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COMPARATIVE EFFICACY OF MAGNETIC FIELD SEED TREATMENT AND PRIMING IN IMPROVING GROWTH AND PRODUCTIVITY OF OKRA

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ABSTRACT

Seed priming (halo- and hydro-priming) and magnetic seed treatments have been used to invigorate seeds. Primed seeds cannot be stored for long duration due to start of gemination processes, although dried to initial seed moisture content at the end of lag phase of germination. On the other hand, magnetic seed treatment invigorates the seeds without starting germination processes and so considered safe for storage of seeds. The comparative evaluation as well as their impact on various physiological aspects of okra plant has been scarcely evaluated. A field experiment was conducted to compare the impact of seed priming (hydro-priming and halo-priming) and magnetic field seed treatments, on growth, photosynthesis related attributes and yield of two okra cv. Sabz Pari and Super Green during summer 2016. Seeds of both cultivars, primed in water (hydro-priming), salt solution (halo-priming using NaCl 1%, $ZnSO_4$ 0.1%, $CuSO_4$ 0.1%, H_3BO_3 1%, KNO_3 1% and 2%), or exposed to magnetic field of 100 or 200 mT for 10 or 20 minutes, were sown in field according to randomized complete block design under factorial arrangements. Results revealed that magnetic field seed treatment, specifically 100 mT for 20 minutes, improved emergence (25-34% over control), seedling fresh and dry weight, leaf weight, pod length, number of fruits per plant and fruit yield per plant (27-38% over control). Chlorophyll contents of both okra cultivars were highest in response to seed priming with 1% KNO_3. Transpiration rate and net photosynthetic rate of both okra cultivars were also high for plants grown using 100 mT for 20 minutes treated seeds of both cultivars. While, sub-stomatal conductance of cv. Sabz Pari and Super Green was highest in response to 100 mT for 10 minutes and 1% NaCl, respectively. However, water use efficiency of Sabz Pari and Super Green was highest for plants raised using seeds primed in 1% KNO_3 and 1% H_3BO_3, respectively. It may be inferred that pre-sowing magnetic field treatment of seed (100 mT for 20 minutes) can be effectively used to improve okra crop stand establishment, growth and yield followed by seed priming in 1% KNO_3. Moreover, magnetic seed treatment, being less damaging to seed, is more suitable than priming; the later one decreases storage life of seed.

Key words: *Abelmoschus esculentus*, Halopriming, Hydropriming, Magnetic field seed treatment, Seedling traits, Gas exchange attributes

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INTRODUCTION

Okra (*Abelmoschus esculentus* L.), also known as ladyfinger, belongs to family Malvaceae, is a well-known summer vegetable crop. It is a rich source of vitamins A, B, and C as well as a good source of iodine and protein. Its stem is a source of fiber that is used in paper industry (Gupta *et al*. 2019). Okra seeds are hard and emergence is spread over a wide period of time after sowing, depending upon temperature and soil conditions (Demir and Ermis 2004). Uniform crop stand ensures uniform maturity and high yield (Sarwar *et al*. 2017). Several pre-sowing treatments have been reported to increase uniform germination and emergence in various agronomic and horticultural crops *viz*., magnetic seed treatment, humidification, soaking, and various types of priming (sand, halo-priming, hydro-priming, and hormonal priming). Priming allows some of the important metabolic processes to occur before actual germination to get started, such as synthesis or activation of some enzymes that catalyze the mobilization of storage reserves in seed, and weakening of endosperm (Farooq *et al*. 2008).

Physical pre-sowing seed treatments are considered eco-friendly as compared to chemical ones (Iqbal *et al*. 2012). Among physical seed treatments, Magnetic Field (MF) pre-sowing seed treatment is safer and inexpensive method to advance the seed germination and seedling growth (Podlesny *et al.* 2005), without any degradation/alteration in the chemical composition of seed. Magnetic seed treatment enhanced seed germination, seedling growth, fresh and dry weight, activities of some enzymes and seed yield in wheat (Gholami and Sharafi 2010). Similarly, pea seeds exposed to magnetic field exhibited increased germination and vigour (Iqbal *et al.* 2012). Okra seeds

