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Enhancement in the germination, growth and yield of Okra (*Abelmoschus esculentus*) using pre-sowing magnetic treatment of seeds

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Received 30 October 2011; revised 28 April 2012

The effect of pre-sowing magnetic treatments was investigated on germination, growth and yield of okra (*Abelmoschus esculentus* cv. Sapz pari). The dry okra seeds were exposed to sinusoidal magnetic field induced by an electromagnet. The average magnetic field exposure was 99 mT for 3 and 11 min and seeds with no magnetic field treatment were considered as control. Both treated and non-treated seeds were sown in experimental plots (120 m²) under similar conditions. Samples were collected at regular intervals for statistical analysis. A significant increase ($P < 0.05$) was observed in germination percentage, number of flowers per plant, leaf area (cm²), plant height (cm) at maturity, number of fruits per plant, pod mass per plant and number of seeds per plant. The 99 mT for 11 min exposure showed better results as compared to control.

Key words: *Abelmoschus esculentus*, Electromagnetic seed treatment, Germination, Okra seed, Seedling growth, Yield

The effect of magnetic field (MF) on plant has been a subject of many research studies. Initial studies showed that magnetic treatment could influence the auxin content, enzyme activity, free radical formation, protein synthesis and increased water up take^{1,2,3,4,5}. Magnetic field treatment showed positive effects on seed germination, crop growth, respiration rate, heat loss, chemical changes in seeds⁶ and also induced resistance in plant against Gemini virus and early blight disease⁷. The magnetic treatments resulted in significant increase in fruit yield, number of fruits per plant, average fruit weight, leaf area, plant height as well as fresh and dry masses of growth parameters^{8,9,10,11,12} and also affected the systems biologically at certain treatment levels^{13,14,15}.

Okra is an important vegetable crop throughout the world. It is usually sown from the mid of February to mid of May and pods should be ready for harvesting within 10 weeks of planting. It is a good source of vitamins, carbohydrates, protein, calories, dietary fiber, folic acid, calcium and magnesium. Okra is not only used as vegetable but also in rope making and paper industry. Okra seed oil is being used for food as well as for biodiesel production¹⁶.

In the present study, we have investigated the effects of pre-sowing magnetic treatment on growth and yield of okra (*Abelmoschus esculentus*). The work has been performed during the crop season of okra and the results of field experiments were also reported.

Materials and Methods

Genetically-uniform okra seeds (*Abelmoschus esculentus* cv. Sapz pari) were obtained from the Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. The magnetic treatments prior to sowing were applied using a homemade electromagnet (Fig. 1) fabricated in the Department of Physics, University of Agriculture, Faisalabad, Pakistan. The details of this apparatus are reported elsewhere¹⁷. Briefly, the electromagnet consisted of four cylindrical coils, each formed by 4000 turns of 0.41 mm enameled copper wire. The resistance of each coil was 26 ohm. Each pair of coils was wound 10 cm apart on an iron bar. The two pairs of bars were placed one above the other. The ends of these bars were held by metallic supports. The coils

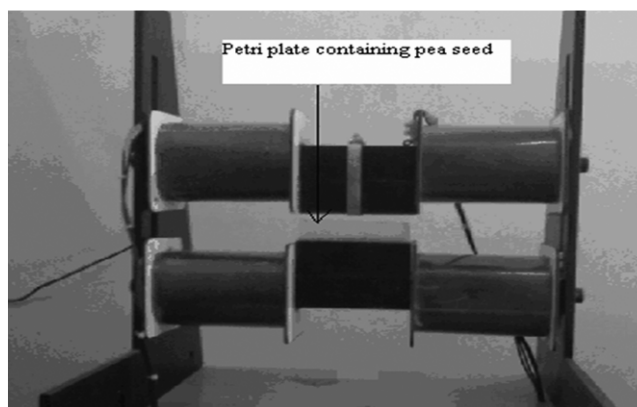


Fig. 1—The experimental electromagnet setup [A rectangular glass dish (Petri plate) is placed in the gap between two iron bars exposing Okra seeds to magnetic field]

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were connected in series and fed through a variable power supply (0 to 220 V) having approximately the shape of a 50 Hz full-wave rectified sinusoidal voltage resulting in the generation of a full-wave rectified sinusoidal non-uniform MF in the gap between the two bars. The required working strength of MF was adjusted by varying the voltage applied to the coils. The MF generated in the region occupied by the seeds was measured using a magnetic flux meter (ELWE, Germany) as reported earlier¹⁸.

