Bulletin of Electrochemistry 6 (3) March 1990, pp 326 –328

Recent advances in the study of the influence of air ions on plant growth

A K Kamra and M Ravichandran
Indian Institute of Tropical Meteorology, Pune - 411 005, INDIA

K S A Gnanasekaran and R Rajasekar
Central Electrochemical Research Institute, Karaikudi - 623 006, INDIA

The normal levels of air ions, such as H^+, O_2^-, OH^-, CO_3^-, CO_4^- etc. in the atmosphere at the ground level varies from 1000 to 5000 per ml. The concentration below the normal has been found to lower the growth rate of the plants. Air ions of either sign, when produced at the rate of 9.5×10^6 ions per ml.s in air and air anion current of 4 $pA.cm^{-1}$ has been found to influence the plant growth. This review discusses the evidences for these influences and the probable mechanisms that bring forth these changes.

Key words: Plant growth, electroculture, ionoculture

INTRODUCTION

The paper discusses the probable mechanisms that bring forth these changes.

ELECTROCULTURE

Applied electric field can accelerate or inhibit the growth of higher plants. The spacial and temporal development of biological system is accompanied by characteristic patterns of endogenous current and field [1–5]. Therefore, either suppression of endogeneous current [6–7] or artificial application of electric currents [8–11] would alter the natural course of development. Constant electric current and field can polarize plant cells and control the direction and rate of their growth [10–16].

Studies on the electrical stimulation of plants have been undertaken since 18th century [1–19]. Maximum effect in enhancing growth has been reported when a current of about 50 pA per plant was passed [20,21]. No appreciable [22] and negative results [23,24] due to electric field were also reported. Decreasing effects of applied electric field on the elemental level (Fe, Zn, Al, Ca, Mg, Mn) and possible mechanisms have also been reported [25–29]. Ozone appeared (0.01 ppm) in the air when a critical current of 2×10^7 A per plant tip was reached [30].

IONOCULTURE (AIR IONS)

Significant biological changes were induced by applied fields or by direct administration of air ions [31]. Ions are the principal mediating agent in electroculture [32,33]. Ions of either sign could accelerate growth of plants. The normal concentration of small air ions in normal air is about 1000–5000 ions. But because of rapid recombination mechanisms, the upper practical limit inducible by external means is about 10^6 $ions.ml^{-1}$. Even such small concentrations (air contains about 2.7×10^{19} $molecules.ml^{-1}$) can affect physiological processes of higher plants. The small air ions readily unite with nuclei and pollutants in air to form large ions (high mass per charge) which have only relatively small effects on organisms. The dominant positive small ions in air are present as the hydrated forms of H^+ or as the negative ions O_2^-, OH^-, CO_3^- and CO_4^- with possible contribution of ON^-. The possible ionic reactions are [34].

$$CO_2^+ + O_2^+ \Longrightarrow O_2^-$$
$$O_2^+ + H_2O \Longrightarrow H^+$$
$$N_2^+ + O_2 \Longrightarrow O_2^+$$
$$O_2^- + H_2O \Longrightarrow OH^-$$
$$CO_2^- \Longrightarrow O^- + CO$$
$$O^- + CO_2 \Longrightarrow CO_3^-$$

The release of indole acetic acid paralleled the effect of positive ions, especially CO_2^+ [35]. The effect of added positive and negative air ions on the growth of oat seedlings (*Avena sativa*) showed that ions of either sign could accelerate growth of plants [36]. In subsequent years [37] similar effects for oats and barley were reported and found out that an increase of 30% to 60% in dry weight could be obtained. Effects of air ions on RNAase activity in green barley leaves (*Hordeum vulgaris*) have been studied [38]. Development of Fe-chlorosis in barley grown in Fe-free nutrient solution was seen to be accelerated by the air ions of either charge [38]. It has been shown that O_2^- or O_2^+ stimulated the production of cytochrome

C and Fe- containing enzyme [34]. Air ions increased the O_2 consumption and decreased the concentration of RNAase [39].

