Indian J. Plant Physiol., Vol. 12, No. 4, (N.S.) pp. 301-311 (Oct.-Dec., 2007)

Mini Review

ELECTROTHERAPY OF PRE-SOWING SEED: A NOVEL TECHNIQUE FOR YIELD IMPROVEMENT IN CROP PLANTS

***A.K. BERA[1], M.K. PATI[2] AND ANITA BERA[3]**

[1]Department of Plant Physiology, [2]Department of Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, Nadia, West Bengal
[3]Institute of Agricultural Science, Calcutta University, 35 Ballygunge Circular Road, Kolkata-700 019, West Bengal

Received on 16 Nov., 2007, Revised on 22 Dec., 2007

SUMMARY

Treating seeds with electric current(EC) improves yield over control in crop plants. EC treatment influences various physiological and biochemical activities in plants leading to higher yield. In monoecious cucurbits, it induces femaleness and reduces male : female flower ratio. Although, this technology was first applied in cucurbitaceous plants to improve yield, but now it has been extended to other crops like cereals, pulses, oilseeds etc. and the results are very much encouraging as evidenced by present review work. Hence, this technology might be considered as a reliable tool to improve yield in various crop plants.

***Key words*: Electrotherapy, pre-sowing seed, yield**

INTRODUCTION

With the introduction of high yielding varieties coupled with management practices, food production has been increased. However, to meet the ever increasing demand of people for affordable food, continuous efforts are required to increase crop yield. Such a situation demands an urgent need for developing various strategies to raise the yield potential of various crop plants. Yield improvement by application of fertilizers, plant growth regulators and/or management practices has been attempted. Bose (1902) observed plant responses to electric current treatment, yet, so far it has not been fully exploited for commercial purposes. Electrical stimulus (electrotherapy) to pre-sowing seed is an innovative area of research and emerged as a magic tool which improves yield of crops in an unprecedented manner which has not been achieved by any other technologies.

Electric current (EC) treatment may initiate physiological and biochemical changes which reflect growth and development processes in plants and ultimately the yield (Wahab *et al*. 1980). Several workers (Alamgir *et al*. 1991., Rahman and Yasmin 1994., Zang and Hashinaga 1997., Bera *et al.* 2006) reported yield improvement in various crops by application of this technology but the process has not been adopted in a commercial scale due to lack of publicity and poor knowledge about seed treatment technique and apparatus required. Plants growing in the field undergo many barriers of crop production like flower formation, sex expression and similar other factors that limit yield. Electrotherapy of pre-sowing

*Corresponding author, E-mail: profakbera@rediffmail.com

seed has been found to overcome certain blocks in crop production. This treatment is very much helpful for yield improvement because of its economy and simplicity to use. In the present paper, detailed methodology of seed treatment, apparatus used for the purpose and a review of research work conducted by different workers have been presented to popularize this technology for yield improvement in various crop plants.

METHODOLOGY

Requirements

(i). Power supply unit (0 – 500 mA) commonly used for gel electrophoresis (Bangalore Genei Pvt. Ltd.)

(ii). Copper electrode: Two (7cm x 7 cm x 0.05 cm) or (12 cm x 8 cm x 0.05 cm) or other sizes developed from copper plate may be used.

(iii). Power cord (+ ve and - ve) to connect electrodes with power supply unit.

(iv). Electrolyte solution: Mixture of 0.05% KNO_3 and 0.05% $Ca(NO_3)_2$ in the ratio 1 : 1.

(v). Glass beaker: Different capacities as per size of the electrodes.

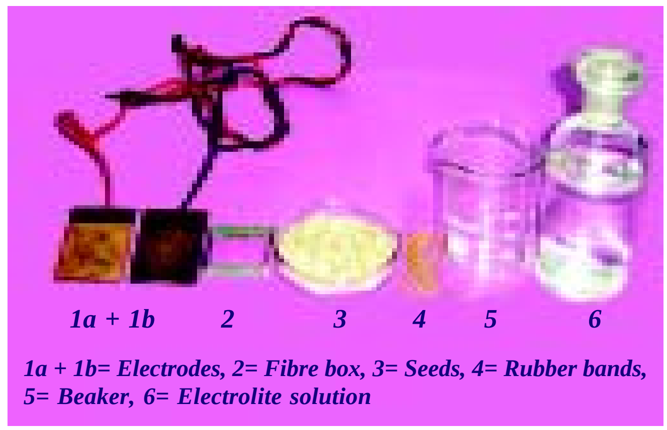
(vi). PVC gasket to hold seed materials within two copper electrodes.

(vii). Rubber strip / band to tie up two electrodes and inside seed materials firmly.

