Horticultural Engineering

Volume 13 No. 4 July 1998

Continuing Education Opportunities

New Jersey Annual Vegetable Meeting
January 19 -21, 1999
Atlantic City New Jersey

This extraordinary annual meeting is sponsored by the Vegetable Growers' Association of New Jersey, Inc. and Rutgers Cooperative Extension, Rutgers the State University of New Jersey and The New Jersey Department of Agriculture.

Each year this meeting features one of the best trade shows and programs on the entire east coast. This year will feature a workshop on Post-Harvest handling of fruits and vegetables.

Additional information concerning the exhibition is available from:

Phil Traino, Executive Secretary
at 609 985 4382.

Greenhouse Design and Environmental Control Short Course

January 11-12, 1999

This short course features one and one half days of technology transfer and a one-half day tour to several state-of-the-art greenhouse operations. Topics for study and discussion include, greenhouse heating and cooling, space utilization, glazing choices, crop production systems, irrigation systems and design of floor heating systems. Additional information is available from your editor or from The Office of Continuing Professional Education 732 932 9271.

Greenhouse Grower Meeting
November 5, 1998
Cook College Student Center
Details in upcoming Newsletters.

NEW ENGLAND GREENHOUSE CONF
October 19 thru 21, 1998

This year's new location is at the
Centrum Center in
Worcester, Mass.
Contact Larry Carville at PO Box 117
Vernon, CT 06066-0117
website http://www.uvm.edu/~pass/greenhouse/negc.html

Creating a Master Plan for Greenhouse Operations
William J.Roberts

This new extension publication will soon be released. The 13-page brochure discusses the essentials of formulating a master plan for greenhouse operations and covers information on economic and engineering planning.

COOPERATIVE EXTENSION
COOK COLLEGE
RUTGERS, THE STATE UNIVERSITY
NEW BRUNSWICK, NJ 08901

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Hydroponic Systems

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(Submitted 4/30/98 to Professor Roberts Greenhouse and Plastic Design class Spring 98)

Introduction

Hydroponics is the practice of growing plants in a medium other than soil, using mixtures of essential plant nutrient elements dissolved in water. It is derived from two Greek words, "hydro" (water) and "ponos" (working), thus water-working.

Hydroponics has been identified as the best technology for crop production not only for urban and health-conscious societies but also for land, labor and resource-scarce societies and remote communities around the world. By hydroponics, it is now technically feasible to obtain fresh supply of vegetables, flowers, herbs, etc. right on top of Mt Everest, deep under the sea in submarines, in remote deserts, in drought prone areas and even in space stations.

History of Development

Hydroponics was practiced in the BC in Egypt, China and India where ancient man used dissolved manure to grow cucumbers, watermelons and other vegetables in sandy river beds (aggregate hydroponics - sand culture). It was then called as riverbed Cultivation. Later, when Plant Physiologists started to grow plants with specific nutrients for experimental purposes, they gave the name nutri-culture. Then, terms like water culture, solution culture, gravel bed culture etc. were mentioned. The chronology of events is given in Table 1 located on the following page.

Hydroponic Systems continued

Though crop production has been practiced for centuries, serious work on the hydroponic methods of growing crops began only in the 1920s. The basics of commercial hydroponics were developed in the 1940s and marketed in the 1960s. Currently, there are numerous commercial hydroponic farms in many parts of the world. Apart from the government research institutions, many small and multinational companies in Australia, Belgium, Denmark, Holland, Japan, Taiwan and the U.S. have invested a lot in commercializing this technology. Horticulture, Plant Physiology and Hydroponics Labs around the world are working hard on refining this futuristic green technology. Now, hydroponics is the standard name for all cultivation methods that use nutrient solutions. **Continued on page four.**

Class Projects

Each year as a part of class activity students in my class are asked to do a paper or design or construct a model project. This year several constructed model home greenhouses and others wrote on such topics as, recycling plastic film, comparison of growing roses in traditional versus new culture and some on hydroponic systems. My desire and instructions to them is that they do a project on something which interests them and will not simply be just another class assignment.

This article by Bouchra Marhaba is a result of her class project. Bouchra is an engineering student from Lebanon. In my opinion she did an excellent job and wrote a good paper and I wanted to share it with you.

