Original article

Plant Growth in Dynamic Foam Column
—some plants grow in dynamic foam—

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Abstract

The dynamic foam column is a new culture where the whole plant body is wrapped continually by dynamic foam. The efficiency of dynamic foam was confirmed through a sequence of short-term experiments : basil seeds germinated and grew into cotyledon and foliage leaf stage ; scion of basil, komastuna and impatiens rooted ; basil and komastuna that had grown beforehand in hydro culture, grew well in dynamic foam. Chrysanthemum green and pellia, however, turned transparent like a submerged leaf. In short, wet dynamic foam of this study was a good culture medium for some plants but not for others.

Dynamic foam is an excellent culture : it delivers water, nutriments, gases and pesticides both to the aerial and the subterranean part of the plant ; dynamic foam is one of the highest insulators against thermal and biological invasion.

Key words : foam, aeroponic, hydroponic

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Introduction

This is a unique study to grow whole plants including roots and leaves in dynamic foam.

The quasi stability of dynamic foam is affected by many factors : surface tension ; liquid viscosity ; mobility of liquid film surface ; gas permeability ; aeration rate ; bubble size and its size distribution ; number and size of liquid drainage pass ; and additional liquid feed to the top of the foam. However, it is not difficult to produce and maintain a dynamic foam column in a wide variety from fine wet foam like shaving cream to coarse dry foam like aged soap bubbles.

Dynamic foam is an excellent culture because it delivers water, nutriments, gases and even pesticides both to the aerial and the subterranean part of the plant, and moreover, it is one of the highest insulators against heat and biological invasion. The foam can be produced with ordinary liquid and air feed systems and can be sustained by a mesh screen or rod array, although columns and rectangular vessels were used in this study.

Foam is an effective culture in the space for the capillary suction must be a solely effective driving force of liquid transportation.

Many applications of foam have been proposed from 1959, most of which were to use stable dry foam to protect from frost[1−5)] and to flush the inside of the irrigation pipe by chemicals-containing foam[6,7)]. NAKABAYASHI[8)] *et al.* studied and proposed that the weight of the circulating medium would be reduced by using wet foam instead of heavy water in a hydroponic system. However, there are few reports on growing whole plants in foam. This study confirms the possibility of using foam through a sequence of short-term and qualitative investigations.

Materials and Methods

1. Plant samples

Plant samples were prepared through three procedures : (1) seeds were germinated and grown in soil culture ; (2) seeds were germinated in soil then raised in hydroponic culture ; (3) cut plants(scion) were soaked in water to take root. Cuttings (scion) were sometimes used directly. Basil (*Ocimum basilicum*), komastuna : a mustard spinach (*Bassic cqmpestris*), chrysanthemum green (*Chrisanthemum coranarium*) and pellia (*Perilla frutescens*) were used in most cases. Cuttings of new guinea impatiens (*Impatiens textori*), sedum (*Mexican canum*) and petunia hybrid were also used.

2. Hydroponic medium and foaming liquid

Hydroponic culture medium was 1/1000 diluted commercial liquid fertilizer (HYPONeX6-10-5 Hyponex JAPAN CORP., LTD). Foaming liquid was a mixture of 1/1000 diluted commercial liquid fertilizer, 1/10000 diluted commercial dishwashing detergent (FAMIRI PYUA, KAO Co.: 42% of Alkyl Ether Sulfate solution (AES)) and 6/1000 synthetic laundry starch (KURANOL, Uehara Chemical Co.: 40% of poly vinyl alcohol solution). Therefore, foaming liquid contains 0.042 (g/l) AES and 2.4 (g/l) poly vinyl alcohol.

3. Dynamic Foam Column

Three types of hand-made apparatus were used. Figure 1 shows the type 1 apparatus which was composed with a reservoir of 10 liters, two transparent vinyl chloride cylinders 8 cm in diameter and 60 cm in height and a showerhead fixed at the bottom of the reservoir. Foaming liquid filled the reservoir until it reached 5 cm above the vent holes of the showerhead which was aerated by an air pump (MVP-75, Iwaki Glass Co.LTD.). Initial bubbles 2 mm in diameter grew to 5–10 mm when they reached the top of the foam column. The height of the dynamic foam column was regulated only by the aeration rate. About 20% of the foaming liquid in the reservoir was exchanged with fresh liquid occasionally according to the red

Figure 2 shows the type 2 apparatus which consisted of a reservoir of 10 litters, an upper acryl rectangular box of 25×17×40 cm, an intermediate perforated board which had 10 oval holes about 5 cm in diameter and a shower head. The perforated board turned fine foam into coarse foam as shown in Fig. 2. Foam overflowed and drained into the lower tray, then was returned into the reservoir by a roller pump (EYEA AR-2100).