exposed to 99 mT for 11 minutes showed significant increase in leaf area, number of fruits per plant and pod yield per plant (Naz *et al*. 2012). Photosynthesis, stomatal conductance and chlorophyll content increased in corn plants exposed to static MFs of 100 and 200 mT, compared to control under irrigated and mild stress condition (Anand *et al*. 2012). Previously, it has been mentioned in literature that magnetic field increase mobility of ions in seed that may in turn improve nutrient availability to the growing axis in the seed. But, there was scarcity of comparative studies on use of priming and magnetic seed treatment. Moreover, impact of magnetic seed treatments on photosynthetic rate, stomatal conductance, transpiration rate and water use efficiency have not been studied in previous studies in okra. Therefore, this study was planned to compare the impact of hydro-priming, halo-priming and magnetic field treatment of okra seed on improvement of seed vigour, photosynthetic rate, water use efficiency, transpiration rate and ultimate plant growth and productivity of two okra cultivars.

MATERIALS AND METHODS

Site, Seed Source and Seed Treatments: This study was conducted at experimental field of Institute of Horticultural Sciences, University of Agriculture Faisalabad, Pakistan. Mean minimum and maximum temperature during the study period was 23.5 °C and 35.5 °C, respectively. Total rainfall during the study period was 69 mm. Seeds of okra cultivars Super Green and Sabz Pari were collected from Siddique Sons (A registered seed merchant) and Vegetable Seed Lab, Institute of Horticultural Sciences, University of Agriculture Faisalabad, Pakistan. Seeds were subjected to various treatments, selected on the basis of literature review, as mentioned in the following section. For the magnetic field treatment of okra seeds, seeds were exposed to magnetic field developed by the electromagnet of different strengths (100 mT or 200 mT) and durations (10 or 20 minutes), in the Physics department, University of Agriculture, Faisalabad, Pakistan, essentially as reported earlier by Naz *et al.* (2012). Seeds (2 g) were primed either in 50 mL of distilled water (hydro-priming) or in 50 mL solutions of various salts (NaCl 1%, $ZnSO_4$ 0.1%, $CuSO_4$ 0.1%, H_3BO_3 1%, KNO_3 1% and 2%) for 12 hours. Seeds were primed at 25±2 ˚C in darkness using aquarium air pump. After priming, seeds were dried to their initial moisture content and used for sowing in field.

Sowing, Cultural Practices and Experimental Layout: Treated and untreated (control) seeds of both okra cultivars were sown during March 2018 in Vegetable Area of Institute of Horticultural Sciences, University of Agriculture, Faisalabad. There were 12 seed treatments (Seeds primed in water [hydro-priming], salt solution [halo-priming using NaCl 1%, $ZnSO_4$ 0.1%, $CuSO_4$ 0.1%, H_3BO_3 1%, KNO_3 1% and 2%], or exposed to magnetic field of 100 or 200 mT for 10 or 20 minutes) including control and each treatment was replicated three times. Experiment was laid out according to the randomized complete block design under factorial arrangements because study was conducted in field conditions. Each experimental plot was of 25 ft^2 area. Seeds were sown on both sides of ridge at one feet plant to plant distance, at alternate position. Recommended dose of phosphorus (50 kg/acre) and potash (30 kg/acre) along with one third dose of total nitrogen (50 kg/acre) was applied at the time of land preparation, before ridge preparation. Remaining two third dose of nitrogen was applied in two splits at 20 and 35 days after sowing. Hoeing and manual weeding was done to keep soil loose and weed free. Imidacloprid was applied two times to control sucking insects and Match (a.i. lufenuron) was sprayed once to control chewing insects. Irrigation was done as per requirement, mostly at weekly interval, keeping in view rainfall.

Seedling Emergence, Growth and Yield Related Traits: The seeds producing normal seedlings were counted after seven days and emergence percentage was calculated. Mean emergence time (days) was determined according to the formula by Ellis and Roberts (1981). Fresh weight (mg) of five randomly selected seedlings from each replication of a treatment was recorded after one month. These seedlings were sundried followed by drying at 65-70 ˚C for 72 hours in a laboratory oven (UNB-500, Memmert, Germany) and their dry weight (mg) was measured. Number of leaves per plant was counted after 65 days of sowing. Pods were harvested at marketable maturity stage, starting 35 days after sowing, usually 5-7days after fruit setting, and their length (cm) and weight (g) was measured. Total weight of the pods per plant harvested periodically till 65 days after sowing, was expressed as yield per plant (g).

