

FORM 1

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

APPLICATION FOR A STANDARD PATENT

617363

I\We,

ISOVER SAINT-GOBAIN

of

"LES MIROIRS"  
18 AVENUE D'ALSACE  
92400 COURBEVOIE  
FRANCE

hereby apply for the grant of a standard patent for an  
invention entitled:

SUBSTRATE FOR SOIL-FREE CULTURE  
HAVING A WATER CONTENT CONTROLLED  
OVER ITS THICKNESS

which is described in the accompanying complete specification

Details of basic application(s):

| Number of basic<br>application | Name of Convention country in<br>which basic application was<br>filed | Date of basic<br>application |
|--------------------------------|-----------------------------------------------------------------------|------------------------------|
|--------------------------------|-----------------------------------------------------------------------|------------------------------|

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FR

02 OCT 87

My/our address for service is care of GRIFFITH HACK & CO., Patent  
Attorneys, 601 St. Kilda Road, Melbourne 3004, Victoria,  
Australia.

DATED this 27th day of September

1988

ISOVER SAINT-GOBAIN

GRIFFITH HACK & CO.

TO: The Commissioner of Patents.

MO03143 27/09/88

Forms 7 and 8

COMMONWEALTH OF AUSTRALIA

Patents Act 1952-1962

DECLARATION IN SUPPORT OF A CONVENTION OR NON-CONVENTION  
APPLICATION FOR A PATENT OR PATENT OF ADDITION

INSTRUCTIONS

- (a) Insert No. if available.  
(b) Insert full name(s) of applicant(s).

In support of the application No. (a) \_\_\_\_\_  
made by (b) ISOVER SAINT-GOBAIN

- (c) Insert title of invention.

for a patent/patent of addition for an invention entitled (c) SUBSTRATE FOR SOIL-FREE CULTURE HAVING A WATER CONTENT CONTROLLED OVER ITS THICKNESS

- (d) Insert full name(s) of declarant(s) who must be PERSON or PERSONS, NOT a corporate body. (See head note).

I, (d) S. Le Vaguerese of Isover Saint-Gobain,  
18, avenue d'Alsace, 92400 Courbevoie, France  
of (e) \_\_\_\_\_

- (e) Insert address(es) of declarant(s).

do solemnly and sincerely declare as follows:—

- (f) Delete entirely if applicant is corporate body.  
(g) Delete entirely if applicant is person or persons.

1. (f) I am/We are the applicant(s) for the patent/patent of addition.  
1. (g) I am authorized by the abovementioned applicant for the patent/patent of addition to make this declaration on its behalf.

- (b) Delete entirely if Convention priority NOT claimed.

- (i) Insert country in which first basic application was filed.

- (j) Insert date of first basic application.

- (k) Insert full name(s) of basic applicant(s).

- (l) Delete entirely if applicant(s) NOT inventor(s).

- (m) Insert full name(s) of actual inventor(s) if applicant(s) NOT inventor(s).

- (n) Insert address(es) of actual inventor(s) if applicant(s) NOT inventor(s).

in (i) France on (j) 2nd October 1987

by (k) Isover Saint-Gobain

in (i) \_\_\_\_\_ on (j) \_\_\_\_\_ 19 \_\_\_\_\_

by (k) \_\_\_\_\_

in (i) \_\_\_\_\_ on (j) \_\_\_\_\_ 19 \_\_\_\_\_

by (k) \_\_\_\_\_

3. (l) I am/We are the actual inventor(s) of the invention.

3. (m) Bernard M. Kafka and Michel M. Baufume

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is/are the actual inventor(s) of the invention and the facts upon which the applicant(s) is/are entitled to make the application are as follows:—

- (o) Recite manner in which applicant(s) derive(s) title from actual inventor(s) if applicant(s) NOT inventor(s).

—as regards entitlement under Section 34 of the Act:—(o) The said applicant is the assignee of the said inventors

- (p) Delete entirely if Convention priority NOT claimed.

- (q) Recite manner in which applicant(s) derive(s) title from basic applicant(s) if applicant(s) NOT basic applicant(s).

—as regards entitlement under Part XVI of the Act:—(q) \_\_\_\_\_

4. The basic application(s) referred to in paragraph 2 of this Declaration was/were the first application(s) made in a Convention country in respect of the invention the subject of the application.