Figure 3 shows the type 3 apparatus, 25×17×60 cm acryl rectangular box. Thick fine foam generated by an air stone at the small reservoir, flooded and ran perpendicularly to the specimen plants. An initial 2 liter foaming liquid at the reservoir was fed continuously to the small reservoir by a roller pump (EYEA AR-

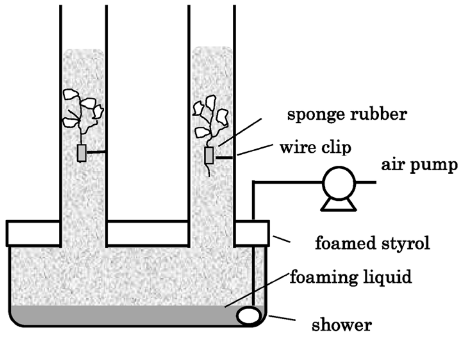


Fig. 1-B. Schematic of Foam Column (Type 1)

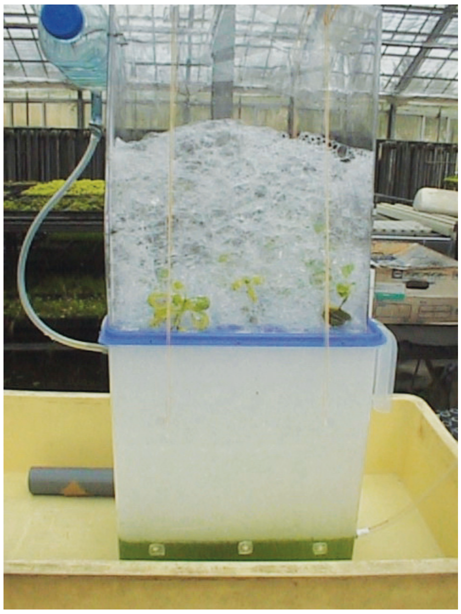
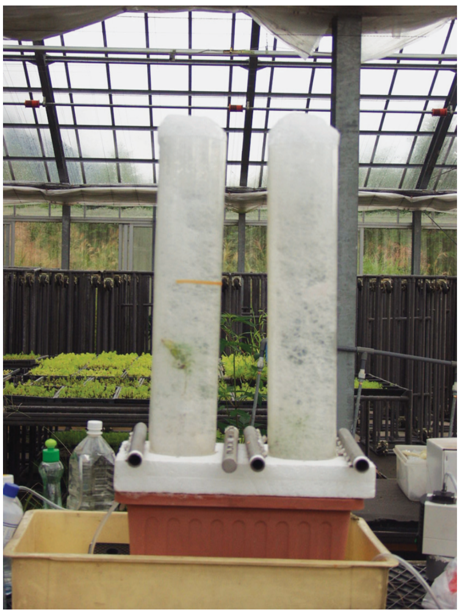


Fig. 2-A. Foam Column (Type 2)



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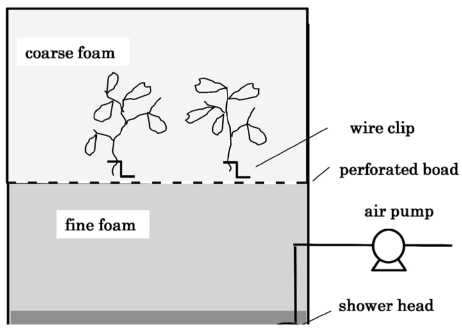

Fig. 2-B. Schematic of Foam Column (Type 2)

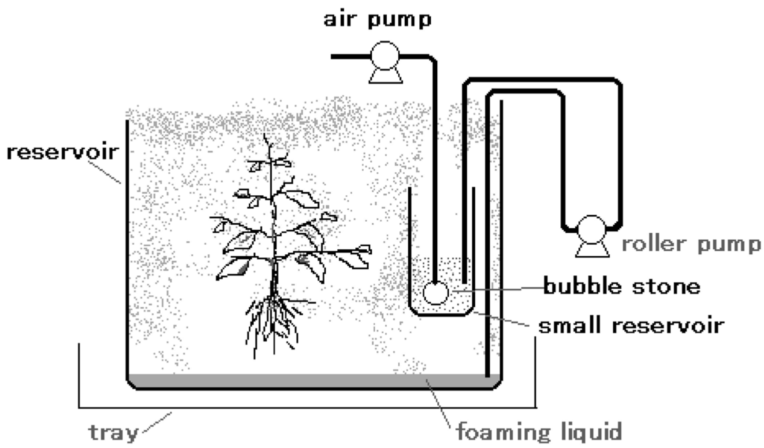

Fig. 3. Foam Column (Type 3)