Physiological Attributes: Three young fully developed and healthy leaves per plant (two plants per replicate) were selected to measure photosynthesis rate (Pn), transpiration rate (E) and stomatal conductance (g_s). These selected leaves were placed one by one in the chamber of portable Infra-Red Gas Analyzer (IRGA) (Analytical Development Company, Hoddesdon, England). Readings of these physiological attributes were taken from 10.00 to 12.00 a.m. Ambient temperature ranged from 24.5 to 33.9 ˚C, atmospheric pressure 99.9 kPa, water vapor pressure in chamber ranged from 6.0 to 8.9 mbar, and at 403.3 mmol $m^{-2}s^{-1}$ flow of air per unit leaf area. Maximum PAR at leaf surface was up to 1711 μmol m^{-2} s^{-1}, while leaf temperature ranged from 28.4 to 32.4 ˚C, and ambient CO_2 concentration was 352 μmol mol^{-1}. WUE was calculated as the ratio between

photosynthesis (Pn) and the amount of water transpired (E).

Statistical Analysis: Experiment comprised of two factors, i.e., cultivars and seed treatments. Therefore, two-way ANOVA was used for statistical analysis of the data in statistical package "Statistix 8.1". The statistical difference among treatment means was checked using the Tukey's (HSD) Test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Seedling Traits: Both okra cultivars (Sabz Pari and Super Green) showed highest seedling emergence (100%) when grown from seeds treated with 100 mT for 20 minutes. While, seeds of Super Green, primed in distilled water (hydro-priming), H_3BO_3 (1%) or NaCl (1%), showed the least emergence. These treatments were statistically similar to seeds of Sabz Pari primed in H_3BO_3 (1%), i.e., 62.5% in all these treatments (Table 1). It is also obvious that all magnetic treatments excelled over priming treatments and control in cv. Super Green, while NaCl (1%) and KNO_3 (1%) treatments were better than magnetic treatments except 100 mT for 20 minutes for okra cv. Sabz Pari. Both okra cultivars took minimum time to emergence (6.14 days) when grown from seeds treated with 100 mT for 20 minutes. While, maximum mean emergence time for Sabz Pari (7.54 days) and Super Green (7.53) was recorded for seeds primed with NaCl (1%) and 100 mT for 10 minutes, respectively (Table 1). This improvement in germination related parameters can be attributed to more uptake of water (Soltani *et al.* 2006) at enhanced rate (Garcia and Arza 2001) in magnetically treated seeds, as well as to increased synthesis of protein or enzyme activities (Afzal *et al.* 2012). Our results are in confirmation to the findings of Naz *et al.* (2012) who recorded significant increase in germination of okra cv. Sabz Pari seeds exposed to 99 mT for 11 minutes. Moreover, all seed priming treatments also increased emergence of both okra cultivars to variable extent; higher for KNO_3 or NaCl than others, which is line with the observations of other researchers (Afzal *et al.* 2011). Superiority of magnetic field seed treatment over halo-priming was also in accordance to the findings of Soltani *et al.* (2006).

Okra cv. Super Green showed highest seedling fresh weight (55.28 g) when grown from seeds treated with 100 mT for 20 minutes (Table 1). While, untreated Super Green seeds produced seedlings with minimum seedling fresh weight (24.03 g). Moreover, seeds treated with 200 mT for 10 minutes showed decreased seedling fresh weight of both cultivars in comparison with other magnetic treatments; more in Sabz Pari as compared to Super Green. Furthermore, seed priming with 1% NaCl, 1% H_3BO_3, 0.1% $CuSO_4$, and 1% KNO_3 significantly decreased seedling fresh weight as compared to hydro-priming, 2% KNO_3 and magnetic seed treatments. Seedling fresh weight of Super Green in response to hydro-priming was statistically at par with most of magnetic seed treatments. It can be visualized from results (Table 1) that okra cv. Super Green showed highest seedling dry weight when grown from seeds treated with 100 mT for 20 minutes (19.68 g). While, untreated Super Green seeds produced minimum seedling dry weight (5.25 g). Furthermore, seed priming with 0.1% $ZnSO_4$, 1% NaCl, 1% H_3BO_3, 0.1% $CuSO_4$, and 1% KNO_3 significantly decreased seedling dry weight as compared to hydro-priming, 2% KNO_3 and magnetic seed treatments. However, hydro- and halo-priming (with 1% and 2% KNO_3) enhanced seedling fresh and dry weight, although less than 100 mT for 20 minutes, yet higher than control, i.e. 39-48% and 64-68% higher fresh and dry weight than control, respectively. Early germinated seeds may have also grew faster and accumulated more photosynthates resulting in more fresh and dry weight of seedlings. Augmented fresh and dry weight of seedlings due to magnetic field seed treatment has also been recorded in asparagus (Soltani *et al.* 2006) and marigold (Afzal *et al*. 2012), which strengthen our findings.