Bill Roberts

Table 1: History of Hydroponics

BC	Compost/manure solution used to grow melons and other vegetables in the riverbeds during summer in Arabia, Babylon, China, Egypt, India and Persia.
1492	Plants need mineral elements (Leonardo de Vinci/France).
1666	Plants grown in water in glass vials (Robert Boyle/Ireland).
1699	Nutrients absorbed by ion exchange (Woodword/England).
1804	Studies on crop nutrition (Nicholas de Saussure/France).
1850	Sand/quartz/charcoal culture (Jean Baussingault/France).
1860	Water/solution culture (Sachs and Knop/Germany).
1920	Formulating nutrient solution (Hoagland /USA).
1940	Static hydroponics with aggregates (Gericke/USA).
1945	Nutriculture studies (Withers and Withers/USA).
1960	Nutrient film technique (Alan Cooper/UK).
1970	Aeroponics (Massantini/Italy).
1975	Floating Hydroponics (Farnworth/ USA).
1980	Raceways Hydroponics - deep flow technique
1980	Many automated and computerized hydroponic farms were established around the world.
1990	Home hydroponics kits gained popularity in Australia, Japan, Singapore and Taiwan.

Hydroponic Techniques

There are seven modern hydroponic techniques. In the Ebb and Flow Technique (EFT), as shown in figure 1, the nutrient solution is drained off 3-4 times a day to permit the roots to breathe. It is also called "Flood and Drain technique, good for home gardens and nurseries. The second technique, shown in figure 2, is the Deep Flow Technique (DFT) where the depth of nutrient solution (several inches deep) is circulated around the roots by a pump and gravity drain. This method is referred to as "Dynamic Root Floatation" or "Raceway Hydroponic" technique, ideal for leafy vegetables. Figure 3 shows the third technique known as the Aerated Flow Technique (AFT), a modified version of DFT. Here, the nutrient solution is profusely aerated by special mechanisms. The Japanese "Kyowa Technique" is similar to AFT. Excellent for growing both leafy and fruit crops. The fourth technique as shown in figure 4 is the Nutrient Film Technique (NFT) where a thin film of nutrient solution flows continuously down the sloped troughs to bathe the roots. The fifth technique as shown in figure 5 is the Drip Irrigation Technique (DIT) where plants are grown in inert or organic substrates. The nutrient solution is fed closely around the roots 6-7 times a day in drops or trickles. Deserts in the Middle East are exporting crop produce because of this technique. It is also suitable for plantation, orchard and landscaping industries. The sixth is the Root Mist Technique (RMT), shown in figure 6, is where a mist of nutrient solution is sprayed constantly onto the roots of plants suspended from a frame in the top. This technique is known as "Aeroponics". It is good for initiating rooting of cuttings and for providing optimum oxygen levels to the root zone. Figure 7 shows the seventh technique, the Fog Feed Technique (FFT). It is similar to RMT but the droplet size is so very **Hy-**

droponics continued
minute that nutrient solution can barely moisten your hand. This technique has yet to be perfected. It is good for plants with aerial roots (i.e. orchids, anthuriums, etc.).

Hydroponic Culture Systems

There are two different types of Hydroponics. (1) If the hydroponic system uses only the nutrient solution, then that system is categorized as "Water Culture" or "Solution Culture". (2) When used in combination with solid inorganic matter like sand, gravel, perlite, vermiculite, etc., or when employing a solid organic medium as peat moss, then that system is categorized as "Substrate Culture" or "Aggregate Culture".

The chief advantage of the former system over aggregate method is that a large volume of solution is always in contact with the root system, providing an adequate water and nutrient supply. The major disadvantages are the difficulties of providing an air supply for the plant roots as well as good support for the roots.

If the nutrient solution is recycled, then the system is called "Closed Hydroponics System", while it is called "Open Hydroponics System" if the nutrient solution is discarded after one use. The closed system can be troublesome due to the changing composition of the nutrient solution with each use. This system also has the potential for quickly spreading diseases. Hence, the “Open System” is more reliable. The most common of all “Open Systems” in wide-use today is the drip irrigation system.

A partial list of some of the popular hydroponic systems on the market are listed in figures 8 and 9.