- (r) Signature(s) of declarant(s).

- (N.B.—No seal or stamp impression to be applied).

Declared at Courbevoie, France this 13th day of September 1988

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(54) Title  
**SUBSTRATE FOR SOIL-FREE CULTURE HAVING A WATER CONTENT CONTROLLED OVER ITS THICKNESS**

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**EP 209958**

(57) Claim

1.            A substrate for soil-free culture of plants formed from a felt of mineral fibres, suitable for the supply of water or an aqueous nutrient solution to the plants, wherein the substrate comprises a heterogeneous fibrous structure displaying a hydroretentivity gradient such that the hydroretentivity decreases in the direction of gravity.

AUSTRALIA

PATENTS ACT 1952

Form 10

COMPLETE SPECIFICATION

(ORIGINAL)

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TO BE COMPLETED BY APPLICANT

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Complete Specification for the invention entitled:  
SUBSTRATE FOR SOIL-FREE CULTURE  
HAVING A WATER CONTENT CONTROLLED  
OVER ITS THICKNESS

The following statement is a full description of this invention  
including the best method of performing it known to me:-

SUBSTRATE FOR SOIL-FREE CULTURE HAVING A WATER  
5 CONTENT CONTROLLED OVER ITS THICKNESS

The present invention concerns substrates for soil-free culture, in particular substrates which have a water content controlled over their thickness.

It is important, for the growth of plants, that  
10 the substrate contains air and can absorb and retain water or nutrient aqueous solutions.

There have been proposed, for soil-free culture, substrates based on mineral fibres, such as rock wool or glass fibres, because these substrates have the  
15 advantage of being highly porous, the fibres occupying generally at most 5% of the total volume of the

substrates. They can act as supports for roots, as a reserve for air and water or nutrient solutions; furthermore they are light and chemically inert.

The present description will refer, for  
5 convenience, to the supply of water to the substrates;  
however, it is to be understood that all aqueous nutrient  
solutions suitable for plants may be used.

The retention of water, or hydrotention, of a  
substrate is an important characteristic for the  
10 procedure of plant culture. The conditions of humidity  
can vary according to various factors such as the type of  
plants to be cultivated, the climate, the seasons, and  
the stage of development of the plant. Whatever may be  
the desired humidity conditions for a particular type of  
15 substrate, it is necessary for the water to be adsorbed  
and retained to a certain extent by the substrate, it  
should not drain away immediately, but rather it should  
remain available to the plant. In fact, water or  
solution which is too strongly bound to the substrate or  
20 which drains away too quickly cannot be satisfactorily  
utilised by the plant.

The substrates based on mineral fibres, as a  
result of their characteristics, give satisfactory  
results when they are used for soil-free culture.  
25 However, they still display one disadvantage; at the time  
of use the substrates are positioned on impermeable  
supports and are generally supplied with water by  
percolation. The water flows under gravity across the  
substrate. The lower part of the substrate remains in  
30 contact with the water by virtue of its capillary nature.  
The lower part of the substrate thus contains more water  
and less air than the upper part. The characteristics of  
water/air distribution are thus not the same over the  
whole thickness of the substrate; the roots develop in a

non-uniform manner within the substrate as a whole; which is harmful to the plant and reduces the effectiveness of the substrate.

5 According to the invention, a new substrate has therefore been sought which does not suffer from the above-mentioned disadvantage and which, in particular, exhibits a water content which is controlled over the thickness of the substrate.

10 According to the present invention there is provided a substrate for soil-free culture of plants formed from a felt of mineral fibres, suitable for the supply of water or an aqueous nutrient solution to the plants, wherein the substrate comprises a heterogeneous fibrous structure displaying a hydroretentivity gradient such that the hydroretentivity decreases in the direction of gravity.

15 This hydroretentivity gradient compensates for the effect of gravity and allows there to be obtained, within the thickness of the substrate and at the time of use, the desired water content.

20 The hydroretention of the substrate corresponds to its ability to absorb and retain water.

25 In order to determine the quantity of water retained by a substrate, referred to as hydroretention, after having been saturated with water the substrate is submitted to suction forces and its water content is determined as a function of these forces. Thus, for a given depression expressed in centimetres of water, the volume of water which is contained within the substrate and which represents a certain percentage of the volume of the substrate, is defined.