Plant Growth and Yield Related Traits: Okra cv. Super Green showed highest leaf weight when grown from seeds treated with 200 mT for 10 minutes (161.5 g), statistically similar to Sabz Pari raised using seed exposed to 100 mT for 10 and 20 minutes (161.25 g in both). Seed of Super Green primed in H_3BO_3 (1%) showed lowest leaf weight per plant (97.5 g), even lower than unprimed seeds (106.25 g) (Fig. 1). Hegazi (2014) also stated that seed priming enhanced the growth and development of plant, which was evident as increased leaf weight of okra in this study.

Results depicted that okra cv. Super Green showed highest pod length (11.4 cm) when grown from seeds treated with 100 mT for 20 minutes that was statistically at par with Super Green seeds primed in 2% KNO_3 (11.32 cm) while, NaCl (1%) treated seeds of Super Green produced pods of minimum length (8.3 cm). Further, it is clear from results that seed treated with NaCl (1%), $CuSO_4$ (0.1%), 100 mT for 10 min and 200 mT for 10 min decreased pod length of both cultivars as compared to other seed treatments (Fig. 2). Highest pod weight (14.7 g) was recorded for okra cv. Super Green in response to seed priming in 1% KNO_3 while minimum pod weight (11.1g) was noticed in cv. Super Green grown from seeds treated with 200 mT for 20 minutes. Further, it is clear from results that seed treated with KNO_3 (2%) decreased pod weight of both cultivars, more in Sabz Pari compared to Super Green (Fig. 3). Increased pod length and pod weight due magnetic field treatment of seed was in accordance to the findings of earlier research on okra

(Naz *et al*. 2012), peas (Podlesny *et al*. 2005) and tomato (De Souza *et al*. 2006).

It can be visualized from results that okra cv. Sabz Pari showed highest number of fruits per plant (11.75) when grown from seeds treated with 100 mT for 20 minutes (Fig. 4), statistically similar to fruit number in Super Green in response to 100 mT for 20 minutes (11.5) and 1% KNO_3 (11.5).

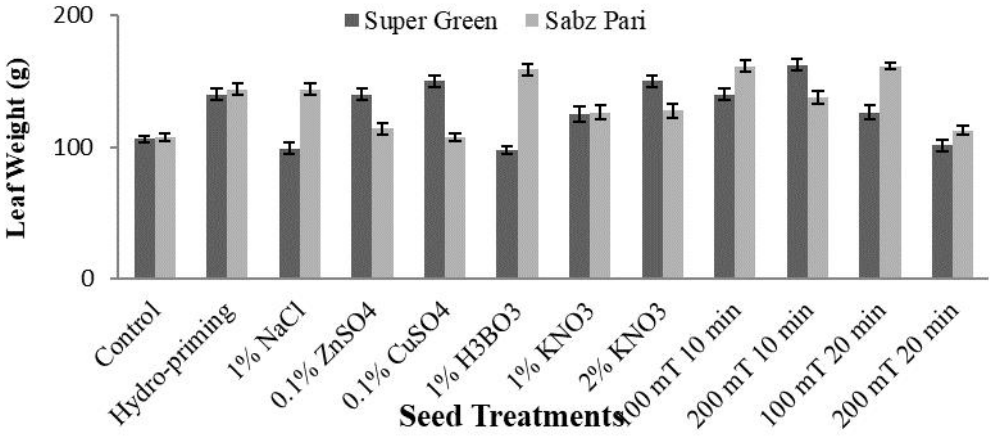

Figure 1. Effect of different seed treatments on leaf weight of two okra cultivars.