The dry okra seeds were placed in a rectangular glass dish (10 cm x 3.5 cm) which was made according to the geometry of the electromagnet. The treatment with no magnetic field exposure (0 mT) was named as control. The other two treatments comprised of 99 mT for 3 min (treatment T₁) and 99 mT for 11 min (treatment T₂). The seeds were labeled and sown in beds during the month of March and irrigation was applied immediately after sowing. Later on water was supplied regularly according to the standard agricultural practice. The beds were 223 cm long and 13 cm wide. The experiment was laid out according to randomized complete block design with 4 replications. Total area under the experiment was 120 m². Plant-to-plant bed-to-bed distance was maintained 25 cm and 55 cm respectively and seeds were sown on both sides of beds. The total number of cultivated plants was 542, of which 240 plants were analyzed and 20 plants per replication were randomly selected for recording the data.

Optimization of MF strength and exposure duration

For optimization of MF and time of exposure, 12 different combinations were investigated and the treatment which showed better results was selected. The treatment combinations were as follows: 33 mT for 3, 7 and 11 min; 71 mT for 3, 7 and 11 min; 99 mT for 3, 7 and 11 min; 120 mT for 3, 7 and 11 min;

As the treatment of 99 mT for 11 min exposure showed better response.

The climatic data recorded during the experimental period is given in Table 1. The data regarding germination, growth and yield characteristics were subjected to statistical analysis using Fishers analysis of variance techniques ($P < 0.05$). The treatments had factorial structure, so two factors factorial experiment with additional treatment was used with randomized complete block design¹⁹. Duncan multiple range test was applied²⁰ at 5% probability level to determine the effect of MF treatment for comparison with control and also to compare the differences among treatment means. Statistical analysis of data was performed using SPSS (for windows) software.

Results and Discussion

Germination and growth dynamics

MF pre-treatments showed significant increase ($P < 0.05$) in seed germination, showing 32.8% and 33% increase with T₁ treatment (99 mT for 3 min) with T₂ (99 mT for 11 min) respectively as compared to control (Table 2). The germination time for treated seeds was reduced by 24 h as compared to control. These results were in agreement with the work reported earlier^{3,21,22}.

Plants grown from seeds treated with T₁ and T₂ showed 106.89% and 200% increase of in number of

Table 1—Climate conditions during the experimental period

| Meteorological variables | March 2009 | April 2009 | May 2009 |
|--------------------------|------------|------------|------------|
| Mean maximum temp. (°C) | 27.5 ± 0.4 | 33.5 ± 0.7 | 40.1 ± 0.6 |
| Mean minimum temp. (°C) | 16.5 ± 0.4 | 19.1 ± 0.5 | 24.8 ± 0.5 |
| Mean temp. (°C) | 2.0 ± 0.5 | 26.3 ± 0.7 | 32.4 ± 0.6 |
| Sunshine (h) | 7.8 ± 0.4 | 09.2 ± 0.3 | 10.4 ± 0.4 |
| Relative humidity (%) | 53.5 ± 2.0 | 41.7 ± 2.6 | 31.4 ± 1.5 |
| Mean rainfall (mm) | 14.0 ± 0.2 | 22.9 ± 0.8 | 09.1 ± 0.7 |

Table 2—Effect of magnetic treatment on germination, growth and crop yield parameter of okra (*cv. Sapz pari*) during the experimental period (March 2009- May 2009)

[Values are mean of 20 plants per treatment with SEM of means]

| Variable measured | Control | 99 mT 3 min | 99 mT 11min | CV % |
|-------------------------------|----------------------------|----------------------------|----------------------------|-------|
| Seed germination (%) | 53.25 ± 3.17 ^b | 70.75 ± 6.58 ^a | 71.00 ± 4.55 ^a | 14.31 |
| No. of flowers per plant | 7.25 ± 2.02 ^c | 15.00 ± 1.83 ^b | 21.75 ± 1.80 ^a | 23.36 |
| Leaf area (cm ²) | 124.56 ± 3.87 ^b | 175.38 ± 11.3 ^a | 170.41 ± 14.4 ^a | 14.96 |
| Plant height at maturity (cm) | 73.21 ± 1.34 ^b | 99.80 ± 1.01 ^a | 102.20 ± 1.88 ^a | 12.88 |
| No. of pods per plant | 10.5 ± 0.3 ^b | 12.0 ± 0.2 ^b | 16.2 ± 1.1 ^a | 13.23 |
| Pod mass (g) per plant | 350.0 ± 23.8 ^c | 486.0 ± 28.8 ^b | 692.0 ± 40.9 ^a | 11.85 |
| No. of seeds per plant | 59.8 ± 1.9 ^c | 75.3 ± 11.9 ^b | 133.9 ± 8.3 ^a | 17.08 |