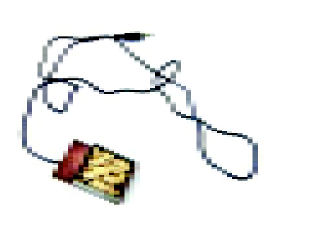
Seed treatment

Sun-dried seeds of different crops were initially soaked in distilled water for 8-12 hours to moisten the embryo. Out of two copper electrodes, one copper electrode was placed horizontally over a working table. One PVC box was placed over the copper electrode in such a manner so that a groove was developed to hold water-soaked seeds (Plate-1 : 1a + 2 + 3). PVC box is prepared by taking 1-2 cm wide PVC plate and square or rectangular block was prepared by holding it over a

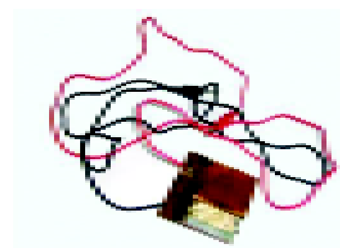
Full set for application of electrical stimulus



Components for application of electrical stimulus



1a + 2 + 3



1a + 2 + 3 + 1b

5 + 6

1a + 1b + 2 + 3 + 4 + 5 + 6

Plate 1. Methodology for application of electrical stimulus to the pre-sowing seeds of bottle gourd

flame. Some holes are developed at the edge of the box for easy passage of electrolyte to the seed (Plate-1 : 1a + 1b + 2 + 3 + 4 + 5 + 6). Water soaked seeds were now placed inside PVC box and covered with another copper electrode (Plate-1 : 1a + 2 + 3 + 1b). The entire set, i.e. two copper electrodes along with water-soaked seeds kept inside PVC box was tied with rubber strip / band firmly. In a glass beaker, the entire set was placed and electrolyte solution was added in such a fashion that upper level of electrolyte solution always lies below the level of electric power cord (+ ve and – ve) connecting point (Plate-1 : 1a + 1b + 2 +3 + 4 + 5 + 6). Electrical power cords (+ ve and – ve) were now connected with the power supply unit in their respective places. A smooth electric current of DC 220 v having desirable intensities and duration was passed through the seeds to serve electrotherapy treatment. Control seeds were soaked in electrolyte solution for specific duration only as applied for seed treatment purpose. Control as well as treated seeds were then air-dried / sun-dried to reduce moisture as far as practicable and finally stored in a desiccator for further use. This treatment remains effective in storage, till viability of the seed persists.

INFLUENCE ON VARIOUS PHYSIOLOGICAL ACTIVITIES AND YIELD

Treating pre-sowing seeds with electric current is an innovative technology for yield improvement in crops. Although, yield improvement in various field crops by pre-sowing electrical stimulus of seed was reported by many, the information appears to be very meager in comparison to yield improvement in crop plants either by application of fertilizers or plant growth regulators and/or management practices. However, work done so far in India and abroad has been reviewed and some data have been presented in this paper which will prove the feasibility of this innovative technology for yield improvement in crops.

Seed vigour and viability

Vigour and viability of seed play important role in crop productivity. Unfavourable weather condition, improper storage of seeds etc are important factors for reduction in vigour, which proceed for losses in seed germination and ultimately the yield of crop. In order to improve quality of seed in respect of crop stand, many workers studied the effect of electrical stimulus on seed viability, vigour, seed germination and seedling growth and found positive results. The dormancy in seed and vegetative propagules caused greater hinderness in crop cultivation. Apple and sour cherry seeds treated with AC electric current during stratification showed 3 phases in their physiological state lasting 40, 20 and 30 days in apple and 70,50 and 60days in sour cherry seeds. AC treatment during the first phase failed to break dormancy in the seeds of both species, but during the 2nd and 3rd phases, the treatment increased germination and improved seedling growth (Lutkova and Oleshko 1972). Seeds of onion cv. Danilovskii – 301 were subjected to electric treatment for various periods (Nikul-shin and Agafonov 1974). It was observed that treatment had a beneficial effect on seed germination and emergence, giving 7 – 12 % more seedling than the untreated control. An increase in the per cent of germination over control was noticed when different species of *Phaseolus* seeds were treated with electric current before sowing (Wayland *et al.* 1980). Similar results were obtained in cucumber cv. Kungurskir (Belousova and Tetuev 1975), watermelon and snake cucumber (Abdel-Wahab *et al*. 1980).

In an experiment, Seregina (1983) observed that dormant bulbs of onion when treated with an electrical field of 2 kV /cm field intensity for 0.5, 1, 2, 5, 10, 20 or 40 seconds of exposure, significantly reduced the number of non-sprouting bulbs from 15 to 5%, advanced sprouting and green leaf production by 4 – 6 days and increased leaf length and width by 12 – 38% compared with control. The effects of direct and alternating electric current were compared with bromoethane (BE), GA and kinetin for breaking potato tuber dormancy (Kocacalskan 1990). It was observed that BE was the most effective treatment for producing high sprout numbers and short emergence time of sprouts, but GA and kinetin were most effective in promoting sprout elongation. Electric currents (AC and DC) were more effective in increasing sprout numbers than were growth regulators except BE. In bottle gourd, pre-sowing seed treatment with 100 mA electrical stimulus for one minute significantly increased the length, leaf number and weight of seedlings (Alamgir *et al*. 1991). Regarding germination and seedling growth, standardization of dose of electric current and duration of exposure play important role because optimum dose increased length of seedling but the length of seedling decreased at over dose as reported by Rahman and Yasmin (1993).