Table 1. Effect of different seed treatments on emergence and seedling traits of two okra cultivars.

Treatments	Mean emergence time (Days)		Final emergence (%)		Fresh weight of seedling (g)		Dry weight of seedling (g)	
	Super Green	Sabz Pari	Super Green	Sabz Pari	Super Green	Sabz Pari	Super Green	Sabz Pari
Control	7.35 ^{b}	7.44 ^{b}	24.02 ^{k}	27.20 ^{k}	66.66 ^{b}	75.00 ^{ab}	5.25 ^{h}	6.02 ^{h}
Hydro-priming	7.24 ^{bc}	6.95 ^{d}	50.52 $^{b-e}$	47.32 ^{ef}	62.50 ^{b}	79.16 ^{ab}	17.55 $^{b-d}$	17.65 $^{b-d}$
1% NaCl	7.36 ^{b}	7.54 ^{a}	38.37 ^{h}	33.95 ^{ij}	62.50 ^{b}	91.66 ^{ab}	9.37 ^{f}	9.55 ^{f}
0.1% $ZnSO_4$	7.13 ^{c}	7.14 ^{c}	33.82 ^{ij}	26.05 ^{k}	66.66 ^{b}	70.83 ^{ab}	6.97 ^{gh}	8.35 ^{g}
0.1% $CuSO_4$	7.35 ^{b}	7.00 ^{c}	36.57 ^{hi}	36.60 ^{hi}	87.50 ^{ab}	83.33 ^{ab}	8.87 ^{f}	9.70 ^{f}
1% H_3BO_3	7.53 ^{a}	7. 35^{b}	27.02 ^{k}	32.02 ^{j}	62.50 ^{b}	62.50 ^{b}	9.65 ^{f}	9.15 ^{f}
1% KNO_3	7.45 ^{b}	7.30 ^{b}	42.65 ^{g}	42.60 ^{g}	83.33 ^{ab}	91.66 ^{ab}	15.30 ^{e}	16.50 ^{de}
2% KNO_3	7.09 ^{cd}	7.35 ^{b}	49.15 $^{c-f}$	50.75 $^{b-e}$	87.50 ^{ab}	87.50 ^{ab}	17.27 $^{b-d}$	18.50 ^{abc}
100 mT (10 min)	7.53 ^{a}	7.16 ^{c}	53.20 ^{ab}	52.90 $^{a-c}$	91.66 ^{ab}	79.16 ^{ab}	17.42 $^{b-d}$	17.45 $^{b-d}$
200 mT (10 min)	7.30 ^{b}	7.34 ^{b}	48.00 $^{d-f}$	46.37 ^{fg}	91.66 ^{ab}	83.33 ^{ab}	17.52 $^{b-d}$	18.02 $^{a-d}$
100 mT (20 min)	6.14 ^{f}	6.14 ^{f}	55.27 ^{a}	53.67 ^{ab}	100.00 ^{a}	100.00 ^{a}	19.67 ^{a}	19.15 ^{ab}
200 mT (20 min)	6.55 ^{e}	6.67 ^{e}	51.70 $^{a-d}$	52.02 $^{a-c}$	91.66 ^{ab}	87.50 ^{ab}	17.65 $^{b-d}$	16.95 $^{c-e}$

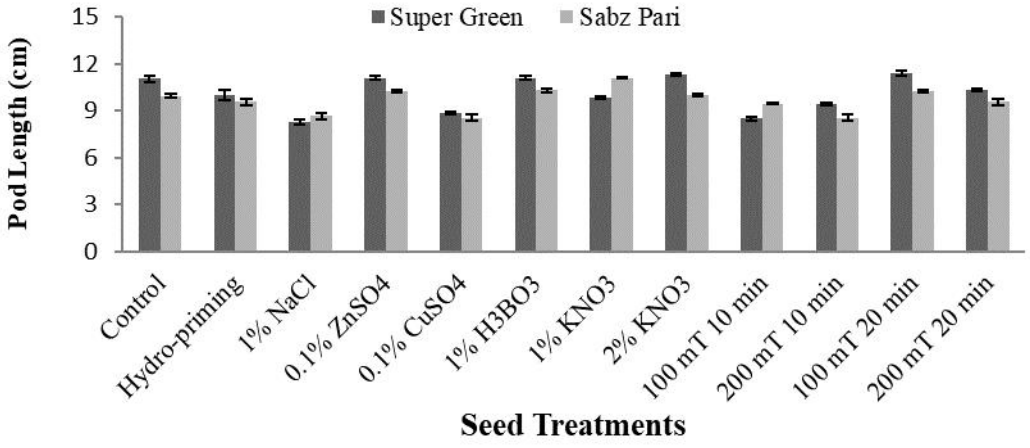

Figure 2. Effect of different seed treatments on pod length of two okra cultivars.