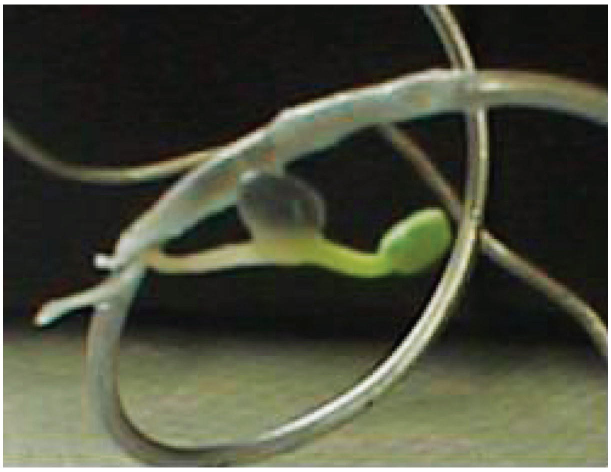

Fig. 4. Basile seed held 5 days in foam column

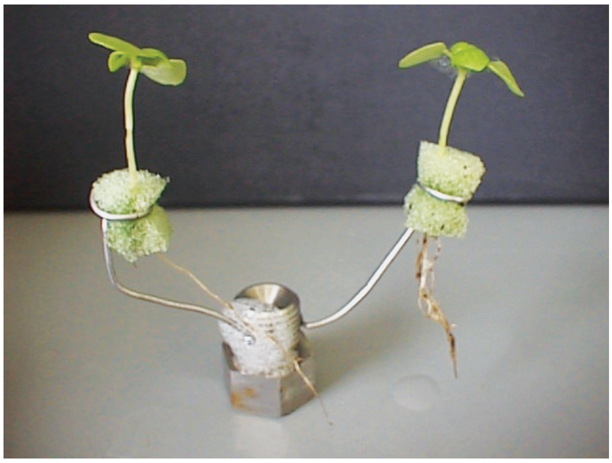

Fig. 5. Basile seedlings held 5 days in foam column

2100). About 50 ml of foaming liquid was supplied occasionally by hand to compensate for the overflow loss.

4. Measurement of light absorption by foam

Four rectangular pipes of different height 30×30×(5~30) cm, lined with aluminum foil were set in an open-air place on a cloudy day. Being filled with foam, luminous intensity at the bottom of the box was measured by TESTO 545 (Testo AG).

5. Specimen setting

Seeds were fixed to a stainless wire stand by instant adhesive (ARON ALPHA, TOA GOSEI Co.) as shown in Fig. 4. Plant samples were held by a small urethane foam piece and fixed to a stainless wire stand as shown in Fig. 5

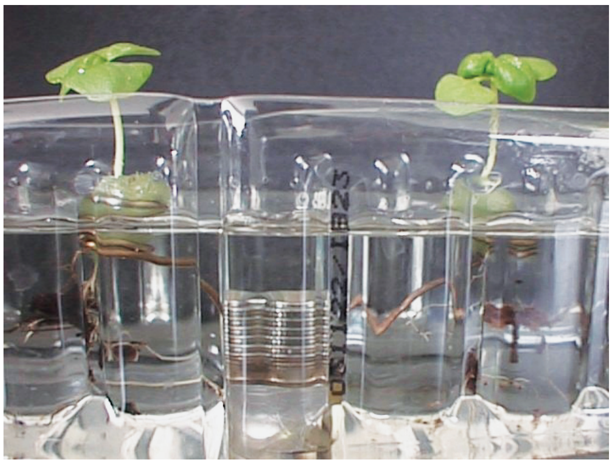

Fig. 6. Basile seedlings held 5 days in hydro culture

Results and Discussion

1. Germination of basile

Figure 4 shows a basile seed in dynamic foam (type 2 apparatus) for 5 days. The seed were adhered to a stainless wire with instant adhesive. The green part was a cotyledon and the opposite white part was a primary root.

