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RESEARCH ARTICLE :

Static and Pulsed magnetic field exposure improves vigour and yield of cherry tomato

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SUMMARY : Cherry tomato seeds were magnetoprimed with various doses of static magnetic field (SMF) in the range of 50 – 150 mT for duration of 30 min and 1 h. SMF dose of 100 mT for 30 min gave maximum increase in germination characteristics and was selected and applied as pulsed dose. The seeds were exposed to pulsed magnetic field dose in the cycles of 2, 3, 5 and 6 min on and off and PMF dose of 3 min on and off cycle showed significant enhancement of 23% in seedling vigour compared to other treatments. These two doses were evaluated for their field performance. Yield increased by 17% in SMF and 27% in plants from PMF primed seeds. There was no significant change in the number of fruits and the increase in yield was due to a significant increase in weight per fruit which was 6.4 g in control compared to 7.76 and 8.55 g in SMF and PMF, respectively. Our results indicate that pulsed magnetopriming is more effective dry seed priming treatment that can be used for increasing productivity of cherry tomato.

KEY WORDS :
Cherry tomato, Germination, Vigour index, Yield, Magnetopriming, Rate of germination

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BACKGROUND AND OBJECTIVES

Globalization has brought about changes in the living standards and living style of people, most noticeable being the change is the food habits among the new generation. As a consequence, demand-driven exotic vegetables production is increasing in India at the rate of 15 to 20% per annum for self sufficiency as approx. 85% is being imported from other countries.Tomato fruit is the most important vegetable world over, for table purpose as well as for processing. It is available throughout the year and is a rich source of energy, carotenoids, flavonoids, phenolics, mineral nutrients, vitamin C and dietary fibres which are beneficial and serve as protective ingredients for human health (Wold *et al.* 2004).Cherry tomato is a small garden variety of tomato that has very high nutritive value, containing vitamin A, lycopene, beta-carotene, vitamin C and minerals like calcium, potassium etc. The cultivation of cherry tomato is a highly economical venture for the farmers as they have assured market through contract with national and international retail chains. However, under reducing resources and increasing cost of vegetable, the major challenge lies ahead to develop technologies that enhance quality and productivity of vegetables. Crop yields can be maximized by establishment of an adequate and uniform plant stand. Rapid and uniform field emergence of seedlings is therefore a challenge to as slow emergence results in smaller plants and seedlings which are more vulnerable to soil- borne diseases thus leading to decline in productivity.

Seed priming is a physiological seed enhancement method for overcoming poor and erratic seed germination in many vegetable and flower species. Seed priming techniques like hydropriming (soaking in water),osmopriming (soaking in solutions of different organic osmotica), solid matrix priming and halopriming (soaking in inorganic salt solutions) are being experimented extensively to increase the speed and synchrony of seed germination of vegetable and field crops (Nakaune *et al*. 2012). The pre-sowing seed treatment with magnetic field called "magnetopriming" is a dry seed priming technique that doesn't hydrate the seed, allows storage of the seed at room temperature and is eco-friendly. Other priming treatments have a mandatory requirement of dehydrating the seed for storage before sowing but magnetopriming is carried out in dry seed and proves to be more useful. Several researchers have reported the beneficial effect of both static and pulsed magnetic fields in different plant species (Anna 2002; Fischer *et al.,* 2004; Florez *et al.,* 2007, Shine *et al.,* 2011, Bhardwaj *et al.,* 2012; Radhakrishnan and Ranjitha Kumari, 2012, Bilalis *et al.,* 2012; 2013). The aim of the study was to optimize the static and pulsed magnetic field dose for seed invigouration in cherry tomato and evaluate its field performance.

RESOURCES AND METHODS

Seed of cherry tomato (Selection 1) were obtained from CPCT, Indian Agricultural Research Institute, New Delhi and used for the study.

Electromagnetic field generator :

An electromagnetic field generator "Testron EM-60" with variable magnetic field strength (50 to 300 mT) with a gap of 10 cm between pole pieces was used for seed treatment. The pole pieces were 15 cm in diameter and 35 cm in length. The number of turns per coil was 1600 and the resistance of the coil was 16 ohm. A DC power supply (80V/ 10A) with continuously variable output current was used for the electromagnet. A digital gauss meter model DGM-30 operating on the principle of Hall Effect, monitored the field strength produced in the pole gap. The probe was made of Indium Arsenide crystal and was encapsulated to a non- magnetic sheet of 5 mm × 4 mm × 1 mm and could measure 0-2 Tesla with full-scale range in increments of 5 mT.At low field strength (50 mT), width wise variation of magnetic field strength from centre to periphery was 0.6 and height wise 1.6% of the applied field. At high field (300 mT), they were 0.4 and 1.2% of the applied field, respectively. The local geomagnetic field was less than 6 mT and the direction of local geomagnetic field was north to south.

