. Keeping in view their claim, the current study was undertaken to determine the influence of magnetic treatment on germination and seedling growth rate in wheat.

MATERIALS AND METHODS

This study was carried out at the Seed Preservation Laboratory, Institute of Agri-Biotechnology and Genetic Resource (IABGR), NARC, Islamabad, Pakistan. The experiment was laid out in completely randomized design (CRD) with 12 treatments under three replications. The study was conducted to check the performance of two magnetic devices one each for seed and water (Magnetic Technologies L.L.C) on the invigoration of the wheat seed with low viability.

Seed source

The wheat germplasm cv. NR-234 was obtained from National Genebank at IABGR, National Agricultural Research Center, Islamabad, Pakistan. Seeds having viability of 45% were used in the experiment. Healthy and uniform-sized seeds were used for the experiment.

Seed treatment

The magnetic device was funnel shaped (Figure 1a) and seeds were passed through it slowly with uniform speed. The numbers of seed passing were 0, two, four and six times. Table 1 summarizes the treatments and their representative codes. The seeds were sown immediately after passing through magnetic device.

Water treatment

The magnetic device for water treatment was also funnel shaped with small size (Figure 1b). The numbers of water passing were 0, three and six times. This magnetized water was used to moist the paper towel before sowing seed.

Sowing procedure

The seeds were sown following between paper (BP) method. In each replication 25 seeds were sown on paper towel (22 × 23 mm; Victory brand, Shinbashi Paper Company, Shizuoka, Japan). The paper towel was moistened either with distilled water (control) or magnetized water (treated and untreated seeds). Germination test was performed according to guidelines issued by International Seed Testing Association (ISTA, 1993; AOSA, 1983). Seeds were placed on moist paper towel sheet and covered with another sheet of paper towel. Sheets were rolled and placed in plastic beaker, covered with polythene bag. The beakers were, then, placed in an incubator at 25±2°C under light conditions of 16 h. Total numbers of seeds germinated were counted daily and percentage was calculated at 7th day. Germination (%), Shoot length (cm), root length (cm), shoot and root dry weight (g) and Seed Germination Index (SGI) was calculated.

Seed germination Index

The rate of germination was recorded daily to check the response of seed against germination. Germination index was calculated as described in Association of Official Seed Analysts (1983) as the following formula:

$$SGI = \frac{\text{No. of germinated seedlings}}{\text{Days of first count}} + - - - - + \frac{\text{No. of germinated seedlings}}{\text{Days of first count}}$$

Figure 1. Magnetic devices used to treat water (A) and wheat seed (B).

Table 1. Treatment codes of seed passing (SP) and water passing treatments.

Treatment code	Explanation of treatment code
0SP- 0WP	0 Seed passing soaking with distilled water (control)
2SP- 0WP	2 Seed passing* soaking with distilled water
4SP- 0WP	4 Seed passing soaking with distilled water
6SP- 0WP	6 Seed passing soaking with distilled water
0SP- 3WP	0 Seed passing soaking with 3 water passing
2SP- 3WP	2 Seed passing soaking with 3 water passing
4SP- 3WP	4 Seed passing soaking with 3 water passing
6SP- 3WP	6 Seed passing soaking with 3 water passing
0SP- 6WP	0 Seed passing soaking with 6 water passing
2SP- 6WP	2 Seed passing soaking with 6 water passing
4SP- 6WP	4 Seed passing soaking with 6 water passing
6SP- 6WP	6 Seed passing soaking with 6 water passing

*Passed through the magnetic device.

Root and shoot length (cm)

Root length and shoot length was measured at the 7th day of sowing.

Dry seedling biomass (g)

The fresh seedlings were placed in drying oven at 75°C for 48 h. Dry weight of seedlings was done on electric balance, which was calculated in grams per seedling.

Statistical analysis

Analysis of variance was carried out as outlined by Steel et al,. (1997).

RESULTS AND DISCUSSION

Germination (%)

It was interesting to note that with water passing (WP) the germination percentage increased with the increase in magnetic exposure (Figure 2a). The germination under water passing values ranged from 45 to 58%, the highest value being associated with 6WP having an increase of 13.3% compared to control. Though manufacturer recommend three times passing, it is suggested to evaluate beyond six passing of water.