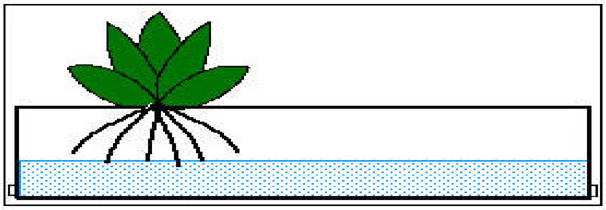

Figure 1: Ebb and Flow Technique-EFT

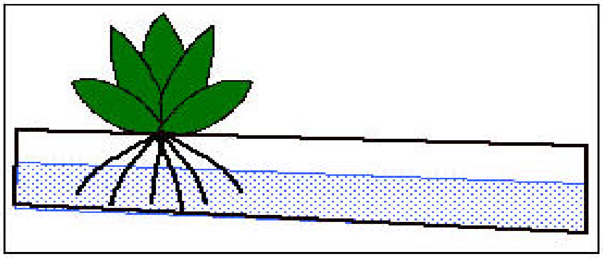

Figure 2: Deep Flow Technique - DFT

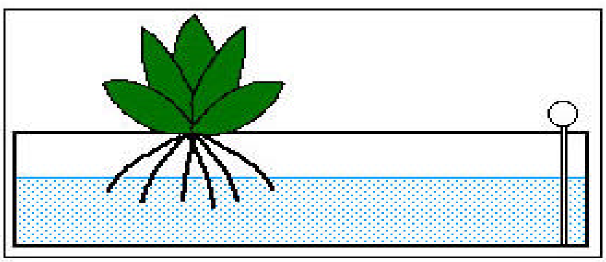

Figure 3: Aerated Flow Technique - AFT

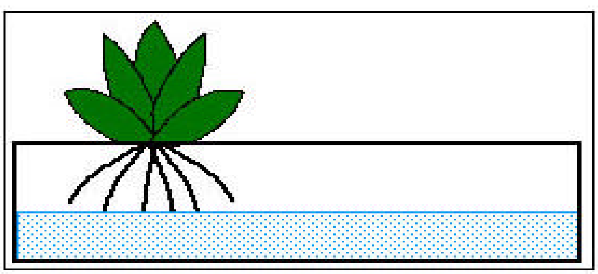

Figure 4: Nutrient Film Technique - NFT

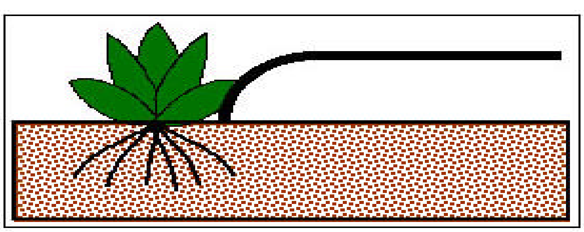

Figure 5: Drip Irrigation Technique - DIT

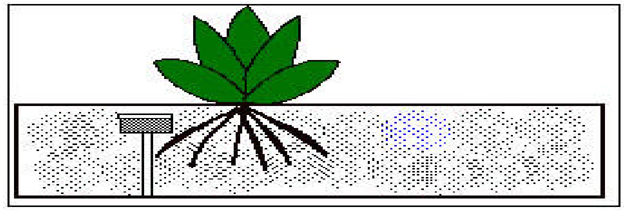

Figure 6: Root Mist Technique - RMT

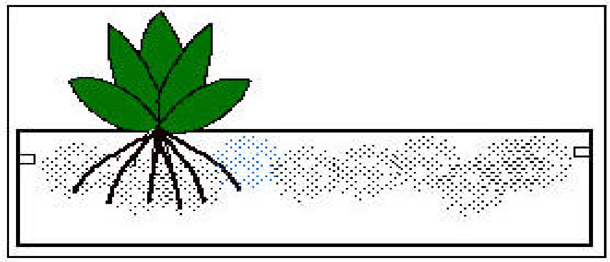

Figure 7: Fog Feed Technique - FFT

A-Frame Tier System (NFT)
Aeroponics (RMT)
Basin/Trough/Tray System (SAT)
Column Culture (RMT)
Gully System (NFT)
Kyowa (Hyponica) System (AFT)
Membrane System
Spiral (Tomita) System (NFT)
Vertical Tube-O-Ponics (RMT)

