The New Era of Root Air-Pruning Technologies for High Plant Productivity and Quality

Increase Production, Quality and Automation with Air-Pruned Plugs/Seedlings/Cuttings/Plants

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As with ever-changing technology, the role of growers and farmers continues to evolve. As growers and farmers our goals are to increase the bottom line and protect the environment in which we live. To achieve these goals growers must evolve beyond traditional practices and stride into the future with new technologies.

Air-Pruning Cultural Practices and Air-Pruning Tray/Pot/Container Systems.

The human has been using traditional/conventional plant containers/pots/trays for thousands of years all over the worlds without knowing such containers would negatively affect plant production and quality. Because containers in which plants are grown confine plant root systems in limited spaces, the biophysical interactions of roots and containers are critically important. Traditional containers (tray-cells, pots and other containers) have smaller bottoms than tops and drain hole(s), and cause root binding, that is, root spiraling and tangling **(Fig. 3)**. Root binding deters root branching and development, and causes non-uniform, slower growth in containers and, after the plants are transplanted, resulting in lower yields and quality, and significant losses in worldwide agricultural and forestry plant production. Therefore, public awareness on how the **air-pruning cultural practices and air-pruning tray/pot/container systems** can bring revolutionary impacts on green industry market worldwide is of utmost importance, and the key process is to educate professionals, farmers/growers, and the publics about the theories, practices, and benefits of air-pruning technologies.

The conceptual bases of root air-pruning technologies are the facts that the growth of each individual plant-root follows the growth pattern of the S-shaped curve **(Fig. 1)** so common in biological growth systems (including human and animals), and that root growth can be suspended at any portion of the growth curve to initiate *new* root growth. The principles discovered and the technologies invented have not only resolved the worldwide traditional containerized plant production problems, but also provided accelerated root development for every plant resulted in higher yields and crop quality. The breakthrough concept of **root air-pruning engineering** establishes, for the first time, the quantitative relationship between plant/root growth characteristics and tray-cell/pot/container designs to produce superior plants by effectively utilizing exponential growth stage of S-shaped curve and eliminating slow old growth for vigorous plant/root growth. This significantly increases plant production and eliminates root binding, providing revolutionary impacts on modern agricultural, horticultural and forestry crop production, and green industries.

As shown in Fig. 1 each root growth follows the S-shaped growth curve. Note that growth starts slowly but soon accelerates exponentially. Later the rate of growth declines to a slow stage before coming to a stop. The air-pruning tray-cells/pots/containers have the inner sidewalls tapered outward toward the bottoms with a detachable screens **(Fig. 2)** that allow the downward turning angles of the roots at the inner walls greater than 90 degrees to eliminate root spiraling and promote proper **root air-pruning**. Plant roots are air-pruned when the tips emerge through an open-bottom container that is covered by a screen supported off the ground. Root tips shrivel when exposed to the air, and temporarily suspend their growth. The plant responds by starting several new root branches. When these new branches reach the air at the bottom screen, they shrivel in turn. Another round of branching begins. This is why proper air-pruning speeds root growth exponentially in containers with a clean root geometry that enhances transplanting and superior growth.

Effective air-pruning suspends root growth **at the end of the exponential growth**. When you suspend growth at the end of these exponential spurts you effectively eliminate the slower growth stages, resulting in more efficient root growth. The combination of more efficient growth with more rapid branching by air-pruning means greater root mass in less growing time. Since, in general, shoot-to-root rations are constant, larger root masses equal larger plants, resulting in significantly increased yields and quality for every crop. It becomes clear that proper tray/pot/container depth and bottom opening are critical for the effective utilization of the exponential portion of the S-shaped root growth curve to achieve superior growth in the shortest period of time.