Alexander and Doijode (1995) reported that viability and vigour in onion seed can be increased by treating seeds with electric field. Onion seeds of 5 years old treated with electromagnetic field of 108 oersteds (1 oersted = 103 / pi A / m) for 30 minutes significantly increased the emergence, germination of seeds, shoot and root lengths as well as fresh and dry weights of the seedlings compared with control. Electric field irrespective of AC or DC have pronounced effect on germination and seedling growth. AC electrical fields in the range of 18 – 105 kV / m hastened germination rate and shortened the mean days to complete germination for chinese cabbage cv. Tsumamina and radish seeds cv. Kaiware but lettuce seeds cv. Sunny were stimulated by DC fields of 65 – 105 kV / m and all AC electrical fields (Zhang and Hashinaga 1997). Tomato seeds exposed to AC electric fields ranging from 4 to 12 kV/cm for three different time periods ranging from 15 to 60 s have been found to accelerate seed germination 1.1 – 2.8 times compared with untreated control seeds. However, an inhibitory effect on germination was noticed when electric field intensities exceed 12 kV/cm and exposure time is more than 60 s (Moon and Chung 1999). Similar observation on the enhancement of seed germination to the tune of 5 times over control was observed when tomato (*Lycopersicon esculentum* cv. Halicz) seeds were exposed to optimum dose of electric field (Pietruszewski and Kornarzynski 2002).

Growth and development

Growth is an irreversible increase in mass or weight where as development denotes phasic change. Proper growth and development of any crop from initial stage to maturity is an indication to achieve higher yield. Electrical stimulus is considered as a magic tool, which can modify the growth of plant by some internal changes as reported by different workers (Ross 1966, Black *et al*. 1971). In vine crops, mainly in cucurbitaceous vegetables, number of branches, total vine length, node number / plant are the indication of proper growth and development of these crops. Omran and Wahab (1974) stated that treating cucumber seeds with electric current before sowing increase the total vine length and number of branches / plant. Pea seeds treated with 2.5 kV/cm for 10 min increased emergence, stimulated root growth and accumulation of dry matter in 15 day-old seedlings. However, treatment of seed with 3.5 kV/cm suppressed plant early growth (Khuratov and Chernianu 1976).

Dayal *et al*. (1983) studied the growth responses of tomato cv. Pusa Early Dwarf and Pusa Ruby to electrostatic field and observed that electrostatic field significantly influence the plant height, number of axillary buds, number of primary and secondary shoots and plant fresh weight. In bottle gourd, electric current treatment of pre-sowing seeds increased the number of branches and total number of nodes and leaves / plant but reduced the total vine length (Rahman *et al*. 1991). The classical methods of seed treatment make use of chemical substances, which are either expensive or harmful for the soil. Morar *et al*. (1995) demonstrated that exposure of pre-sowing seeds to a high-intensity electric field can be an effective substitute for chemical agents. Experiments were carried out on infected bean seeds. Under normal conditions (no treatment), only about 30% of a reference sample of such seeds germinated. Other samples were subjected to AC electric fields, ranging from 2 to 16 kV/cm. The exposure time ranged from 1 to 30 s. In the optimum laboratory test, more than 99% of the seeds germinated. The weight of the resulted plants was significantly superior to that of the beans developed from non-treated seeds. The field tests proved the efficiency of this method, which could be successfully employed for the prevention or treatment of various seed-transmitted diseases of plants. Increase in the number of productive tillers accompanied by decrease in the number of non-productive tillers in rice by application of this technology has been reported, which is an indication of flower induction leading to higher yield in this crop (Bera and Maity 2004). The intensity and duration of electrical stimulus for improved plant growth and development varies with crops (Alamgir *et al*. 1991, Rahman and Yasmin 1993). Pati and Bera

(2004) reported similar views in their observation with poi (*Basella alba*) and okra (*Abelmoschus esculentus*), where it was observed that electric current treatment influences different growth parameters but the intensity and duration of treatment differ in poi and okra.

Sex modification

In cucurbits large number of male flowers appear in plant than actually needed. Hence, sex modification of cucurbitaceous vegetables by electric current treatment of pre-sowing seed is considered as an innovative area of research. Modification of sex in various cucurbitaceous crops by pre-sowing electric current treatment of seed is presented in Table 1. The members of cucurbitaceous vegetable exhibited variation in sex forms. In cucurbits, the monoecious sex expression is the most common, dioecious next and hermaphrodism very rare (Yampolsky 1922). In monoecious cucurbits, mainly in bottle gourd, the male to female flower ratio was very high and in early stage of reproductive growth, male flower is greater than the female flower as a result the yield was found to be very poor (Chowdhury and Bable 1969). Although, the sex expression of monoecious cucurbits is determined genetically (Roy and Roy 1971, Roy 1974), yet it can be modified by the application of electrical stimulus to seeds. In Egypt, Wahab *et al.* (1980) studied the effect of pre-sowing electrical stimulus on seeds of watermelon (cv. Sugar Baby) and snake gourd (Flexusus group) and found increased formation of female flower and reduced male : female flower ratio. Kumar *et al.* (1990) in India observed stimulatory effect of electric current on sex modification in bitter gourd cv. Faizabadi. In Bangladesh, Rahman *et al.* (1991) also found increased formation of female flower and decreased male : female flower ratio in bottle gourd. Similar observation was noticed in cucumber (Pati *et al.* 2007) but, how decrease in male : female flower ratio is achieved is not well understood. However, the influence of the biological activity of growth regulators may be considered as some of the possible explanations (Pati *et al.* 2007).