Figure 8: Popular Hydroponic Systems using Solution or Water Culture

Sand Culture (DFT/DIT)
Gravel/Pebble Culture (DFT/DIT)
Gelloponics (DFT/SAT)
Rockwool Culture (DIT)
Leca Culture (DFT/NFT)
Vermiculoponics (DIT/DFT)
Zeoponics (DFT/DIT)

Figure 9 Popular Hydroponic Systems using Substrate or Aggregate Culture

Formulating Nutrient Solutions

All plants need 16 elements to grow. They are C, H, O, N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, B, Mo and Cl. In nature, the plants derive these elements from the atmosphere or minerals in the soil. Most of the elements used in preparing nutrient solutions are derived from these naturally occurring minerals. Hydroponic solutions purity can be controlled unlike the soil culture that may contain impurities.

There are numerous formulations of nutrient solutions available in the market. This is based on the availability and price of the raw materials. Some are in solid form as nutrient salts or fertilizers, some in liquid form and some in tablet form. Their composition depends on the raw materials and the intended purpose. Normally, nutrient solution for vegetative growth will have more nitrogen and less potassium and those for flowering and fruiting phase will have less nitrogen and more potassium.

Pros and Cons of Commercial Hydroponics

The main advantages of hydroponics include:

(a) higher crop yields,
(b) smaller space requirements,
(c) freedom from diseases,
(d) less labor,
(e) no weeding,
(f) higher growth rate,
(g) tendency to uniform results, and
(h) better control of pH and nutrient application,

The main disadvantages include:

(a) high initial capital costs due to the use of tanks, pumps, lights, pipes, etc., and
(b) high requirements for operational and technical skills.

Soilless cultures involve growing plants in different kinds of containers; a bed, pot, bag, tank, tray, and basket. The size of

Hydroponic systems continued

the containers is often chosen on the basis of convenience. However, for all containers, the depth should be 1.5 to 2 times the diameter of the surface area covered by the plant canopy when the plant reaches its maximum size.

Conclusion

It is the result of hard work on the part of numerous scientists, amateurs and entrepreneurs in their quest to perfect the crop production technology. It is now undergoing rapid development. In a few years time, the productivity and quality of most crops should be increased many fold by employing hydroponic technology. This technique, with other biotechnology techniques, will contribute greatly to new developments in plant breeding, nursery management, agronomy and pre- and post-harvest technologies.

Hydroponics is considered to be another technology to overcome food shortage in future, especially in land, labor and resource scarce societies. It has the potential of being the best technology to certain phytochemicals from plant roots, especially by the pharmaceutical industries.

When land, labor and natural resources get scarce and people look for healthy alternatives to farming and gardening, there is no choice but to go for hydroponics.

References

Cooper, A., The ABC of NFT; Nutrient Film Technique, Grower Book, London, United Kingdom, 1979.

Douglass, J.S., Hydroponics; The Bengal System with Notes on Other Methods of Soilless Cultivation, Fifth Edition, Oxford University Press, New York, 1976.

Harris, D., Hydroponics Growing Without Soil, David & Charles, London, United Kingdom, 1974.

Rahman, M.F, Crop Production By Hydroponics, Lecture Notes, Hydroponics Lab, Department of Biotechnology, Ngee Ann Polytechnic, Singapore, 1998.

Successful ASP Conference:
Patricia Heuser Exec Sec. ASP

The turnout for the ASP Conference was great. Thanks to a lot of hard work by Dr. Merle Jensen. About 300 people attended and over 240 people went on the greenhouse tours in Wilcox and Cochise. We first visited Whitney Scott's 10,000 plant vertical strawberry operation in Cochise. Whitney and his wife Corina have a "U Pick" strawberry greenhouse and a pistachio farm. We appreciated the Scott's gracious hospitality.