A varying germination response was observed against different seed passing through magnetic device (Figure 2b). At control treatment (without seed passing), germination observed was 45.3%, which was raised to 49.3% when subjected to two and six passing from magnetic device. However, with the four seed passing it reduced to 37.3%. This four seed passing from magnetic device again reached to 49.3% with two more times passing. It showed some cyclic interaction of germination improvement and decline on incremental exposure. The increase in germination rate observed with the seed passing was 4% to control. The interaction between seed passing and water passing treatments (Figures 2c and d), having the values ranged from 36 to 46.67%, presents a much complex behavior. The highest value is of 2SP-3WP with 46.67% was only positive interaction. Moreover, with one exception, all the values observed for germination percentage were less than control in case of interaction. The structured water was more invigorative to seed germination with positive correlation as compared to seed magnetization. Although six WP alone enhanced 15% germination, its interaction failed to enhance germination, rather with respect to control all combinations were negatively affected in terms of germination percentage.

The data pertaining to germination percentage as affected by different seed as well as water passing was subjected to analysis of variance. However, no significant differences among different treatments were observed in this study. These need to be studied on larger group of crops with many varieties to establish concrete opinion.

Seed germination index (SGI)

In case of using structured/magnetized water for sowing wheat seeds, it was observed that SGI increased from 6.69 (control) to 7.38 when water was passed through magnetic device three times (Figure 2e). However, with the increment in water passing to six times, SGI (7.33) was slightly decreased. The enhanced speed of seed germination does suggest that magnetized water has acquired some structural changes; perhaps promoting water flow and bioactive molecules availability. The results pertaining to speed of germination against varying exposure to magnetic field reveal a decrease with the increment in magnetic exposure up to four SP, whereas at six SP it was increased (6.51) to be at par with control (6.09) which remained the highest in this case (Figure 2f). It reflected a negative impact of magnetic device as varying exposures in terms of seed passing yielded SGI values less than control.

The interaction of different wheat seed passing to constant level of water passing (three SP) also displayed an inconsistent behavior (Figure 2g). The seed passed twice from magnetic device when sown on three times passed water, it showed a decrease in SGI from 6.69 (control) to 6.02. However, when four times passed seed were sown on three times passed water, an increase was observed in SGI which was equal to control. An abrupt decrease in SGI (4.28) was noted when six times passed seed was sown on three water passing. In all the cases SGI for wheat remained less than or at par to the control. Again the data indicates that each seed magnetization turn on and/or off certain physiological processes that result in the respective germination and SGI. Moreover, the interaction of various wheat seed passing to fixed water passing (six times), in general, revealed an inverse response for SGI (Figure 2h). Up to four seed passing, SGI decreased for control (6.69) to four seed passing (3.63). However, six seed passing showed again an increase in SGI up to 5.27, which was also less than SGI observed at control treatment, although it may be noted that six WP alone enhanced the germination as well as the SGI more than control. The interaction of various seed passing to fixed water passing again showed a decline in SGI which remained less than control.

Seedling growth

Shoot length (cm)

The water passing levels had a negative trend in shoots lengths with the increment in water passing as the shoot length (9.14 cm) was lower than control (Figure 3a). Whereas the different seed passing treatments showed a decrease in shoot length of wheat seedlings with the