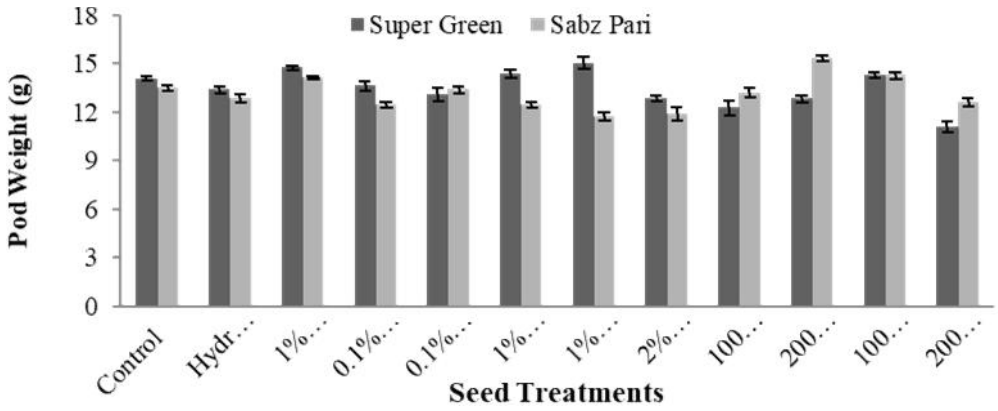

Figure 3. Effect of different seed treatments on pod weight of two okra cultivars.

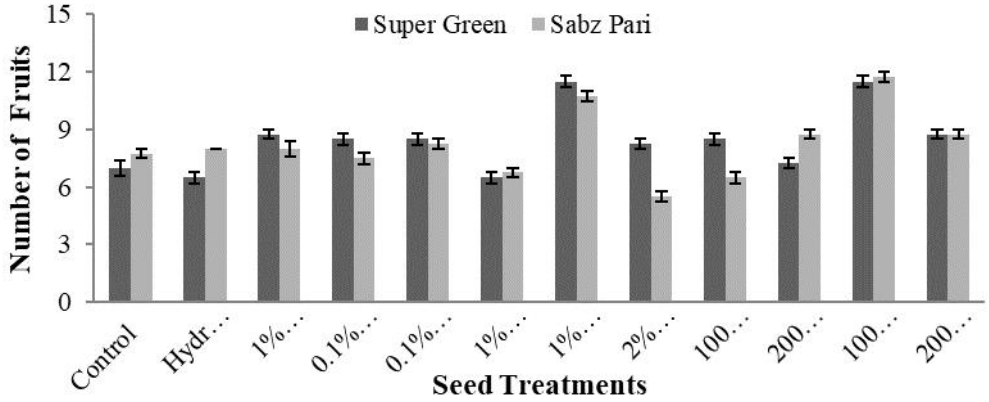

Figure 4. Effect of different seed treatments on number of fruits of two okra cultivars.

While, seeds of Sabz Pari treated with KNO_3 (2%) produced minimum number of fruits. Further, it is clear from results that seed treated with H_3BO_3 (1%) decreased number of fruits of both cultivars, more in Super Green as compared to Sabz Pari. Increased number of okra pods per plant due magnetic field treatment of seed has also been reported in earlier studies on peas (Podlesny *et al*. 2005), okra (Naz *et al*. 2012), and tomato (De Souza *et al*. 2006).

Okra cv. Super Green produced highest fruit yield per plant when grown from seeds treated with 100 mT for 20 minutes (467.5 g), statistically at par with 1% KNO_3 (458.7 g) for same cv. (Fig. 5). While, hydro-primed Super Green seeds produced minimum yield per plant (315 g). Improvement of yield due to seed priming with 1% KNO_3 can be due to improved chlorophyll contents, photosynthetic rates and water use efficiency. Sharma *et al*. (2014) reported up to 55% increase in okra yield due to priming that strengthen findings of this study. Priming has also been reported to improve yield of some horticultural and agronomic crops (Dabrowska *et al*. 2000; Srivastava *et al*. 2010).