Air-pruning tray-cell/container configuration also facilitate automation by allowing air-pruned plants be manually/automatically removed from the open bottoms of tray-cells. The patented principles of automated transplanting are illustrated in **Fig. 4**. During the transplanting process, the detachable screen bottom is removed. This allows the air-pruning tray to become an integral component of the transplanter. The tray can be indexed in X-Y directions. The individual plugs or seedlings are pneumatically/mechanically dislodged and removed downward through the tray cells. Plant leaves fold aerodynamically to pass through the cell and drop tube without damage. The technologies greatly simplified transplanting operations to bring the fully automated greenhouse and field transplanting machines to a reality.

The concept of root air-pruning technologies has been realized in the forms of **air-pruning trays and pots**, manufactured in the United States, Taiwan and China and used in the United States, Taiwan, China and Japan. Some of their impacts on the growth performance are illustrated in **Fig. 5 (Color photos).** The direct impacts of this concept are that farmers, growers and ag-business can now significantly increase plant production and quality for both greenhouse and field crops to benefit green industries worldwide. Along with these direct benefits, indirect benefits on savings of labor, fertilizer, chemicals, growth media, water, and heating fuel consumption, and increased utilization cycles of greenhouse facilities by significantly shortening the plant growth periods, easy automation, energy and environmental conservation and reduced water and air pollution are also significant.

The air-pruning related products won the **AE50 Outstanding Innovations** best product awards from ASAE for 1999 and 2000. (ASAE is the engineering society for agriculture, food and biological systems). The breakthrough concept of root air-pruning technologies won the prestigious **Rain Bird Engineering Concept of the Year Award** for 2001.

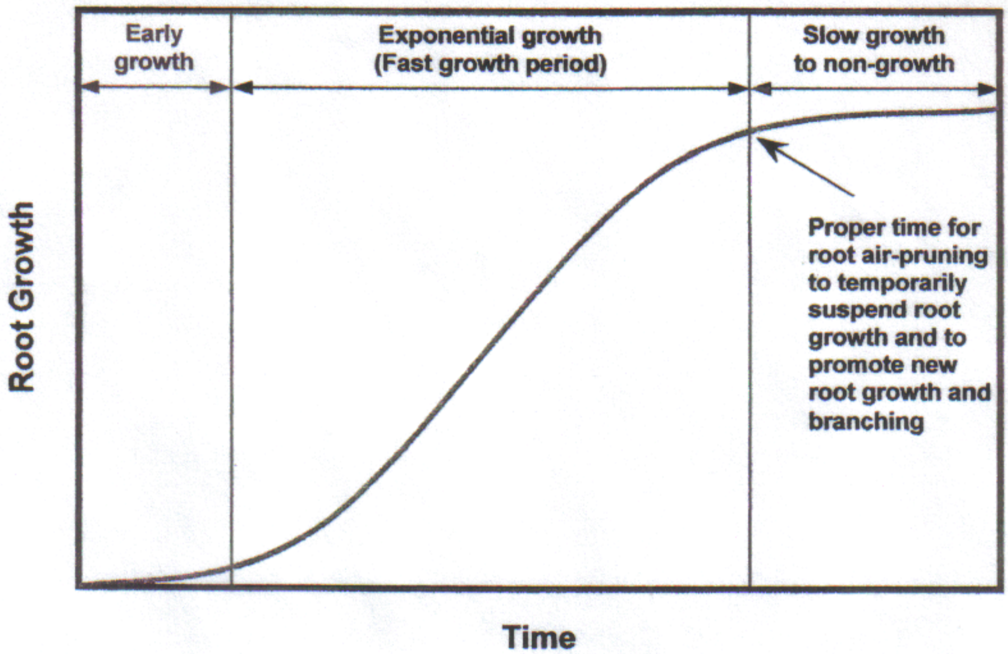

Fig. 1. Root growth versus time: the S-shaped growth curves illustrating the three stages of root growth and the proper time root air-pruning to temporarily suspend root growth.