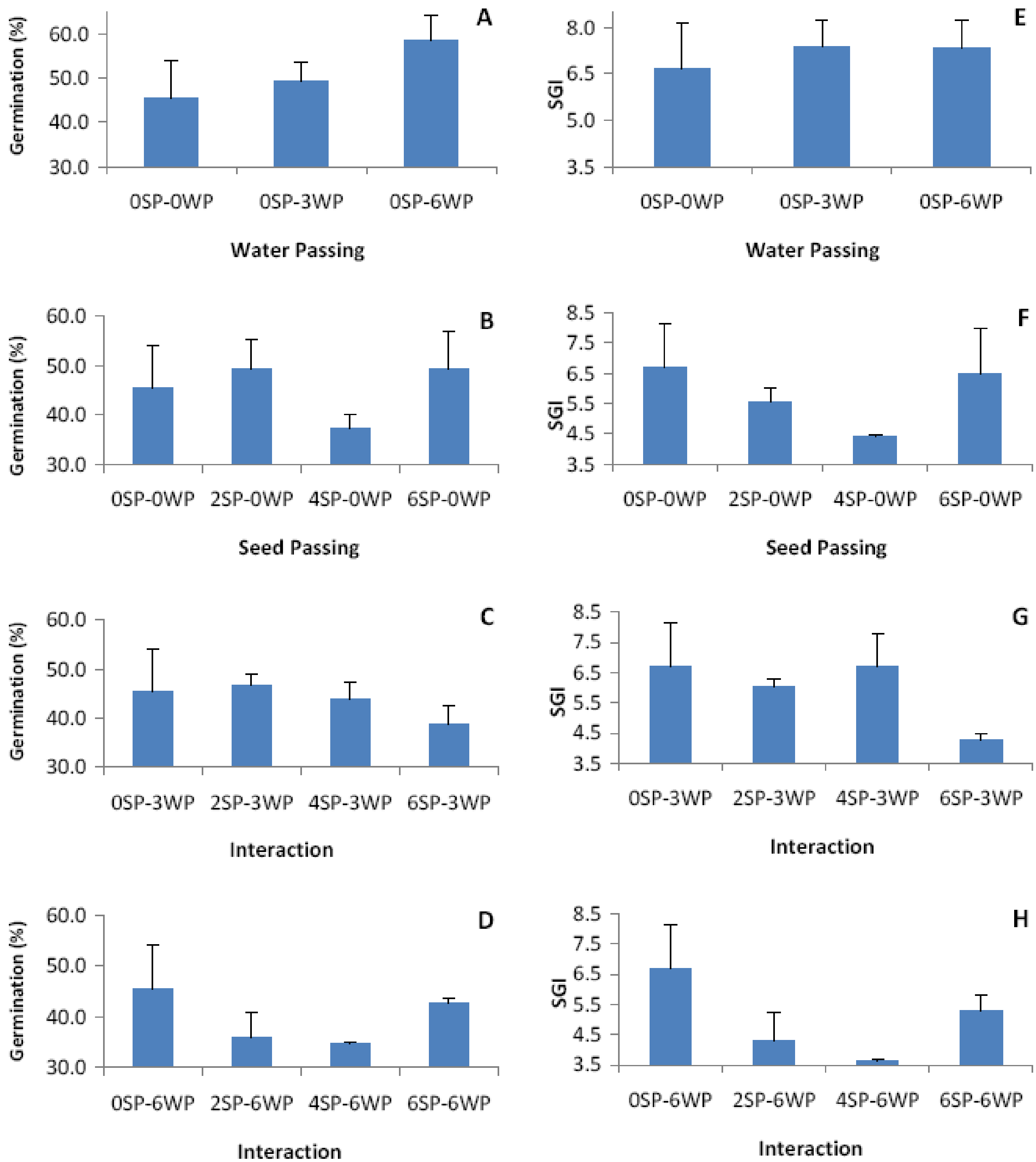

Figure 2. Germination response of wheat seeds exposed to magnetized water (A), seed passing through magnetized device (B), interaction with 3WP (C), interaction with 6WP (D), and seed germination index (SGI) response of wheat seeds exposed to magnetized water (E), seed passing (F), interaction with 3WP (G) and interaction with 6WP (H).

increase in seed passing and also remained less than control (Figure 3b). The mean shoot length at two SP (8.58 cm) was decreased to 7.44 cm at four SP which again increased to 8 cm at six SP. Furthermore, the interaction of different seed passing with the constant level of three WP as well as six WP of water passing exhibited a decrease in shoot length with the increase in number of seed passing (Figures 3c and d). All the values observed for shoot length were less than control. Though the shoot length was decreased with respect to