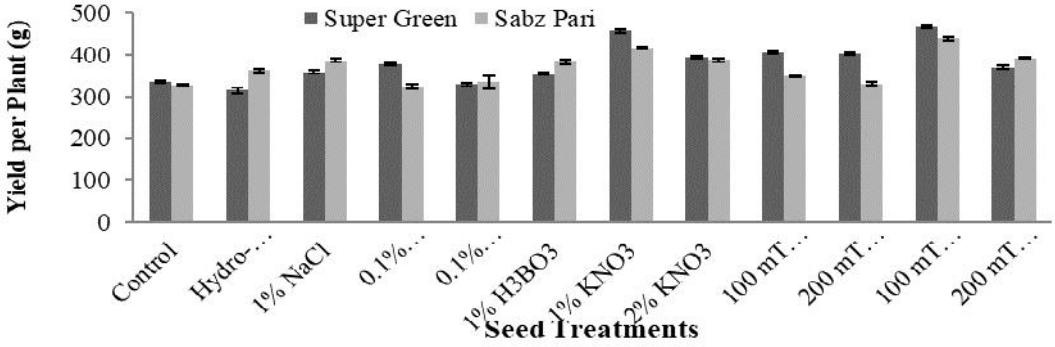

Figure 5. Effect of different seed treatments on yield per plant of two okra cultivars.

Chlorophyll Contents and Physiological Attributes: It is evident from results (Table 2) that both cultivars showed highest chlorophyll contents in response to priming with KNO_3 (1%); higher in Sabz Pari (61.95 CCI) than Super Green (61.45 CCI), but were statistically similar. Moreover, chlorophyll contents of 100 mT for 20 minutes treated seed were statistically at par or statically similar or at par with 1% KNO_3. Super Green cv. of okra showed minimum chlorophyll contents when grown from seeds treated with 200 mT for 10 min (31.72 CCI). Negative effect of magnetic field treatments on chlorophyll contents was more pronounced in Super Green than Sabz Pari. Recently, Anwar *et al*. (2020) also reported enhancement in chlorophyll contents of cucumber seedlings due to seed priming with KNO_3. They also stated that seed priming increased nitrogen and magnesium contents of leaves that are required for chlorophyll synthesis. Increase in chlorophyll contents of okra cultivars Sabz Pari and Arka Anamika due to seed priming in water and ascorbic acid were also reported by Hussain *et al*. (2017), which affirm results of this study.

Okra cv. Sabz Pari showed highest stomatal conductance when grown from seeds treated with 100 mT for 10 minutes (551 µmol $m^{-2}s^{-1}$). While, stomatal conductance of Super Green was highest for 1% NaCl (542 µmol $m^{-2}s^{-1}$). Moreover, it is evident that prolonged exposure (20 minutes) of seed to both (100 and 200 mT) magnetic field seed treatments decreased sub-stomatal conductance of both okra cultivars to less than the control (Table 2). Okra seeds treated with 100 mT for 20 minutes induced highest transpiration rate in Super Green (1.35 mmol H_2O $m^{-2}s^{-1}$) followed by Sabz Pari (1.16 mmol H_2O $m^{-2}s^{-1}$). While, Super Green seeds treated with H_3BO_3 (1%) showed minimum transpiration rate (0.53 mmol H_2O $m^{-2}s^{-1}$) (Table 2). It is obvious that all priming and magnetic seed treatments increased photosynthetic rate of both cultivars compared to control (untreated seeds) (Table 2). Seed treatment 100 mT for 20 minutes induced highest net photosynthetic rate in okra cv. Sabz Pari (6.55 µmol CO_2 $m^{-2}s^{-1}$) and Super Green (6.37 µmol CO_2 $m^{-2}s^{-1}$). Okra cv. Super Green showed highest water use efficiency when grown from seeds treated with H_3BO_3 (1%) while, Sabz Pari exhibited highest water use efficiency in response to priming in 1% KNO_3 (Table 2).