Optimization of static and pulsed magnetopriming dose for seed invigouration

Static magnetic field :

Cherry tomato seeds were exposed to static magnetic field of 50-150 mTin increments of 50 mTfor varying durations of 30 min and 1 h, by placing in a cylindrical-shaped sample holder of 42 cm^3capacity, made of a non-magnetic thin transparent plastic sheet. Three hundred visibly sound, mature, healthy seeds held in the plastic container were placed between the poles of the electromagnet having a uniform magnetic field. The required strength of the magnetic field was obtained by regulating the current in the coils of the electromagnet. A gauss meter was used to measure the strength of the magnetic field between the poles. The variation in temperature during the course of seed exposure was 25 ± 0.5^{o}C.For parallel control, seeds from the same lot used for magnetic field exposure were kept under conditions which had no influence of the induced magnetic field, as magnetic field generator was housed in a separate chamber. The field strength and duration was standardized for maximum enhancement of germination and vigour under laboratory conditions and best combination was selected for standardization in the pulsed mode.

Pulsed magnetic field :

Among all the treatments in the static mode, 100 mT for 30 min was most effective in enhancing the germination parameters in magnetoprimed seeds and was further employed for treating seeds in pulsed mode. Four pulsed doses (the number of times the sample was exposed to magnetic field in 30 min) were designed for PMF treatment with 100 mT (30 min) applied in the cycle of 2, 3, 5 and 6 min on and off.

Germination- percentage :

The germination of the seeds was determined by using "between papers" method given by ISTA (1985). One hundred seeds in four replications of 25 seeds each were placed between two layers of moist germination papers. The germination papers were rolled carefully ensuring that no excess pressure was placed on the seeds. These were wrapped in a sheet of wax paper to reduce surface evaporation of moisture and placed in the germination incubator at 25°C in an upright position. After 14 days, seeds were evaluated for normal, abnormal seedling, un-germinated and dead seeds.

Rate of germination :

Seeds were placed in Petri dish on a double layer of moistened filter paper and incubated in darkness in a germinator at 25°C. A daily germination count of the incubated seeds was taken until no more seeds germinated, and the speed of germination was calculated following Maguire (1962) as :

Speed of germination = $\sum$(n/t)

where n = number of seeds germinated and t = time of count.

$$\sum (n/t) = \frac{\text{Number of seed germinated}}{\text{Days of the first count}} + \ldots + \frac{\text{Number of seeds germinated}}{\text{Day of the final count}}$$

Seedling growth and vigour indices :

Ten normal seedlings from each replicate kept for germination, were randomly selected to measure shoot and root length in cm. They were subsequently dried at 80°C in an oven and weighed together till a constant weight was obtained.

Seedling vigour was calculated following Abdul-Baki and Anderson [1973] as :

Vigour index I = Germination% × seedling length (Root + Shoot) (cm)

Vigour index II = Germination% × seedling dry weight (Root + Shoot) (g)

From the results of the optimization magnetic dose, it was observed that germination and related characteristics showed enhanced performance in the static magnetic field of 100 mT for 30 min and 3 min on and off pulsed dose.