30 Two values suffice, in a conventional manner, as reference to determine the retention of water or hydroretention of a substrate; the volume percentage of water which is retained by the substrate under a depression of 10cm of water and the volume percentage of water which is retained by the substrate under a depression of 20cm of water. The substrate displays \_\_\_\_\_



satisfactory hydroretention when the volume of water which is extracted between these two values and which corresponds to the available water, is large.

It is established that the volume percentage of water retained by substrates is high under a depression of 10cm of water, and it is generally low under a depression of 20cm of water. To differentiate between different substrates with regard to their hydroretention, reference is therefore made to the volume percentages obtained at a depression of 10cm of water.

Various procedures exist for determining the hydroretention of a substrate. That which was used for the present invention is described hereinafter.

As has been indicated, in a substrate formed of mineral fibres, less than 5% of its volume is occupied by the fibres. 95% of the volume of the substrate can therefore be occupied by air and water. In general, a substrate having a satisfactory hydroretention contains at least about 50% of water, at a depression of 10cm of water, and this value can be different for a particular type of culture.

In the convention substrates, the distribution of water is not constant over the whole thickness as a result of gravity, and this is detrimental to good plant growth. The control of hydroretention over the whole thickness of the substrate, in accordance with the invention, permits this advantage to be alleviated.

In the attached drawings, given only by way of example,

Fig. 1 shows graphs of the hydroretention of conventional substrates of the same average density, but containing fibres having different average diameters;

Fig. 2 shows graphs of the hydroretention of conventional substrates containing fibres of the same average diameter, but of different average densities;

Figs. 3, 4 and 5 show graphs of hydrotention of substrates I, III and V, in accordance with the invention and substrates II, IV and VI of identical structure but utilised under conditions not in accordance with the invention; and

Fig. 6 shows apparatus for the determination of hydrotention.

The hydrotentivity is associated with the capillarity of the felt which forms the substrate. The capillarity depends on the diameter of the fibres, and thus of their fineness, and the density of the felt obtained from these fibres.

It has been noted that, for the same density, the hydrotentivity of a felt increases with the fineness of the fibres.

Fig. 1 shows graphs of hydrotention (volume percentage of water as a function of the depression expressed in centimetres of water) of conventional substrates A, B, and C, which are not in accordance with the invention, formed of a felt 75mm in thickness and having an average density of  $35 \text{ kg/m}^3$ . These substrates contain glass fibres of differing average diameters; for substrate A, the average diameter of the fibres is  $4 \text{ }\mu\text{m}$ , for substrate B, it is  $56 \text{ }\mu\text{m}$  and for substrate C, it is  $825 \text{ }\mu\text{m}$ . It can be established that the substrate which displays the highest hydrotention is that which is formed from the finest fibres, i.e. substrate A.

With felts which contain fibres of the same average diameter, the hydrotentivity decreases when the average density decreases.

Fig. 2 shows hydrotention curves for substrates containing fibres of the same average diameter,  $4 \text{ }\mu\text{m}$ , but having different average densities. It has been established that the greatest hydrotention is obtained with the substrate having the highest average density.

In order to obtain substrates which display a particular water content over their whole thickness, with a minimum accumulation of water in their lower part as a result of gravity, the invention provides a substrate  
5 which is formed of a heterogeneous structure of which the hydrotentivity decreases in the direction of gravity, as a result of the existence of a density gradient within the thickness of the substrate.

In particular, a substrate in accordance with  
10 the invention can be formed of a felt of mineral fibres of the same average diameter, but having a density which decreases over the thickness of the substrate in the direction of gravity.

Another substrate according to the invention  
15 comprises a heterogeneous fibrous structure having a hydrotentivity gradient resulting from a gradient in the fineness of the fibres over the thickness of the substrate.

Such a substrate, in accordance with the  
20 invention, is, for example, formed of a felt of mineral fibres having a predetermined average density and having an average fibre diameter which increases in the direction of gravity.

The density of the felts utilised for  
25 substrates in accordance with the invention can vary greatly. It is generally from 15 to 60 kg/m<sup>3</sup> and preferably from 20 to 30 kg/m<sup>3</sup>.