Anwar *et al*. (2020) stated improvement in photosynthetic activities including stomatal conductance, transpiration rate and rate of photosynthesis in cucumber seedlings grown by using seeds primed in KNO_3 and attributed this increase in photosynthetic activities to increased chlorophyll contents as recorded in this study on okra. Previously, Iqbal and Ashraf (2005) also asserted that pre-sowing seed treatments significantly increased photosynthesis activity in wheat plants, which support these results in okra.

Table 2. Effect of different seed treatments on physiological traits of two okra cultivars.

Treatments	Attributes									
	Chlorophyll contents (CCI)		Stomatal conductance (µmol $m^{-2}s^{-1}$)		Photosynthesis rate (µmol CO_2 $m^{-2}s^{-1}$)		Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)		Water use efficiency (µml/mmol)	
	Super Green	Sabz Pari	Super Green	Sabz Pari	Super Green	Sabz Pari	Super Green	Sabz Pari	Super Green	Sabz Pari
Control	36.05^{n}	38.85^{lm}	360.00^{a-d}	355.75^{a-d}	3.07^{f}	3.38^{ef}	0.94^{de}	0.55^{l}	3.27^{c}	6.09^{b}
Hydro-priming	46.05^{j}	55.87^{d}	427.25^{a-d}	385.75^{a-d}	5.15^{a-f}	4.42^{b-f}	0.83^{g-i}	0.60^{k}	6.19^{b}	6.94^{b}
1% NaCl	55.40^{de}	41.90^{k}	542.00^{a}	374.25^{a-d}	5.63^{a-d}	4.53^{c-f}	0.76^{ij}	0.87^{e-g}	7.43^{ab}	5.18^{bc}
0.1% $ZnSO_4$	41.70^{k}	57.35^{c}	504.25^{ab}	435.75^{a-d}	4.23^{c-f}	4.37^{b-f}	0.85^{fg}	0.74^{j}	4.94^{bc}	5.88^{bc}
0.1% $CuSO_4$	48.72^{hi}	49.35^{gh}	453.00^{a-c}	413.25^{a-d}	5.21^{a-e}	5.46^{a-e}	0.77^{h-j}	0.92^{d-f}	6.72^{b}	5.92^{bc}
1% H_3BO_3	54.15^{e}	35.50^{n}	424.75^{a-d}	460.75^{ab}	5.28^{a-e}	5.37^{a-e}	0.53^{l}	0.84^{f-h}	9.83^{a}	6.37^{b}
1% KNO_3	61.45^{a}	61.95^{a}	367.50^{a-d}	524.75^{a}	4.74^{a-f}	5.24^{a-e}	0.64^{k}	0.73^{j}	7.37^{ab}	7.16^{ab}
2% KNO_3	39.70^{l}	55.67^{d}	442.00^{a-d}	487.25^{ab}	5.35^{a-e}	5.31^{a-e}	1.05^{c}	0.85^{fg}	5.08^{bc}	6.22^{b}
100 mT (10 min)	38.97^{lm}	52.72^{f}	384.00^{a-d}	551.00^{a}	5.66^{a-d}	3.94^{d-f}	0.84^{f-h}	0.63^{k}	6.74^{b}	6.23^{b}
200 mT (10 min)	31.72^{o}	47.65^{i}	456.50^{ab}	440.50^{a-d}	6.11^{a-c}	4.56^{a-f}	0.96^{d}	0.94^{de}	6.37^{b}	4.87^{bc}
100 mT (20 min)	58.82^{b}	60.70^{a}	248.00^{d}	258.50^{cd}	6.37^{ab}	6.55^{a}	1.35^{a}	1.16^{b}	4.70^{bc}	5.65^{bc}
200 mT (20 min)	37.72^{m}	50.30^{g}	311.75^{b-d}	356.25^{a-d}	5.01^{a-f}	4.61^{a-f}	0.72^{j}	0.87^{e-g}	6.93^{b}	5.30^{bc}

Conclusion: It can be concluded that magnetic field treatment of 100 mT for 20 minutes and 1% KNO_3 enhanced vegetative growth, photosynthesis and yield compared to all other treatments; former was superior to the later one in almost all traits, but the difference in most of the cases was non-significant. Moreover, magnetic seed treatment, being less damaging to seed, is more suitable than seed priming that decreases the storage life of seed.

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