OBSERVATIONS AND ANALYSIS

The results of optimization studies for improving seed vigour with static and pulsed magnetic field exposure are presented in Table 1a and 1b, respectively. Graphs are drawn for individual parameters for depiction of data individually. Static magnetic field exposure did not result in any significant change in the germination percentage of cherry tomatoes although SMF dose of 100 mT(30 min) resulted in 5 % increase compared to unprimed control. On the basis of marginal increase observed under SMF exposure, 100 mT (30 min) was given as pulsed dose for 2, 3, 5, 6 min to cherry tomato seeds. Germination percentage was not significantly affected although there was 6% increase at PMF (3 min on/off) dose. Rate of germination showed insignificant increase by 8- 16% at lower static magnetic field dose of 50- 100mT for varying duration. The maximum rate of germination was recorded at SMF dose of 100 mT for 30 min duration. Rate of germination was adversely affected in MF dose between 100mT (1h) – 150mT (1h) with rate of germination falling below the rate observed in untreated control. The 100 mT (30 min) dose applied as pulsed dose for 2, 3, 5, 6 min showed the maximum increase (21 %) in rate of germination at 3 min on and off pulse in comparison to untreated control. SMF exposed seeds did not show a significant change in root length but shoot length was significantly higher. Several researchers have reported the beneficial effect of priming with magnetic fields (Martínez *et al.,* 2009; Dominguez *et al.,* 2010; Shine *et al.,* 2011; Bhardwaj *et al.,* 2012; Bilalis *et al.,* 2013).Our results demonstrated thatmagnetopriming of the seed with 100 mT(30 min) static and pulsed dose of 100 mT (30 min) applied as 3 min on and off cycle enhanced all germination associated characteristics in cherry tomato. The shoot length increased by 9-20% at varying doses of SMF compared to untreated control (Table 1a). On the other hand, pulsed magnetic field treatment showed a significant increase in root and shoot length. Root and shoot length increased by 21 and 18 %, respectively at PMF (3 min on and off (Table 1b).Dry weight of ten randomly selected seedlings increased by 13% in SMF dose of 100 mT (30 min)compared to unprimed control. Similarly,19 % increase in seedling dry weight was observed in pulsed magnetic field dose applied in 3 min pulses. Studies have revealed that phytoferritin occur in plant cells as crystalline magnetite (Fe_3O_4), å-Fe_2O_3 and hematite (á- Fe_2O_3) (McClean *et al.*, 2001) and may interact strongly with the magnetic fields than do diamagnetic or paramagnetic materials. These particles can also affect the superoxide generated free radicals

(Scaiano *et al.*, 1997). Enzyme catalysed reactions that involve intermediates with radical pairs (Grissom, 1995) and some porphyrins that form free radicals during mitochondrial respiratory chain may also be influenced by external magnetic field as it affects singlet-triplet conversions The radical pair mechanism (RPM) is currently the only physically plausible mechanism indicating the role of cryptochrome as a candidate for magnetoreception that results in generation of flavin-trytophan radical pairs (Occhipinti *et al.*, 2014).

The static magnetic field strength and its duration had positive effect on vigor indices. Vigor index I increased in the range of 10-24% and vigor index II in 9-37% among the various treatments. Seeds treated with 100 mT (30 min) recorded the highest increaseof 24% in vigor index I and 37% in vigor index II. Increase in vigour was less when SMF dose was increased to 150 mT for 30 min and 1h.Analysis of vigour indices in PMF treated seeds showed that PMF (3min on and off) resulted in 20 and 23 % increase in Vigour Index I and II, respectively over the untreated control (Fig. 4.4 b and 4.5b). PMF (6 min on and off) dose adversely affected the vigour indices as both the values became less than unprimed control. Based on the results of all the germination related characteristics tested in Static and Pulsed magnetoprimed and unprimed seeds, SMF dose of 100mT (30 min)and PMF dose of 100 mT (30 min) applied as 3 min on and off cycle was selected for evaluating the field performance and yield of the crop. In the vegetative stage, the treatment led to a significant increase in the leaf area, leaf dry weight, and specific leaf area per plant consequently resulting in higher biomass. The earliness in flowering and fruit setting observed inmagnetoprimed seeds can be exploited to the benefit of farmers as it can fetch a good market value for the seasonal horticultural crops by supplying fruits early.The economic return after treating the cherry tomato seedswith pulsed magnetic field so as to achieve an increased yield of 27% showsit to be very renumerative for the farmers(Table 3)

Flowering started at 22-26 days after transplanting in plants from pulsed and static magnetic field treatment which was 7-9 earlier than plants from unprimed control. Initiation of fruiting was at 41-43 and 42-45 days after transplanting in plants from pulsed and static magnetic field treatment which was 6-9 earlier than plants from unprimed control. The fruits were harvested at the light red/red stage starting from 97 days (1st week of January, 2014) after transplanting. Nine harvests were taken in all that continued uptil16th April 2014. No significant difference was found between fruit number amongst the various treatments although there was 8-10 % reduction in number of fruits per square meter in fruits from SMF and PMF treated seeds compared to control. The average yield per square meter showed a non significant increase of 17% in fruits from SMF treated seeds. However a significant increase of 27% was observed in plants from PMF treated seeds (Table 2). Though the number of fruits was higher in control plants but the average fruit size was less than fruits from magnetoprimed plants. It was observed that average fruit weight was 6.4 g in control compared to 7.76 and 8.55 g in SMF and PMF, respectively (Table 2).

Conclusion :

Static and pulsed magnetic field treatment can be used for improving the productivity of cherry tomato under controlled environment. Pulsed magnetic field treatment yields a better response and can be very renumerative and ecofriendly seed enhancement technology for yield improvement of cherry tomatoes.

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