The average diameter of the fibres may have an appropriate value. It is generally between 2 µm and 12  
30 µm and preferably between 4 µm and 8 µm. Fibres having a diameter less than 2 µm are not preferred because they result in felts having a high hydrotentivity; the air content would be small and would bring about asphyxiation of the roots; besides, felts prepared from such fine

fibres display low resistance to mechanical forces. Fibres having a diameter greater than  $12\text{ }\mu\text{m}$  would form felts having poor hydroretention.

The hydroretentivity gradient as previously defined can also be obtained by density and fineness gradients over the thickness of the substrate.

Whatever the direction of variation of the density and/or the fineness may be, the felts forming substrates according to the invention must display a hydroretentivity which decreases in the direction of gravity; thus the fibres which are located close to the upper surface have characteristics which allows them to retain more water than those situated at the bottom of the substrate.

The accumulation of water in the lower part of the substrate caused by gravity is thus reduced.

A culture may necessitate the use of a particular substrate displaying a specific hydroretention, which depends particularly, as has already been said, on the plant itself, the climate, and the seasons. By virtue of the invention there may be obtained a substrate which is appropriate to every culture by varying in a suitable manner the characteristics of density and diameter of the fibres of the felt used to form the substrate.

The invention thus permits control of the water content of the substrate by creating a hydroretentivity gradient within a felt which constitutes a substrate which water content may be constant or may vary over the whole thickness of the substrate, according to the intended use. In particular, good results are obtained when the hydroretentivity is very high within the upper part of the substrate. That is particularly so when the upper part of the substrate contains fibres of very small average diameter, for example between  $2\text{ }\mu\text{m}$  and  $5\text{ }\mu\text{m}$ , or has a high density, for example between 30 and  $60\text{ kg/m}^3$ .

The substrates according to the invention can display density and/or fineness gradients by varying the density and/or the diameters progressively over the whole thickness of the substrate. The substrates can also be  
5 formed of several distinct layers each of which displays density and fibre fineness characteristics appropriate to obtain the desired result, i.e. a hydroretentivity which decreases in the direction of gravity.

In order to determine the layers of fibres that  
10 are to form the substrate, reference is made to their weight per unit area ( $\text{g/m}^2$ ) which depends on the density and the thickness. Each layer can display a different or the same weight per unit area, for example from 300 g to 2500  $\text{g/m}^2$ . The number of layers forming the substrate  
15 can vary depending on the desired result. Substrates can be used having from 2 to 8 layers of fibres and preferably having at least three layers. A high number of layers permits the hydroretentivity gradient to be finely controlled over the whole thickness of the  
20 substrate.

The overall thickness of the substrate can be varied depending on the final use. It is most often of the order of 70 mm to 75mm. The substrates may have greater or lesser thickness; however, the thickness  
25 should be sufficient to permit satisfactory development of the roots and a good supply to the plants of water or nutrient solutions.

The substrates in accordance with the invention are formed from a felt of mineral fibres. Rock wool  
30 which is produced from materials such as basaltic rocks, blast-furness slag, etc. This rock wool, by virtue of its porosity, may be used to form substrates according to the invention. However, as a result of its manufacturing process, the felt obtained contains a substantial  
35 percentage of material not converted into fibres. These are particles having a greater diameter than that of the

fibres proper and which play a much smaller part in the formation of the capillary network and, consequently of the hydrotentivity properties.

Glass wool can also be used for the substrates  
5 of the invention, the properties of this wool may make it particularly suitable for the formation of substrates for soil-free culture. The present processes for the manufacture of glass fibres, for example that in which the fibres are formed by passing molten material through  
10 a centrifugal die, have the advantage of permitting the formation of felts of homogeneous structure. Felts obtained from these fibres, which do not contain any non-fibrous material, are thus lighter than felts of rock wool and display improved hydrotentivity. Felts of  
15 glass fibre have, besides, substantial advantages in that they are highly compressible and return to their original thickness when the pressure is relieved, which characteristics permit improved packaging and storage.

To improve the ability of the substrate to  
20 accept water, a wetting agent may be added to the mineral fibre felt which forms the substrate. This wetting agent can be introduced during the manufacture of the felt or indeed at any later time. The addition can be carried out by any suitable process such as spraying or dipping.