Direct correlation between the effect of positive and negative air ions upon the light induced swelling and dark induced shrinking in the isolated spinach chloroplasts has been observed [40]. A strong correlation between the concentration of small air ions and the germination rate of uredospores of *Puccinia striiformis*, the casual agent of stripe rust of wheat and growth in the annual, *Exacum affine* (percian violet), as well as in seedling geraniums, when exposed to a mild current of air anions of 4 $pA.cm^{-2}$ has been observed [19].

When air ions of either signs were produced at a rate of 9.5×10^6 $ions.ml^{-1}$ in air above the seedlings, there was delay in the emergence of shoots in *Brassica nigra*; but an acceleration in shoot length by fifth day than control was also observed [42]. Air ion depletion to lower than normal levels resulted in lower growth rates [43].

MECHANISM

It has been suggested that the air ions in some way enhance or guide synthesis of cytochrome C and other Fe-containing enzymes. It is suggested that the distribution of iron among various metabolite pathways is then affected by ions of either charge, by the action of ions upon certain 'governors' of the iron distribution pathways in the mitrochondria and chloroplasts. These yet unknown 'pathway governors' are then the site of the more important action of air ions upon growth pattern. It has been pointed out that it seemed reasonable then to ascribe the effect of the applied field to mechanisms involving the metalloenzymes. An excellent detailed review and discussion concerned with the effect of air ions has appeared [31]. It has also been observed that air ions play a large role, but other factors such as ozone and nitrogen oxides, humidity and air pollutants can be expected to affect the results.

Ion uptake is an electric phenomenon and must involve current flow [44]. Conservative patterns of electrical current flow have been described [45–47] with active transport distally driving passive inflow of current into the root tip. Both transport mechanisms could be altered by the superposition of electric current upon the accumulation system [12]. It is hypothesized that electric fields were active in bringing about redistributions of auxin [48]. It is also said that extrinsic current might interfere with endogenous auxin or giberrelin activity [10]. The effects observed are consistent with the auxin hypothesis [11]. Auxin or IAA is known to be connected to bioelectric phenomena in plants [12,49–51] and K/Na selectivity in ion uptake [52]. The inhibition of the polar transport of IAA abolishes the current induced enhancement of growth and organogenesis inplant tissue cultures [53] which tends to confirm the above mentioned conjecture.

Ionoculture is a fairly new field new field of study. Knowledge of this would help to increase agricultural production.

Acknowledgement: The authors express their thankfulness to the Directors of I.I.T.M., Pune and C.E.C.R.I. Karaikudi for their kind permission to publish this paper.

REFERENCES

1. B Hess, A Boiteux, H Busse and G Gerisch, in *Membrane Dissipative Structures and Evolution*, (Ed) G Nicolis and R Lefever, John Wiley and Sons, New York (1975) p 137
2. L F Jaffe in *Ionic Control of Development*, (Ed) R A Cone and J E Bowling, Raven Press, New York (1979) p 199
3. R F Stump, K R Robinson, R L Harold and F M Harold, *Proc Nat Acad Sci U.S.A.*, **77** (1980) 6673
4. R B Borgens, *Int Rev Cytol*, **76** (1982) 245
5. S H Brawley, D F Wetherell and K R Robinson, *Proc Nat Acad Sci U.S.A.*, **81** (1984) 6064
6. D L Kropf, J H Caldwell, N A R Gow and F M Harold, *J Cell Biol*, **99** (1984) 486
7. S H Brawley and K R Robinson, *J Cell Biol*, **100** (1985) 1173
8. E L Breazeale, W T McGeorge and J F Breazeale, *Soil Sci*, **71** (1951) 371
9. E L Breazeale and W T McGeorge, *Soil Sci*, **75** (1953) 443
10. J D Black, F R Forsyth, D S Fensom and R B Ross, *Can J Bot*, **49** (1971) 1809
11. D Krizaj, L Vodovnik, F Pohleven and N Gogala, *J Bioelectricity*, **6** (1987) 129
12. L M Jaffe and R Nuccitelli, *Ann Rev Biophys Bioeng*, **6** (1977) 445
13. T M Chen and L F Jaffe, *Planta*, **144** (1979) 401
14. K S Rathore and A Goldsworthy, *Biotechnol*, **3** (1985) 1107
15. H Asnarul, *Sci Reporter*, **18** (1981) 344
16. M Inoe, M W Miller, C Cox and E L Carstensen, *Bioelectromagnetics*, **6** (1985) 293