The second stop on the tour was at Bonita Greenhouses in Wilcox. This 40-acre range, currently expanding to 60 acres, was a site to see. This is the most interesting operation since I visited their 135 acre greenhouse operation in Littlehampton, England over 10 years ago. The Bonita hydroponic tomato operation was very impressive and so was the production. The double cropping system is yielding over 54kg/M^2 or 11 lbs. per square foot per year! The plant density was 10,500 plants per acre. They are growing in Rockwool slabs. The cost of the first 40 acres was approximately 40 million dollars. Good greenhouses and good growing systems do not come cheap. (to convert square meters to acres: 10,000 square meters, 1 hectare = 2.5 acres.) According to our tour guide their production on 160,000 square meters is 54 kg/M^2 or 11 pounds per square foot as stated earlier. At $1.00 per pound that is $475,000 per acre or $11.00/square foot/year. Not bad.

Perhaps this goes to show what can be done with a state-of-the-art greenhouse as well as a few good growers. With all these huge acres of tomatoes going in perhaps it's time for the smaller grower to look at crop diversification and direct marketing. We

ASP Conference continued

also visited Wilcox Greenhouse (which was about 8 acres using the same type of glass greenhouse and rockwool growing system.

Published by permission from
Vertical Growing News - Newsletter
Verti-Gro Inc. Volume 1 #2 April 98

Bonita Greenhouses Energy Perspective
Bill Roberts

I was privileged to attend the ASP conference and would like to confirm what Pat Heuser has said about the meeting. It was well done and represented great effort on the part of Merle Jensen and his crew including Gene Giacomelli of our Department on Sabbatical working with Merle at the University of Arizona.

One of the interesting aspects of the excellent Bonita Greenhouse operation from an engineering point of view was energy use.

During the tour I questioned the guide about the absence of a thermal screen which could be useful for summer shading as well as energy conservation during the heating season. His response was that they liked the application of exterior white-wash on the greenhouse for shading. They had a mechanized rig which applied the whitewash and they were happy with it. I mentioned that an internal shading system, although not as efficient overall, could be managed and changed as needed. He responded that the weather was the same every day so once they started shading it would be needed every day.

I then brought up the idea of energy conservation during the heating season. I indicated that from our experience they could expect a 30% reduction in energy with interior moving thermal screens. This would be be in addition to the value it has as a

Energy Perspective Continued

a manageable shading device. His response to me was that if they used the thermal screen at night they couldn't use all of the energy produced during the day by the boilers. When he said this, I finally realized their philosophy of operation.

During the day one of the boilers, operating on natural gas, runs full-time producing hot water, which is stored in five large storage tanks, and CO_2 for the enhancement of production for the tomato crop. The hot water which is stored is used at night to heat the greenhouse through the overhead, floor area and perimeter heating pipes. On mild nights the use of the thermal screen which would reduce the heating load would be a detriment because they needed to use all of the hot water that night so the boiler could operate the next day producing the CO_2 required for the production system.

I had never looked at a management system from this point of view. We have always been concerned with saving energy. It is obvious that CO_2 production is controlling the operation. The thought occurred to me that perhaps another source for CO_2 could be found and the 30% reduction in heating costs resulting from the installation of the thermal screen could be used to pay for the system. This would also eliminate the need for external greenhouse shading. Perhaps this concept might give an overall savings in energy without sacrificing production.

Congratulations are due Bonita. Greenhouses Inc. Production and quality are excellent!!

NRAES Publications Available

Strawberry Production Guide NRAES 88

This production guide is the most comprehensive production guide ever produced for strawberry growers. This 14 chapter, 162 page publication is a must for every strawberry grower's library. Advisors and service personnel working with the industry will also profit by owning this Production Guide. The publication features 37 figures and 47 tables and 115 full-color photographs and provides the latest up-to-date coverage of every aspect of strawberry culture, from preparing the production site to harvesting and marketing.

The cost is $45.00 per copy plus shipping and handling. Contact NRAES via phone at 607 255-7654, fax at 607 254-8770 or by e-mail at NRAES@CORNELL.EDU.

Bramble Production Guide NRAES 35

This guide contains over 100 color photos showing bramble varieties, diseases, insects and growing techniques. The 15 chapters cover all aspects of bramble production from site selection through post-harvest handling. This 188 page loose-leaf guide is designed for information to be added as it is made available.

The cost is $45.00 per copy plus shipping and handling. Contact NRAES via phone at 607 255-7654, fax at 607 254-8770 or by e-mail at NRAES@CORNELL.EDU.