2. Growth of cotyledon-stage seedlings

Basile seedlings were picked out from the soil care-

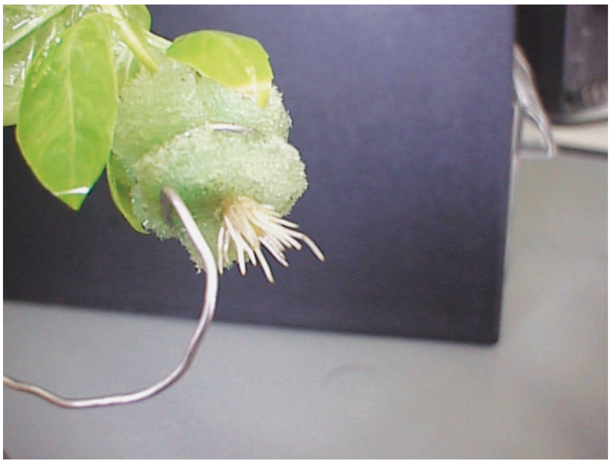

Fig. 7. Rooting of cuttings (scion) of Basile held 10 days in foam column

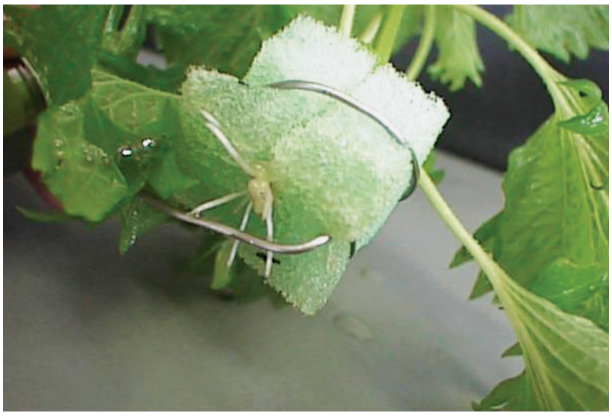

Fig. 8. Rooting of cuttings (scion) of perilla held 10 days in foam column

Fig. 9. Root regeneration of basile picked up from hydro culture and held 10 days in foam column

Fig. 10. Damage to chrysanthemum leaves held 10 days in foam column

fully by hand, then grown in dynamic foam (type 3 apparatus) or hydro culture for 5 days. Figure 5 and 6 show a seedling grown in dynamic foam and hydro culture respectively. The growth of seedlings in dynamic foam seemed to be slightly suppressed due to deficiency of light.

3. Rooting of cutting (scion)

Cuttings (scion) of basil and perilland rooted in 10 days in dynamic foam (type 2 apparatus), and little retardation of rooting was observed between dynamic foam and hydro culture. Figure 7 and 8 show basil and perilla in dynamic foam for 10 days respectively. While leaves of chrysanthemum green and petunia hybrid drooped or curled before rooting in dynamic foam.

4. Root regeneration of ordinary seedlings

There were cases where basil, komastuna and perilla, which were picked up carefully from the soil or hydro culture, lost their original roots then regenerated new adventitious-like roots in wet dynamic foam (type 2 apparatus). Figure 9 shows black dead roots and white new roots of basil after 10 days in wet dynamic foam. Its stems and leaves also grew during the root regeneration. However, no relation between root regeneration and growth of stems and leaves was found in this study.

5. Damages by foam

Leaves of chrysanthemum green became transparent like submerged leaves and their fringes curled in dynamic foam (type 2 apparatus) for 5 days as shown in Fig.10. There were cases where perilla became transparent and partly drooped.

In this study, seedlings were exposed to open air occasionally due to the instability of dynamic foam on cold nights.

Apart from those foam tests, some plants were submerged in aerated water for 1 week, then transferred to open hydro culture. Chrysanthemum green, perilla and petunia hybrid became transparent in water and they sometimes withered in open hydro culture. While, basil, komastuna and sedum maintained ordinary appearances both in foam and open hydro culture.

It is not clear whether the contact of foam solely or the iteration of foam and open air causes damages to chrysanthemum green, perilla and petunia hybrid.

6. Growth of basil in a dynamic foam column at sunny place

A scion of well rooted basil was set in a type 3 foam column that was placed in a sunny place during the day and in a room during the night from 28th August to 9th September in 2003. The temperature around the basil seedling was kept at 24–26℃ while the surface layer of the foam reached 34℃ in the sun. The basil seedling increased from 15.0 g to 17.5 g in weight over 13 days. Bad weather impeded further tests.

The foam thickness was from 10 to 20 cm, therefore about half of the sunlight reached the basil. However, the basil might not get adequate light due to the cloudy and cold summer of 2003. Its low growth rate is attributable to the deficiency of light.