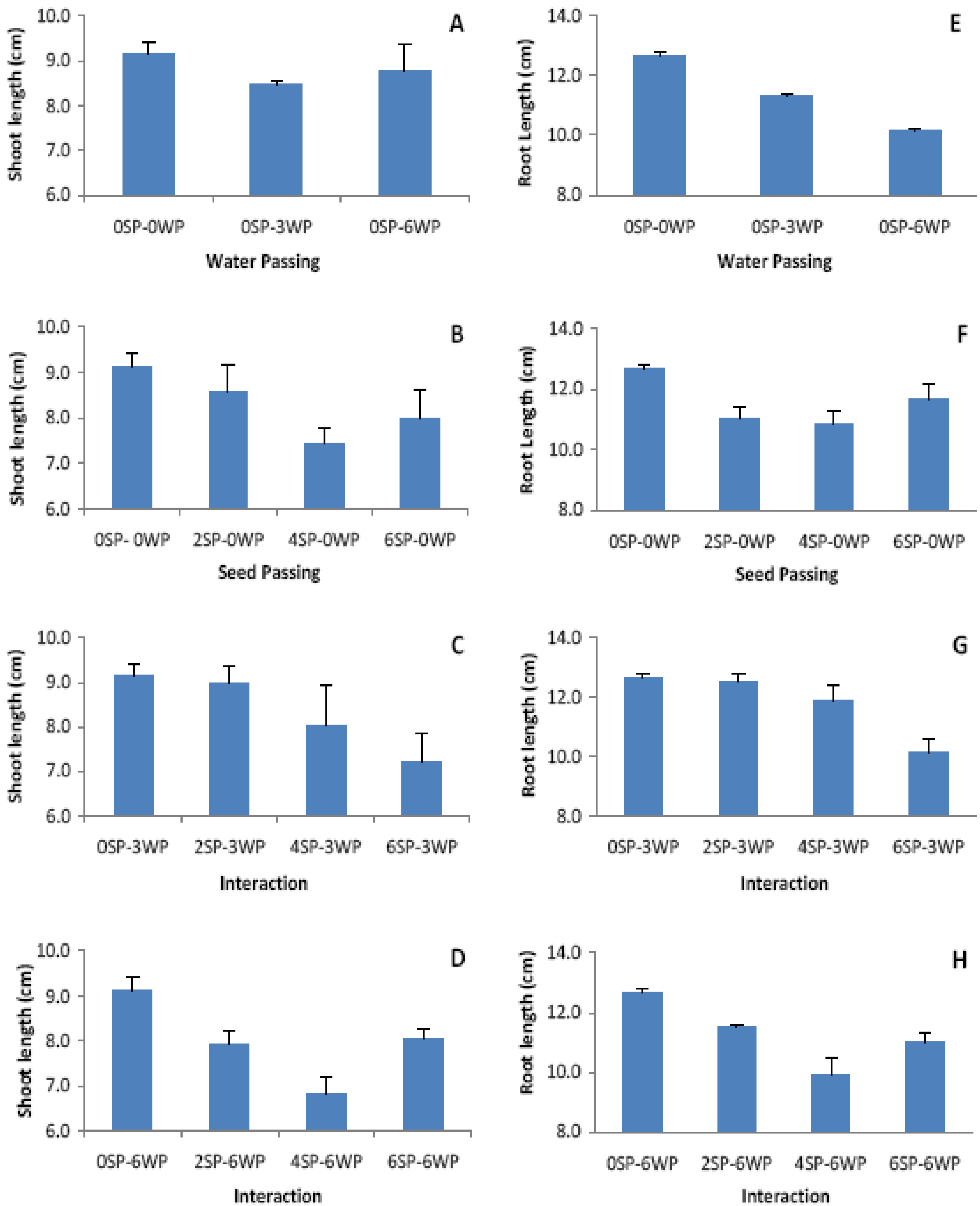

Figure 3. Shoot length (cm) response of wheat seeds exposed to magnetized water (A), seed passing through magnetized device (B), interaction with 3WP (C) and interaction with 6WP (D), and root length (cm) response of wheat seeds exposed to magnetized water (E), seed passing (F), interaction with 3WP (G) and interaction with 6WP (H).

control at the seedling stage (7th day), however, this decrease can not be attributed as negative character until studied at maturity in field conditions. As in between paper method, some light is restricted and seedling etiolated, and these stout shoot seedlings may be more vigorous in soil conditions.

Root length (cm)

The root length gradually decreased in response to increase in water passing (Figure 3e). The highest root length (12.65 cm) was observed at control which was followed by 11.30 cm and 10.16 cm at three WP and six