Table 1. Summary table showing modification of sex in different crop plants by pre-sowing electric current treatment of seeds

Crop plants	Common name	Treatment		Total no. of male flowers plant^{-1}	Total no. of female flowers plant^{-1}	Male : female flower ratio	References
		Optimum dose of electric current (mA)	Optimum duration of electric current (min)				
Lagenaria siceraria Mol. Standl.	Bottle gourd	225	3	379.00	34.33	11.04	Pati 2007
		Control	-	501.67	28.67	17.50	Ph.D. Thesis
Cucumis sativus	Cucumber	200	1	149.67	23.67	6.32	Pati and Bera 2007
		Control	-	207.33	17.67	11.73	(Unpublished)
Luffa acutangula Roxb.	Ridge gourd	150	3	76.33	17.33	4.40	Bera *et al*. 2006
		Control	-	77.33	11.00	7.03	
Trichosanthes anguina L	Snake gourd	200	3	158.00	15.67	10.08	Bera *et al.* 2006
		Control	-	158.33	11.67	13.57	
Citrulus vulgaris	Watermelon	200	1	519.00	71.66	7.24	Wahab *et al*. 1980
		Control	-	597.00	39.66	15.05	

Yield parameters and yield

Yield of any crop is a cumulative effect of different yield attributing traits. Increase in yield by electric current treatment in cucumber was observed by Izakov *et al.* (1958). The optimum dose of electric current for yield improvement in cucumber was found to be 150 mA for one minute duration (Omran and Wahab 1974). However, the doses of electric current vary crop-wise irrespective of family. Belousova and Tetuev (1975) observed that electric current at different intensities and duration of exposure increased the crop yield by 16 – 37% in cucumber cv. Kungurskir. It has also been established that yield improvement in crop plants could not only been achieved by pre-sowing electrical stimulus of seeds but application of electric current at lower intensity directly to the growing plants have similar fate. Salnikov *et al*. (1979) found 14% increase in yield of cucumber plants cv. VIR 517 over control by direct application of electric current to the growing plant. In another experiment, Wahab *et al*. (1980) reported increase in fresh weight of watermelon and snake cucumber fruits when 200 mA for three minutes and 100 mA for one minute duration respectively was applied to the pre-sowing seeds of these crop. An overview of optimum dose of electric current, duration of treatment and per cent increase in yield over control in various crop plants is presented in Table 2. In sunflower, electric shock of certain intensities and duration receiving them in seed stage can considerably modify the plant characters. Inflorescence circumference, number of filled seeds, weight of filled seeds in the inflorescence were found to increase by application of electrical stimulus to pre-sowing seed (Francis *et al*. 1989). In

Table 2. Summary table showing yield improvement in different crop plants by pre-sowing electric current treatment of seeds

Crop plants	Common name	Treatment		Yield (kg/plant)	Per cent increase over control	References
		Optimum dose of electric current (mA)	Optimum duration of electric current (min)			
Lagenaria siceraria Mol. Standl.	Bottle gourd	225 Control	3 -	12.582 9.468	+32.89	Pati 2007 Ph.D. Thesis
Cucumis sativus	Cucumber	200 Control	1 -	1.745 1.213	+43.86	Pati and Bera 2007 (Unpublished)
Abelmoschus esculentus	Okra	100 Control	5 -	0.155 0.117	+ 32.48	Pati and Bera 2004
Basella alba	Poi	300 Control	5 -	1.15 0.82	+ 40.24	Pati and Bera 2004
Vigna radiata	Mungbean	150 Control	1 -	16.94 15.45	+ 09.64	Pati *et al*. 2005
Oryza stiva	Rice	100 Control	5 -	25.74 21.36	+ 20.50	Bera and Maity 2004
Luffa acutangula Roxb.	Ridge gourd	150 Control	3 -	1.367 0.886	+ 54.29	Bera *et al*. 2006
Trichosanthes anguina L	Snake gourd	200 Control	3 -	1.818 1.411	+ 28.84	Bera *et al*. 2006

bitter gourd cv. Faizabadi pre-sowing seed treatment with 200 mA electric current for 3 minutes duration significantly increased the number of fruit set / plant and fruit yield / plant over control (Kumar *et al.* 1990). Rahman *et al.* (1991) observed that treating seeds of bottle gourd with an electric current of 150 mA for 5 minutes duration resulted in the highest number of fruit set (3.43) and yield / plant (7.58 kg) compared with 2.14 and 5.14 kg / plant respectively in control. Pati and Bera (2004) observed that 100 mA electric current for 5 minutes duration was optimum for increasing yield in okra. Whereas, highest yield of poi (*Basella alba*) was achieved when seeds were treated with 300 mA electric current for 5 minutes duration. Although, most of the research works regarding yield improvement by pre-sowing electrical stimulus of seeds were conducted on cucurbitaceous vegetables, electrical stimulus successfully increased the yield of root crops (Gallen and Shishkina 1973), tuber crops (Shmigel and Grigor 1996). Electric current treatment of rice (*Oryza sativa* cv. Swarnamasuri) grain at the intensity of 100 mA for 5 minutes duration has profound effect on growth, yield parameters and contributing 20.50 per cent higher yield over control (Bera and Maity 2004). Meiqiang *et al.* (2005) treated tomato seeds (*Lycopersicon esculentum* L. Mill. Cv. Zhongshu No.6) by magnetized plasma before being sown to investigate its effect on the growth and yield of tomatoes. It was observed that germination per cent was significantly increased over control and 1.5 A treatment increased the tomato yield by 20.7%. In mungbean, EC treatment for one minute duration and 150 mA intensity significantly increased number of nodes and leaves per plant, number of pods per plant, 100 seed weight and ultimately the yield over control (Pati *et al.* 2005). Similar observation on enhancement of yield was noticed in ridge gourd and snake gourd (Bera *et al.* 2006), where maximum yield was achieved with 150 mA current intensity for 3 minutes and 200 mA current intensity for 3 minutes duration respectively.