In rows, means sharing similar letters are statistically non-significant ($P > 0.05$). CV, Coefficient of variation.

flowers per plant (Table 2) and was in accordance with a previously reported work¹⁷. Leaf area increased by 40.8% and 36.8% with T₁ and T₂, respectively (Table 2) as compared to control which might be due to increased photosynthetic rates due to greater interception of light^{10,23}. The plant height at maturity stage also showed 36.3% and 39.6% increase on T₁ and T₂ treatment as compared to control (Table 2). The improvement in plants height raised from treated seeds might be due to the influence of MF on both the activation of ions and polarization of dipoles in the living cells^{21,24-27}.

Previous studies have shown that the changes induced by the MF at cellular level result in a wide range of physiological effects, such as rate of germination, seed weight, plant height, protein content, productivity, leaf size, fruit weight, fruit number¹⁸. With the biostimulation of seeds and plants through biophysical methods, the survival capabilities of the plants as well as the resistance to the climate influences are increased.

A recent study conducted by Anand *et al*³ has also shown that MF treatment of maize (*Zea mays* L.) seeds enhances the seedling growth, leaf water status, photosynthesis rate and lowered the antioxidant defense system of seedlings under soil water stress. The study has suggested that pre sowing static MF treatment of seeds can be effectively used for improving growth under water stress.

Okra yield

MF pretreatment showed significant increase in crop yield parameters such as number of fruits per plant, total mass of fruits per plant and number of seeds per plant as compared to control (Table 2). The treatment T₂ resulted in significant increase ($P < 0.05$) in the number of fruits per plant (54.76%) as compared to control, however, treatment T₁ showed no significant influence ($P > 0.05$) on the number of fruits per plant. The magnetic treatment also had a significant effect on fruit mass per plant, showing an increase of 38.85 and 97.71% for T₁ and T₂, respectively, while the increase in number of seeds per plant was 25.85% and 123.83% for treatment T₁ and T₂, respectively (Table 2).

The increase in yield might be attributed to the lower levels of environmental stresses on the seeds due to magnetic treatment²⁸⁻³⁰. The increase in seed yield might be due to the increased photosynthetic rate, in addition to the increased number of flower and fruits per plant²⁶. Earlier, 28 to 51% increase in yield

in tomato³¹ and 20 to 25% increase in the yield of buckwheat³² has been reported from magnetically-exposed seeds. Increase in yield has also been reported in barley, sunflower, cotton and lettuce³³⁻³⁶.

Seed germination stimulation, growth and development at lateral stages might be attributed to a combined effect of biochemical, physiological, metabolic changes as well as enhanced enzymatic activities. It is assumed that magnetic treatment influences the structure of cell membrane and in this way increases the permeability and ion transport in the ion channels that affect the metabolic pathways. The enzymes which are necessary for seed germination at particular stages of germination have been reported significantly higher¹⁸.

The MF affects the biological objects by non-conventional spins, free radicals, liquids crystals or mobile electron charges. Chemically, these free radicals are very active species, which take part in fast reactions and cause changes in the biochemical and physiological processes during seed germination and an increase in water uptake rate due to magnetic treatment that is responsible for increased germination as well as seedling growth and yield^{18,37}. Significantly high α -amylase activity which is responsible for the degradation of food reserves of the seedling during germination, is reported in magnetically-treated seeds¹¹. Similarly, high dehydrogenase and glucose-6-phosphate dehydrogenase activities have also been reported in treated seeds during germination.

One theory of the MF interaction with biological systems is 'radical-pair mechanism' consisting of the modulation of single-triplet inter-conversion rates of a radical pair by MF. MF increases the average radical concentration, prolongs their life time and enhances the probability of radical reaction with cellular components³⁸. The effects of MF on germination and yield become more prominent up to a certain level when the exposure time of MF increases, which indicate obvious effects of MF on germination, growth and yield.

Conclusion

The effect of magnetic treatment on seeds depended not only on the MF strength but also on the duration of exposure. The magnetic treatment of 99 mT for 11 min exposure showed better results as compared to control and 99 mT for 3 min treatment. The considerable improvement in germination rate, growth and yield was observed as compared to control due to the pre-sowing magnetic treatments.

Acknowledgements

The authors are grateful to the Ayub Agricultural Research Institute, Faisalabad, Pakistan for providing technical support to carry out this research work.

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