17. F W Wheaton, A Review, Report No 4262 Agricult. Exp. Station, Univ. Maryland, Maryland (1970)
18. H A Pohl, *J Biol Phys*, **5** (1978) 3
19. H A Pohl and G W Todd, *Int J Biometeor*, **25** (1981) 309
20. V H Blackman, A T Legg and F G Gregory, *Proc Roy Soc.*, **B 95** (1923) 214
21. V H Blackman, *J Agri Sci*, **14** (1924) 240
22. G Collins, L Flint and J W Mclane, *J Agri Res*, **38** (1929) 585
23. L J Brigs, A B Campbell, R H Heald and L H Flint, *U.S. Dept. Agric. Bulletin* (1926) 1379
24. L J Brigs, in *Physiology of Plants*, (Ed) W Seifriz, J Wiley and Sons, New York (1938)
25. L E Murr, *Nature (London)*, **201** (1964) 1305
26. *ibid*, **206** (1965) 467
27. *ibid*, **207** (1965) 1177
28. *Int J Biometeor*, **10** (1966) 147
29. idem, *Adv Frontiers Plant Sci*, **15** (1966) 97
30. C H Bachmann, D G Hademanos and L W Underwood, *J Atmos Terr Phys*, **33** (1971) 497
31. A Kotaka and A P Krueger, *Adv Frontiers Plant Sci*, **20** (1967) 115
32. A P Krueger, S Kotaka and P C Andriese, *Int J Biometeor*, **8** (1964) 5
33. A P Krueger, A E Strubbe, M B Yost and E J Reed, *Int J Biometeor*, **22** (1978) 210
34. A P Krueger, *Scientia*, **104** (1969) 460
35. R F Smith and W H Fuller, *Plant Physiol*, **36** (1961) 747
36. A P Krueger, S Kotaka and P C Andriese, *Int J Biometeor*, **6** (1962) 33
37. A P Krueger, S Kotaka and P C Andriese, *Int J Biometeor*, **8** (1963) 17
38. S Kotaka and A P Krueger, *Int J Biometeor*, **16** (1972) 1
39. A P Krueger and A Kotaka and E J Reed, *The Effect of Airions on Plants, Congress International Le Soleil au Service de l' Homme, Paris*, July (1973)
40. S Kotaka, A P Krueger and P C Andriese, *Int J Biometeor*, **12** (1968) 85
41. E L Sharp, *Science*, **156** (1967) 1359
42. R Pratt, *J Pharm Sci*, **51** (1962) 184
43. A P Krueger, S Kotaka and P C Andriese, *Int J Biometeor*, **9** (1965) 201
44. P S Nobel, *Biophysical Plant Ecology and Physiology*, Freeman and Co., New York (1983)
45. M H Weisenseel and L F Jaffe, *Planta*, **133** (1976) 1
46. H M Behrens, M H Weisenseel and A Seivers, *Plant Physiol*, **70** (1982) 1079
47. A L Miller, J I Raven, J I Sprent and M H Weisenseel *Plant cell and Environment*, **9** (1986) 79
48. F W Went, *Jb Wiss Bot*, **76** (1932) 528
49. D S Fensem, in *Plant Physiology*, New Series (Ed) R P Pharis and D M Reid, Springer Verlag, Berlin (1985) p 625
50. W M Clark, *Plant Physiol*, **12** (1937) 409
51. C Benning, *Planta* (1986) 228
52. R F M Van Steveninck, in *Encyclopaedia of Plant Physiology 2 B*, (Ed) U.Lüettge and U J Pittman, Springer, Verlag Berlin (1976) p 307
53. A Goldsworthy and K S Rathore, *J Exp Bot*, **3** (1985) 1134