Biochemical parameters

Plants absorb nutrients from soil and also from other sources. Individual elements have a number of functions at different stages of growth and development of plant. A large number of scientists observed that electrical stimulus greatly increased the rate of uptake of nutrients from the soil to the plant. Breazeale *et al.* (1951) and Breazeale and Mc George (1953) demonstrated that cation uptake could be stimulated by application of controlled direct voltage and suggested that cation uptake by plant is an electrical phenomenon. Increased water absorption from soil as well as cultural media by pea was observed by Fensom (1962). Application of electric currents have been found to increase respiration and nitrate uptake (Chatilov and Trifonova 1968) and absorption of microelements (Trifonova 1970).

Black *et al.* (1971) reported the effect of small increments of direct current (DC) on the growth and ion uptake in tomato plant and noticed a significant increase in K, Ca and P uptake by the plants when currents were in between 3 and 15 µA per plant. Electric current treatment of pre-sowing seed may initiate long term physiological and biochemical changes in crops that reflect growth and development processes of plant and ultimately increase yield (Braton and Henry 1977). Laszol (1984) applied electric current through platinum electrode at the root collar or base of the capsicum plant and observed increase in N,P,K content in different plant parts. Possibly the effect of EC on plant growth may be through its effect on metabolism and growth regulators as suggested by Cherniary and Khuratov (1976) and Braton and Henry (1977).

Plants while growing in the field suffer from different kinds of stresses leading to poorer crop yield. H_2O_2 is the most detrimental oxy-radical produced in the plant in response to different kinds of abiotic stresses. Catalase and peroxidase serve the indispensable role of preventing accumulation of H_2O_2. Mihalyfi and Serf (1976) reported that electric current treatment enhanced the catalase activity in squash. In bottle gourd, 225 mA intensity for three minutes duration exhibited higher catalase, peroxidase and nitrate reductase activities in the leaves compared to control (Pati *et al.* 2007). Electric current treatment of pre-sowing pea seed was found to relate with the turn over of starch and increased accumulation of mono and disaccharide and decreased accumulation of amylopectin fraction in pea leaves (Cherniany and Khuratov 1976). Montavon *et al.* (1987) reported that application of electrical potential of 10 V (electric current a" 12.5 µA) to spinach plant increase glucose 6 phosphate dehydrogenese (G-6-PD) activity in the shoot apex.

Chlorophylls, the green pigments of plant are the most important pigments active in the photosynthetic processes. The information regarding the pigment as influenced by electrical stimulus was very scanty. However, some scientists are trying to find out the effect of electrical stimulus on pigment content in leaf. Alamgir *et al*. (1991) reported that electric current treatment of pre-sowing seeds of bottle gourd increased chlorophyll a and carotenoids in leaf but chlorophyll b was reduced. Rahman and Yasmin (1993) observed that 75 mA electric current treatment for one minute duration, significantly increased the chlorophyll a, b and carotenoids in bottle gourd leaf. In rice, chlorophyll a, b and total chlorophyll content were found to increase in leaf and chlorophyll senescence was delayed throughout the post-anthesis period when electric current of 100 mA for 5 minutes duration was applied to pre-sowing rice grain (Bera and Maity 2004). The leaves of bottle gourd are well known as a good source of sugar, starch, protein and are consumed as cooked leafy vegetable. So, increase in sugar, starch and protein content of leaf has a prime importance. Pati (2007) reported that EC treatment of pre-sowing bottle gourd seed increased these nutrients in bottle gourd leaf, attaining maximum values with 225 mA intensity for 3 minutes duration at 80 days after sowing and decreased thereafter as the plant progress towards maturity.