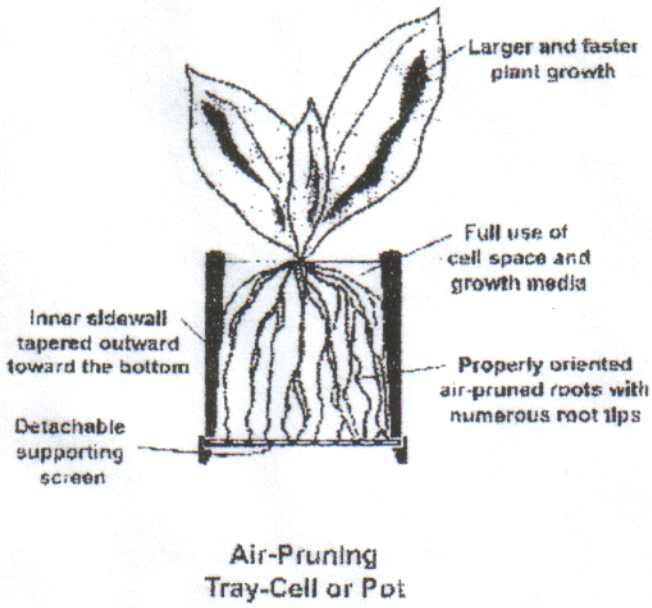

Fig. 2. Sectional view of an air-pruning tray-cell/pot/container system: Note that it is larger at the open bottom and gradually gets smaller toward the open top. The bottom is covered with a detachable supporting screen. Note as well the superior root formation and plant growth, and the effective use of all container space and growth media.

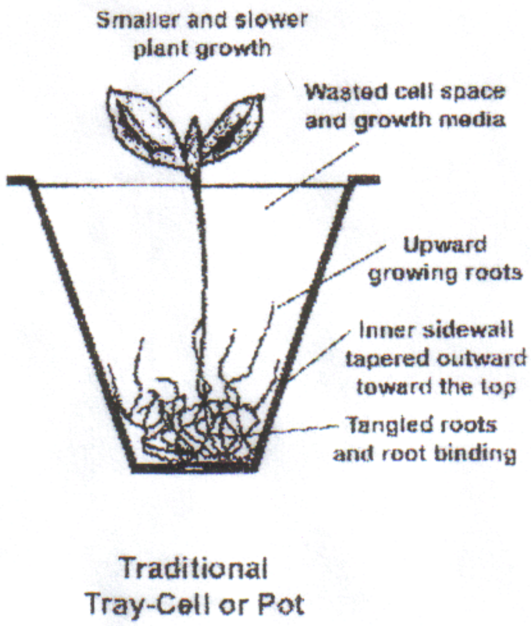

Fig. 3. Sectional view of the traditional tray-cell/pot/container: Note that it is smaller toward the closed bottom where the drain hole or holes are. Note as well the characteristic root binding, inferior root formation and plant growth, and the ineffective use of the container space and growth media.

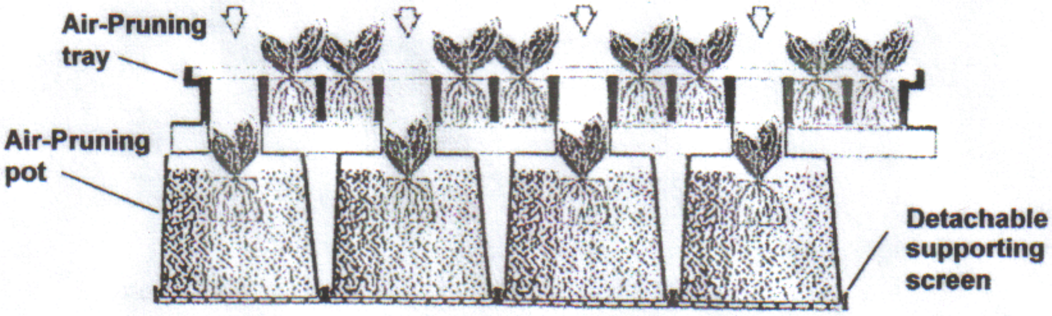

Fig. 4. Patented principles of automated transplanting system: During the transplanting process, the tray's detachable screen bottom is removed. This allows the air-pruning tray to become an integral component of the transplanting system. The tray can be indexed in X-Y directions. The individual plugs or seedlings are mechanically/pneumatically removed downward through the tray cells.