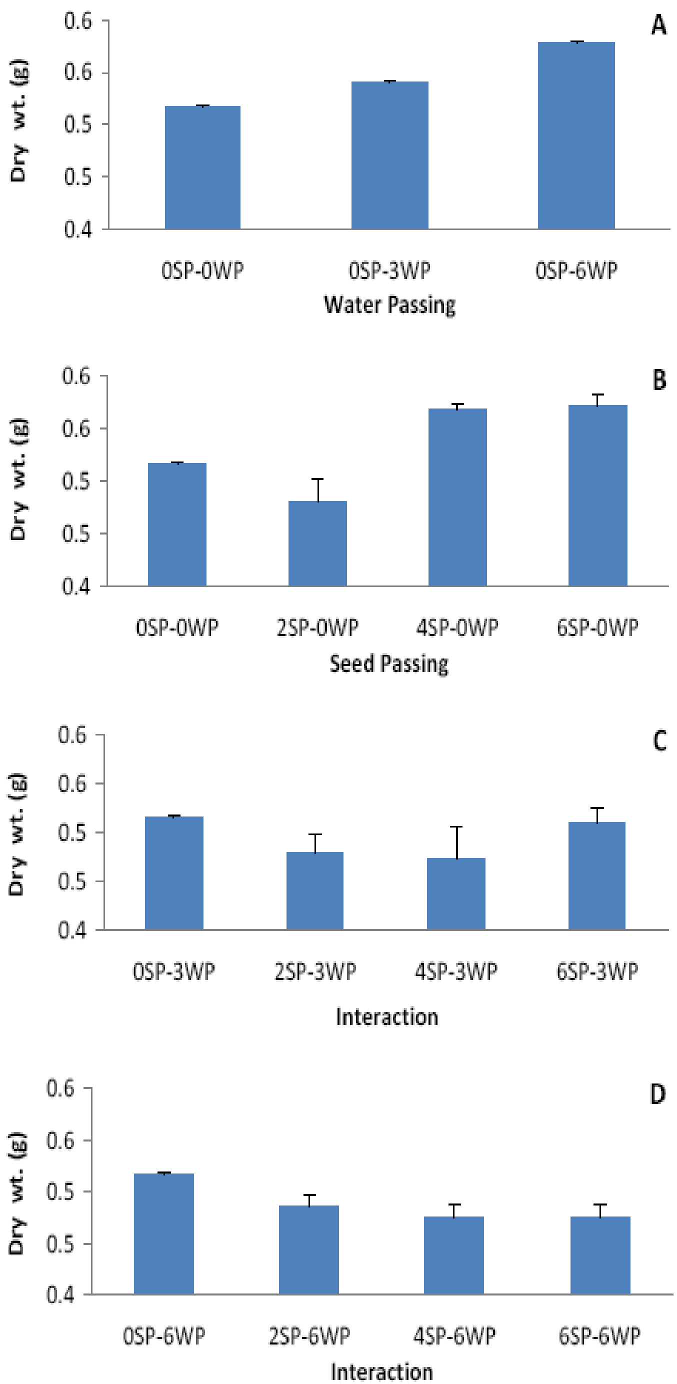

Figure 4. Seedling dry weight (g) response of wheat exposed to magnetized water (A), seed passing through magnetized device (B), interaction with 3WP (C) and interaction with 6WP (D).

WP, respectively. The impact of increased magnetic exposure resulted in decline in root length. However, it may be noted that the seedling weight increased though the length of both shoot and root decreased. Response of various seed passing treatments on root length of wheat seedlings showed a negative effect to the increase in number of seed passing (Figure 3f). The highest root length observed in this case was at control (12.65 cm) which was followed by 11.64 cm at six SP, whereas at two SP and four SP root length was 11.06 and 10.84 cm, respectively. The similar trend was also observed in case of SGI.

On the other hand, the increasing levels of wheat seed passing to fixed level of water passing (three WP; Figure 3g) and (six WP; Figure 3h) exhibited a general decline in root length (Figure 3g). The highest root length observed was at control (12.65 cm) which was followed by 12.51, 11.87 and 10.16 cm at two SP, four SP and six SP, respectively. It appears that with the exception of germination and seedling dry weight, none of the seed as well as water exposure to magnetic field yielded better response than control. However, as earlier stated, the decrease in length of seedling and having more accumulated biomass may be a positive attribute to vigour. This needs to be tested in soil condition till adult stage. Magnetization of either water or seed does affect the seed and seedling and how it can be related to positive attributes further needed to be studies.

Seedlings dry weight (g)

Seedling dry biomass was determined to see the effect of various water and seed passing through magnetic device. In case of water passing, a linear increase in seedling dry weight was observed with the increase in water passing (Figure 4a). The highest seedling dry weight was observed at the highest level (six WP) of water passing, which was followed by three WP and control. This increase in seedling weight supports the inference that the reduction in shoot length (Figures 3a and 4a) may not be negative attribute. Same is true for seed passing treatment (Figures 3b and 4b). An inconsistent trend was observed in seedling dry weight against varying levels of seed passing (Figure 4b). The highest seedling dry weight (0.57 g) was observed at four SP and six SP and both were higher than control (0.52 g).

The interaction of different seed passing with a fixed number of water passing (three WP; Figure 4c) and six WP; Figure 4d) treatments showed a similar pattern as observed in SGI and root length. The seedling dry weight at control (0.52 g) was at the top and a decreasing trend at two SP and four SP with the seedling dry weight of 0.48 and 0.47 g, respectively. Again an increase in dry weight was observed at six SP with a weight of 0.51 g, but was still lower than control. These interactions are complex and need to be further studied in detail.

Conclusion

Wheat seeds with low vigor were subjected to either magnetized water and seed magnetization or both. A definite influence of magnetization was noted on the structure of water and physiological properties of seeds when exposed. However, the structural water affects wheat seed germination positively and proportionally to the number of passing through the device. Whereas in case of seed exposed to magnetization, the response is variable and the interaction more complex. This study therefore recommends the use of water magnetization for the enhancement of wheat seeds germination.

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