Fruit and seed quality

Seeds of malting barley cv. Beta ketzoras placed for 30 s in an electric field with the current density of 2 X 10-9A/cm^2 imbibed faster, a water content of 40 – 41% being reached 12 h earlier than in untreated seeds. Germination energy of the treated seeds was 13% higher than control seeds and the seedlings grew faster. Lower current intensities or shorter exposures produced a less marked effect (Randev and Derimanov 1973). Electric current treatment of pre-sowing seed has direct effect on fruit parameters. Different workers reported that electric current treatment of pre-sowing seeds significantly increased fruit weight and fruit diameter over control and fruits contain less number of seeds (Omran and Wahab 1974., Salnikov *et al*. 1979). Wahab *et al.* (1980) studied the effect of electric current treatment of pre-sowing seed on the quality of fruits in watermelon and snake cucumber. It was observed that application of EC improved fruit quality in watermelon where, rind thickness decreased while total soluble solids increased in fruits. It is evident that decreasing rind thickness increased the edible portion of fruit. In snake cucumber, electric current treatment induced two fruits on the same node and on the alternate nodes, all of which reached maturity and considerably decreased the number of abnormal fruits, which are generally formed in cucurbitaceous crops when the plant attained old age. Pati and Bera (2004) reported that 150 mA of electric current for 5 minutes duration significantly increased fresh weight and length of fruit in okra but circumference of fruit was not influenced significantly. Treating seeds with electrical stimulus before sowing not only modify the fruit characters but also increased the nutritive values of fruit. In bottle gourd, electrical stimulus of 225 mA intensity for three minutes duration was found to be beneficial as highest total soluble solids, reducing sugar, starch and protein content of fruit were obtained by this treatment, but non-reducing sugar and ascorbic acid content were highest in the fruits of control plant. The reduction in ascorbic acid in the fruits of treated plant compared to control might be due to negative correlation between reducing sugar and ascorbic acid content of fruit (Pati *et al.* 2007). Application of electric current to pre-sowing seeds has wide application on the preservation of fruits and vegetables. Lite and Sheng (1996) studied the role of electric field in fruit and vegetable preservation and suggested that the transmembrane potential is changed by the extra electric field, thus affecting the metabolism. The electric field around fruits and vegetables has an influence on the respiratory system, water and enzyme status.

CONCLUSION

Food security and poverty alleviation is the main theme of Agricultural research. In order to feed the ever-growing population, it is becoming mandatory to increase productivity of crop. Since, available cultivated land is inelastic, it becomes imperative to boost yield per unit land area as against the present level. Agricultural research concerned with increasing crop yield, has been primarily localized by the use of fertilizers, pesticides, irrigation and better management practices coupled with utilization of high yielding varieties. In comparison with all these technologies, pre-sowing electrical stimulus of seeds emerged as a magic tool to improve yield in various crop plants in an unprecedented manner, which has never been achieved by any other technologies. This technology is very simple and within the affordable limit of common farmers.

During last two decades, commendable attempts have been made to increase yield by pre-sowing electrical stimulus of seed and results so far available are encouraging. Although, improvement in yield by application of this technology has been reported in several crops, yet the physiological and biochemical mechanism by which electrical stimulus influences yield is yet to be explored. Black *et al*. (1971) reported that EC treatment increased accumulation of K, Ca and P in tomato plants along with increased growth. Possibly, the effect of EC on plant growth may be through its effect on metabolism and growth regulators as suggested by Cherniary and Khuratov (1976). Stroganov and Dragavstev (1983) were of opinion that electricity is the flow of electrons and electrons in sufficient quanta may bombard with the genetic material. The embryo located inside the seed is a zygote. It is possible that the genetic material present in at least some of the cells may get modified and thereby induces some physiological and biochemical changes in plants. However, more concerted research is needed to ascertain the exact mechanism. From the present study, it is concluded that electric current of pre-sowing seed could be recognized as a potential tool for improving yield in various crop plants, particularly among cucurbits where, number of male flower is higher than female flower and determination of intensity of electric current and duration of exposure are mandatory prior to undergoing such an investigation.

FUTURE SCOPE

Uptil now, major work has been done on cucurbitaceous crops as this technology bears paramount effect on the modification of sex. However, information on cereals, pulses and other non-cucurbitaceous vegetables are also encouraging. Hence, enough scope exists for utilization of this technology for improvement of yield in other crops. Seed borne diseases are very common in the tropics and limit establishment of healthy crops, thereby limiting yield. Seed purification before storage by electric current treatment of seed might help to overcome infestation of pests and diseases of crop plants. Purification of drinking water by application of EC in lethal dose has been found to eradicate microbial organisms under laboratory condition without affecting quality of water. Therefore, this technology might be helpful for sterilization purposes and could be exploited in food processing industry and preservation of fruits, vegetables and other agricultural products as the method is cheap, less hazardous and easy to apply within affordable limit.

ACKNOWLEDGEMENTS

The financial assistance received from Deptt. of Science & Technology, Govt. of West Bengal, Bikash Bhavan, Salt Lake, Kolkata – 700 091 in the form of ad-hoc research project is gratefully acknowledged.

REFERENCES

Abdel-Wahab, A.M., Omran, A.F., Elkholy, E. and Hafez, H. (1980). Studies on the effect of treating watermelon and snake cucumber seeds with electric current. *Seed Sci. & Technol*. **8:** 95-102.

Alamgir, A.N.M., Rahman, M.A., Baset, O.A. and Taher, M.A. (1991). Effect of electric current treatment of seeds on growth of seedling of bottle gourd (*Lagenaria siceraria* Mol. Standl.). *Indian J. Plant Physiol*. **34:** 274-277.

Alexander, M.P. and Doijode, S.D. (1995). Electromagnetic field, a novel tool to increase germination and seedling vigour of conserved onion (*Allium cepa* L.) seeds with low viability. *Plant Genetic Resources Newsletter* **104:** 1-5.