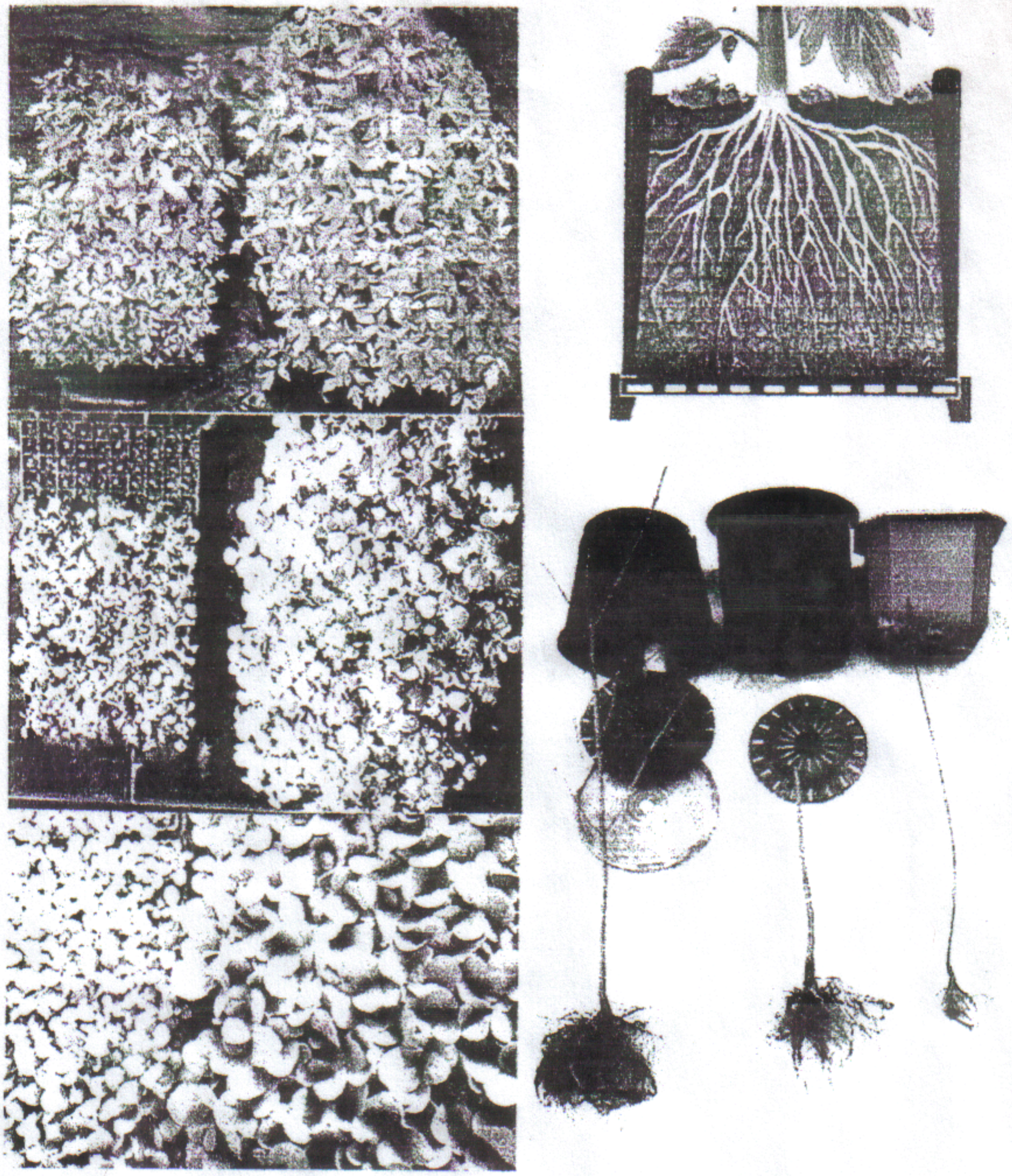

Fig. 5. Left photos: Side-by-side comparisons of the growth performance for tomatoes (**top**), impatiens (**middle**), and tobacco (**bottom**) seedlings grown in traditional trays (on the left) and air-pruning trays (on the right) under the same growing conditions for 30 days after seeding. For impatiens, the top 5 rows of tray cells were started from seeds and the others were started from cuttings. **Right top photo:** Sectional view of an air-pruning tray-cell / pot / container system showing the inner sidewall tapered outward toward the bottom; the detachable supporting screen bottom; the properly oriented air-pruned roots; and the full use of growing space and media. **Right bottom photo:** Root system comparison of maple trees grown in an air-pruning pot with supporting screen (**left**), in a traditional pot with air-pruning supporting screen (**center**), and in a traditional pot (**right**).

RAIN BIRD ENGINEERING CONCEPT OF THE YEAR AWARD

The award is presented to an engineer or engineering team for unique contribution to developing or advancing a new engineering concept. Through this award, ASAE spotlights ideas that result in new hardware, standards of practice, design trends, educational methods or in some other way significantly affect agricultural engineering or the industries it serves.

To be eligible for this award, an engineer or engineering team must first have published the new concept in Resource: Engineering & Technology for a Sustainable World, the Transactions of the ASAE, Applied Engineering in Agriculture or some other ASAE publication.

Herbert N. Stapleton, who in 1974 was the first recipient of the Engineering Concept of the Year Award, funded the award from 1985 to 1993. The award is now endowed by Rain Bird International.

PREVIOUS CONCEPT OF THE YEAR AWARD WINNERS

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1999 . . . . .D. Ken Giles, Graeme W. Henderson
2000 . . . . .No recipient