Both these publications are available from NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, New York 14853-

GREENHOUSE COVERING RADIATION TRANSMISSION WORKSHOP
October 1 & 2, 1998 [noon to noon]
Rutgers University, New Brunswick, NJ
[Registration deadline 9/1/98]

The major companies in the greenhouse glazing and covering industry, greenhouse suppliers & manufacturers, their distributors & salespeople are invited to a workshop which will focus on solar radiation within the greenhouse environment, and the primary effects of the greenhouse covering on the light and heat environment of the crop, as well as, procedures and instrumentation for determining and interpreting glazing transmission. The registration cost of $500 includes: Pre-workshop study guide, Notebook of lecture outline and notes, Pre-workshop product film test results [optional], Breaks and group dinner. ***Workshop will be limited to 30 attendees representing the greenhouse glazing industry and CCEA Partners and Advisory Boards.***

Register by September 1,1998 by http://aesop.rutgers.edu/~ccea for registration and information

....and now the complete details....

A WORKSHOP ON GREENHOUSE LIGHT TRANSMISSION

GREENHOUSE COVERING RADIATION TRANSMISSION WORKSHOP
October 1 & 2, 1998 [noon to noon]
Rutgers University, New Brunswick, NJ
[Registration deadline 9/1/98]

Light transmission in greenhouses! It is a complex topic. There are numerous conclusive studies and many commercial advertisements. Light transmission is difficult to measure, and a challenge to understand. What is the most up to date story?

Workshop Details continued

WHO SHOULD ATTEND? The major companies in the greenhouse covering industry, greenhouse suppliers & manufacturers, their distributors & salespeople.

WHY ATTEND?

- Learn about the complexity of solar radiation within the greenhouse environment, and the primary effects of the greenhouse covering on the light and heat environment of the crop.
- Separate the information and misinformation.
- Know what critical factors to determine before judging the results of a transmission test.
- Gain understanding of procedures and instrumentation for determining and interpreting radiation transmission of greenhouse glazing.
- Become better prepared for completing an in-house test of your own films, or for supporting a professional test program of your product.
- Take advantage of an optional pre-workshop product film test.

REGISTRATION:

$500 per participant, 20% reduction for 3 or more from same company. $300 for CCEA partners. Workshop will be limited to 30 attendees. Register by September 1, 1998 at the following website.
http://aesop.rutgers.edu/~ccea
Tel 732 932 9753
fax 732 932 7931
e mail giacomel@bioresource.rutgers.edu

Workshop Details continued

COST INCLUDES: Pre-workshop study guide. Notebook of lecture outline and notes. Pre-workshop product film test results [optional]. Breaks and group dinner.

DEVELOPED AND SPONSORED BY CCEA, The Center for Controlled Environment Agriculture, and the Department of Bioresource Engineering---Horticultural and Phytomation Engineering Program.

WORKSHOP PROGRAM SUMMARY:
The program contains 3 Lecture/Discussion sessions, and a Demonstration session.

PART 1. Background on information and mis-information of the basic physics of the light and heat energy transmission through greenhouse glazings. Components of radiation defined. Definition of units. Measuring radiation transmission. Sensors. Proper [and incorrect] use. Glazing, structure and other factors affecting light transmission in greenhouses. Differences among laboratory tests, short and long-term tests, testing stands, and greenhouse structure test with crop. What is important to the industry and to the grower? Radiation is energy and energy is heat. Macroclimate and microclimate. Greenhouse heat transfer for winter heating and summer cooling.

PART 2. Basic plant physiology and bioresponses to plant environment. What are the needs of the plant? How does the plant use the energy? Manipulating the plant growth with radiation.

PART 3. Discussion on the responsibility of the industry. Considerations for manipulating the radiation which passes through the glazing and reaches the plant. Which wave**Workshop Details continued**
lengths can be eliminated. Which must be maintained. What to consider when getting a product tested.

PART 4. There will be a demonstration of Greenhouse radiation measurement equipment for parameters including, PAR, solar and total wavebands. Spectroradiometer. Direct and diffuse radiation. [Bioresource Engineering greenhouses]

PRE-WORKSHOP OPTIONS:
Contact us about the optional pre-workshop product film test.
[AUGUST 1ST DEADLINE]

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suggestions are welcomed.

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