Belousova, K.K. and Tetuev, V.A. (1975). The effect of an electric field on seed quality and productivity of the cucumber cultivar kungurskir. *Referativnyi Zhurnal* **9:** 619.

Bera, A.K. and Maity, U. (2004). Enhancing yield potential in rice by pre-sowing electric current treatment of rice grains. *Plant Archives* **4:** 17-24.

Bera, A.K., Pati, M.K. and Ghanti, P. (2006). Effect of pre-sowing electrical stimulus of seed on growth and yield of ridge gourd (*Luffa acutangula* Roxb.) and snake gourd (*Trichosanthes anguina* L.) *Indian J. Plant Physiol*. **11:** 291-294.

Black, S.D., Forsyth, F.R., Fensom, D.S. and Ross, R.B. (1971). Electrical stimulation and its effect on growth and ion accumulation in tomato plants. *Can. J. Bot*. **49:** 1809-1815.

Bose, J.C. (1902). Electric responses in ordinary plants under mechanical stimulus. *J. Linean Soc. Prot*. **35:** 275-304.

Braton, B.O. and Henry, E.W. (1977). Electric stimulation and its effect on IAA and peroxidase level in tomato plants (*Lycopersicon esculentum*). *J. Exp. Biol*. **28:** 103-108.

Breazeale, E.L., Mc George, W.T. and Breazeale, J.F. (1951). Nutrition of plants considered as an electrical phenomenon – a new approach. *Soil Sci*. **71:** 371-375.

Breazeale, E.L. and Mc George, W.T. (1953). Cation uptake by plants as affected by an applied potential. *Soil Sci*. **75:** 443-448.

Chatilov, F.V. and Trifonova, M.F. (1968). The effect of constant electric current on metabolism in germinating seeds of barley. *Electron Abrabotki Materialof* **1:** 67-70.

Cherniany, E. and Khuratov, P.K. (1976). Effect of electric pole treatment of pea seeds and the rate of absorption of water. *Trubi Cubanskii Celskii Khogaistvenois Inst. Pub*. **132:** 48-50.

Chowdhury, B. and Bable, Y.S. (1969). Studies on sex expression, sex ratio and fruit set as affected by different plant growth regulator sprays in bottle gourd. *Hort. Sci*. **1:** 61-67.

Dayal, S., Srivastava, K.G. and Singh, R. P. (1983). Growth responses of tomato to seed and seedling exposure to electrostatic field. *Indian J. Agric. Sci*. **53:** 962-970.

Fensom, D.S. (1962). The bioelectric potentials of plants and their functional significance IV. Change in the rate of water absorption in excised stem of *Acer saccharum* induced by applied electromotive forces : the “flushing effect”. *Can. J. Bot.* **40:** 405-413.

Francis, M.S., Mathew, K.M., Subramanian, M. and Hariharan, M. (1989). Effect of pre-treatment of sunflower seeds with different intensities of electric current. *Acta Botanica Indica* **17:** 268-270.

Gallen, N.A. and Shishkina, L.A. (1973). The effect of an electric current field on some physiological processes in carrots. *Spornik Trudov Bashirskogo Sel Skokhozyartvennago Instituta* **17:** 211-212.

Izakov, F.J.A., Loginova, T.J.A. and Basov, A.M. (1958). The effect of a direct electric field on seeds. *Sadi Ororod* **4:** 21-22.

Khuratov, A.Kh. and Chernianu, I. (1976). The effect of seed treatment with an electrical field of alternating current on the growth and development of peas. *Trudy Kubanskogo S Kh Instituta* **147:** 92-99.

Kocacalskan, I. (1990). Effectiveness of electrical currents in breaking potato tuber dormancy compared with other methods. *J. Hort. Sci*. **65:** 683-687.

Kumar, R., Vyas, R.P. and Gopal, R.D. (1990). Effect of electric current on bitter gourd (*Momordica charantia*) seeds. *Seed Res*. **18:** 166-168.

Laszol, P. (1984). Investigation on the bioelectric properties of vegetable plants. *Kerteszeti Egyetem Kozlemenyei* **46:** 53-59.

Lite, L. and Sheng, F. (1996). Prelimenary analysis on mechanism of fruit and vegetable preservation using electrostatic field. *J. China Agri. Uni.* **1:** 62-65.

Lutkova, I.N. and Oleshko, P.M. (1972). The effect of alternating current on the seeds of fruit crops during stratification. *Biologicheskii Shornik* **126:** 85-98.

Meiqiang, Y., Mingjing, H., Buzhou, Ma and Tengcai, Ma (2005). Stimulating effects of seed treatment by magnetized plasma on tomato growth and yield. *Plasma Sci. Technol.* **7:** 3143-3147.

Mihalyfi, J.P. and Serf, L. (1976). Catalase activity of the seeds as affected by the electric fields. *Acta Agron. Hung*. **16:** 335-338.

Montavon, M., Toukhi, M.E.L., Auderset, G. and Greppin, H. (1987). Effect of photoperiod and electrical potentials applied to petioles on the glucose-6-phosphate dehydrogenese activity used as marker of floral induction in shoot apices of spinach. *Ann. Bot.* **60:** 225-230.