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Barney K. Huang is the recipient of the Rain Bird Engineering Concept of the Year award for 2001. Huang is the president of International Innovative Technology, Inc., and Air-Pruning Technologies in Raleigh, North Carolina. He is also a member of the research faculty of Branden University. He is being honored for his contributions in the development and advancement of a new engineering concept that significantly affects agricultural engineering and agricultural, horticultural and forestry plant production worldwide. Huang's breakthrough concept of root air-pruning engineering not only addressed root-binding problems in agriculture and forestry but also provided accelerated root development to increase plant production and quality in both greenhouses and in the field. Both of his product designs, the air-pruning tray system and the fully automatic air-pruning field transplanting system, earned AE50 awards. The principles discovered and the technologies invented by Huang represent milestones in the agri-bio industry.

Many of his other achievements include inventions, developments and commercial implementations of fully automatic transplanters in conjunction with air-pruning technologies, solar tobacco and peanut curing, and solar grain and biomass drying. His book Computer Simulation Analysis of Biological and Agricultural Systems contains an approach to the interfacing of computer technologies in biological and life sciences in engineering, agricultural and forestry applications.

Huang has published more than 150 scientific articles and books and holds over 40 U.S. and foreign patents. His awards and honors include four ASAE paper awards, Korea Tobacco Research Institute Excellence Award, American Biographical Institute Distinguished Leadership Award and the Golden Academy Award for Lifetime Achievement. He is often invited to lecture and consult nationally and internationally and has received honorary professorships from three universities. He has also been honored by listings in over 30 national and international Who's Who and similar biographical compilations.

A 38-year member of ASAE, Huang has served on the Publications Review, Plant Dynamics, Soil Dynamics Research, Tractor and Implement Hydraulic, Vehicular Automation, Nursery and Greenhouse Mechanization, Aquaculture, and Textbook committees.