6-1. Light absorption of foam

Figure 11 shows the ratio of luminous intensity at the bottom of the foam layer to that of a non-foam layer. Coarse foam corresponds to the upper foam layer in Fig. 2, and fine foam to the lower foam layer in Fig. 2 or that in Fig. 1. Figure 11 suggests that bubble sizes did not affect the light absorption significantly, and that about half of the light was absorbed by a 15 cm wet foam layer. While, dry foam scarcely absorbs light as shown in Fig. 12 where a fluorescent lamp is visible through dry foam of 25 cm thickness. As it was difficult to make dry foam stable for long periods, dry foam was not investigated, although it will play a significant role in foam culture.

6-2. Temperature distribution in dynamic foam

The temperature distribution of dynamic foam in type 3 apparatus which was placed in a sunny place and cooled by crashed ice in the tray, was 33℃ at the top of the foam, 31℃ 5 cm beneath the surface, 28–29℃ around the plant and 27℃ at the both reservoirs. In another experiment, 34℃ at the surface and 24–26℃ around the plant.

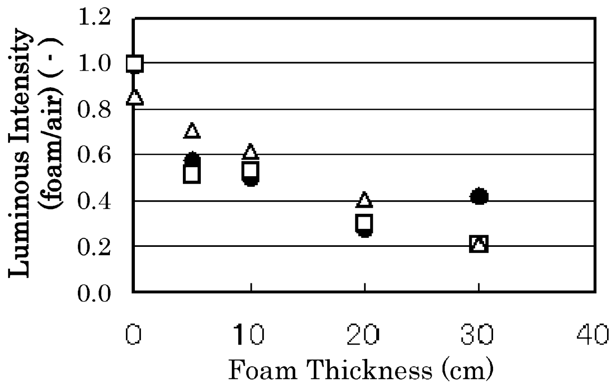

Fig. 11. Light Absorption of Foam
● : coarse foam, □ : fine foam (run1),
△ : fine foam (run2)

Fig. 12. Image of fluorescent lamp behind dry foam of 25 cm thickness.

It is a physically sound result that most parts of the dynamic foam were kept at the same temperature as the feed liquid. Indeed, heat absorbed at the foam surface results in the temperature rise of the drain liquid but it is not difficult to control the temperature of the drain liquid before its reuse as feed liquid. Light shielding and thermal insulation of dynamic foam will be effective for greenhouse culture in summer season.

Conclosion

Dynamic foam is an excellent culture for some plants : (1) basil and komastuna grew in wet dynamic foam ; (2) basil, komastuna and impatiens regenerated adventitious-like roots in wet foam then grew well in open air soil culture ; (3) basil seeds germinated and grew into the cotyledon and foliage leaf stage. While wet foam or iteration of wet foam and dry air is harmful to other plants : the leaves of chrysanthemum green and perilla became transparent like submerged leaves and withered in the succeeding open hydro culture. In short, depending on the type of plant, wet foam is a good culture or a harmful medium.

Dynamic foam is an excellent culture because it delivers water, nutriments, gases and pesticides both to the aerial and the subterranean parts of the plant and because it is one of the highest insulators against thermal and biological invasion. Some problems can easily be resolved : the synthetic detergent and vinyl alcohol used in this study can be superseded by natural materials ; the height and liquid content distribution can be regulated by applying current sensors and devices ; light absorption of wet foam can be improved by precise control of liquid content distribution and new luminous devices such as Laser Diode or optical fibers.

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泡沫中での植物生育

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要　約　動的泡沫層中に植物全体を設置・栽培することで，根と地上部への水・栄養・ガス・薬剤供給と高断熱機能や虫侵入防御機能とが期待できる。

泡沫層中での生育を検討した結果，バジル，ニューギニアインパチェンス，セダム，小松菜は良好な生育を示し，再び水耕や土耕に戻すと順調に生育した。また，切り枝の場合は順調な生育とともに不定根が発生した。

炎天下での泡沫層内部温度が供給液温に保たれたことから十分な断熱効果が確認できた。光透過性に関しては，やや wet な泡沫では 15 センチメーターで照度が半減することが確認できた。

一方，春菊，大葉，ペチュニアは泡沫層中で透明状態となり，萎れや葉周辺部のカールが見られた。水中葉，沈水葉に相当すると考えられる。これらを再び水耕や土耕に戻すと枯死した。

キーワード : 泡沫，気相栽培，水耕栽培

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