Morar, R., Munteanu, R., Simion, E., Munteanu, I. and Dascalescu, L. (1995). Electrostatic treatment of bean seeds. Paper presented at Industry Applications Conference, Thirtieth IAS Annual Meeting, 1995, Vol. 2, pp. 1335-1337. Orlando, FL, USA.

Moon, Jae Duk and Chung, Hwa Sook (1999). Acceleration of germination of tomato seed by applying AC electric and magnetic fields. *J. Electrostatistics* **48:** 103-114.

Nikul shin, V.P. and Agafonov, A.F. (1974). The effect of an experimental method of onion seed treatment on seed quality and bulb of commercial quality. *Biol. Osnovy Povysh Urozhainosti S Kh Kul Tur*. **2:** 214-218.

Omran, A.F and Wahab, A.M. (1974). The effect of treating cucumber seeds with electric current on growth and yield. *Egypt. J. Hort.* **1:** 79-88.

Pati, M.K. and Bera, A.K. (2004). Yield improvement in Okra (*Abelmoschus esculentus*) and poi *(Basella alba* L.) by pre-sowing electric current treatment of seeds. *Environ. Ecology* **22:** 196-198.

Pati, M.K., Bera, A.K. and Maity, U. (2005). Improvement in growth and yield of mungbean (*Vigna radiata* L. wilczek) by pre-sowing electric current treatment of seed. *Environ. Ecology* **23S:** 340-343.

Pati, M.K. (2007). Effect of pre-sowing electrical stimulus on growth and yield of bottle gourd (*Lagenaria siceraria* Mol. Standl.). Ph.D. Thesis, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India.

Pietruszewski, S. and Kornarzynski, K. (2002). Techniques of assistance tomato seed germination used electric field and model this process with the help of logistic curve. *Acta Scientiarum Polonorum Technica Agraria* **1:** 83-88.

Rahman, M.A., Alamgir, A.N.M., Khan, M.A.A. and Baset, Q.A. (1991). Modifications of growth, sex expression and yield by pre-sowing electric current treatment of seeds of *Lagenaria siceraria*. *Indian J. Plant Physiol*. **34:** 77-79.

Rahman, M.A. and Yasmin, F. (1993). Effect of electric current treatment to seeds of bottle gourd for NPK and seedling leaf pigments. Chittagong University Studies Part II. *Science* **17:** 37-41.

Rahman, M.A. and Yasmin, F. (1994). Performance of electric current treated seeds of bottle gourd (*Lagenaria siceraria Mol*. Standl.) on growth, sex expression and yield. *Bangladesh J. Bot.* **23:** 67-72.

Randev, R. and Derimanov, A. (1973). The effect of an electric field on the growth, development, yield and malting quality of barley. I. Speed of water uptake by seeds, seed germination and seedling growth. *Rasteniev, Dni Nauki*. **10:** 27-33.

Ross, R.B. (1966). Effect of electrical stimulation on growth and yield of tomato plant. *Can. J. Bot.* **24:** 375-381.

Roy, R.P. (1974). Sex mechanism of higher plants. *J. Indian Bot. Soc*. **53:** 141-153.

Roy, R.P. and Roy, P.M. (1971). Mechanism of sex determination in *Coccinia indica*. *J. Indian Bot. Soc*. **50:** 391-400.

Salnikov, A.I., Aleksandrova, G.A., Bynov, F.A., Agapova, M.V. and Tetynev, V.A. (1979). The effect of electric field on some physical and biochemical processes and on the yield of cucumber under glass. *Referativnyi Zhurnal* **4:** 327-330.

Seregina, M.T. (1983). Electrical field as a factor of dormancy breaking and growth activation in bulb onions at the III rd stage of organogenesis. *Elektronnaya Ordabotak Materialov* **4:** 73-76.

Shmigel, V.N. and Grigor, E.V. (1996). Electrical treatment of seed potatoes. *Mekhanizatsiya-i-Elektrifikatsiya-Sel Skogo-Khozyaistva* **5:** 9-11.

Stroganov, A.N. and Dragavstev, V.A. (1983). Effect of pre-sowing treatment of seed with an electric field on the genetic control of barley characters. *Genetika* **19:** 1523-1532.

Trifonova, M.F. (1970). Effect of pre-sowing treatment of seeds with a weak direct current on uptake of trace elements by barley plants. *Fiziologiya Rast*. **17:** 103-106.

Wahab, A.M., Omran, A.F., Elkholy, E. and Hafez, H. (1980). Studies on the effect of treating watermelon and snake cucumber seeds with electric current. *Seed Sci. Technol*. **8:** 95-102.

Wayland, S.C., Mandrid, W.E. and Albuquerque, N.M. (1980). The effect of externally low frequency electromagnetic field on *Phaseolus lanatus* and *Phaseolus vulgaris*. *Stud. Nat. Sci.* **2:** 9-11.

Yampolsky, C. (1922). Distribution of sex forms in the Phanerogamic Flora. *Biblioth Genetics* **3:** 1-5.

Zhang, H. and Hashinaga, F. (1997). Effect of high electric fields on the germination and early growth of some vegetable seeds. *J. Jap. Soc. Hort. Sci.* **66:** 347-352.