25 The examples which follow are given by way of indication in order to illustrate the invention.

In these examples, at least so that this may be precisely indicated, the substrates are formed of a felt of glass fibres obtained by the well-known process  
30 utilising the centrifugal die. According to this process, the fibres are formed by passing the molten material through the orifices of a centrifugal die, they are then drawn out and carried by a strong gaseous current as far as a receiving mat which is mobile and  
35 permeable to the gaseous current. When the substrate

comprises several layers, these are obtained by depositing fibres from successive centrifugal dies onto the mobile receiving mat.

The hydrotention of the substrates is  
5 determined by the following process (see Fig. 6). A container 1 containing a porous material 2, such as sand, saturated with water is used. The base of the container communicates, via a flexible pipe, with a vessel 4, which contains water. The level of the water is maintained  
10 constant by an overflow system 5. The position of the vessel 4 can be controlled as desired on a vertical support. The "constant level" is controlled so that the level of water in the sand container is at 37.5 mm above the sand (i.e. half the height of the samples which is  
15 equal to 75mm). Samples 10cm x 10cm x 7.5cm are cut out of a felt of mineral fibres. These are weighed. They are immersed in a container filled with water for 24 hours. The samples (6) are then placed on the sand 2. The constant level is then lowered by a certain amount,  
20 in order to submit the substrate to a suction force. The lowering of the level or depression (d) is measured by referring to the height of the middle of the sample. After each depression, the sample is weighed at the end of 24 hours in order to obtain the hydric equilibrium,  
25 then it is replaced on the sand and the constant level is lowered once again in order to increase the depression in water.

There is thus obtained the weight of water retained by the substrate and consequently the volume  
30 percentage of water with respect to the total volume of the substrate as a function of the suction forces applied to it.

Example 1

A substrate I according to the invention is prepared, having a density of  $25 \text{ kg/m}^3$ , containing glass fibres of which the fineness defined by the diameter of the fibres, increases in the direction of gravity.

The substrate has a total thickness of 75 mm and is formed from 3 layers each having a weight per unit area of  $600 \text{ g/m}^2$ . These layers are distributed in the following order from top to bottom, i.e. in the direction of gravity: the first layer includes glass fibres having an average diameter of  $4 \text{ }\mu\text{m}$ , the second layer glass fibres having an average diameter of  $5.6 \text{ }\mu\text{m}$  and the last layer fibres having an average diameter of  $8 \text{ }\mu\text{m}$ .

The hydroretention of substrate 1 is determined as a function of suction forces by means of the procedure described above. It is shown by curve I in Fig. 3. It is established that, for a depression of 10cm of water, the volume of water retained by the substrate represents a little more than 50% of the total volume of the substrate.

The same sample is taken and utilised in the opposite direction, i.e. such that the upper layer of the substrate I, which contains the finest fibres, forms the bottom layer of the substrate (referred to as substrate II).

A substrate II is therefore obtained in which the fineness of the fibres decreases in the direction of gravity.

Curve II in Fig. 3 give the hydoretention of substrate II. It may be seen that, for a depression of 10cm of water, the volume of water retained by the substrate is less than 40%. Thus, the substrate (II), in which the finest fibres are located in the lowest part and the coarsest fibres at the surface, retains less water than the substrate (I) of identical structure, but inverted.

### Example 2

A substrate III of density  $25 \text{ kg/m}^3$ , having a total thickness of 75mm comprises 3 layers of glass fibres distributed in the following order from top to bottom: a first layer having a weight per unit area of  $300 \text{ g/m}^2$  containing fibres having an average diameter of  $4 \mu\text{m}$ ; a second layer of weight per unit area of  $900 \text{ g/m}^2$  comprising fibres having an average diameter of  $5.6 \mu\text{m}$  and a layer of weight per unit area of  $600 \text{ g/m}^2$  containing glass fibres having an average diameter of  $8 \mu\text{m}$ . The hydroretention curve for substrate III is given in Fig. 4 (curve III). It is established that, for a depression of 10cm of water, the volume of water retained by the substrate represents about 45% of the volume of the substrate.

A sample of the same substrate III, used in the opposite orientation, with the first layer of fine fibres  $4 \mu\text{m}$  in diameter located at the base of the substrate (substrate IV), displays a hydroretention (about 35% water for a depression of 10cm of water) which is inferior to that of substrate III of the same structure but inverted.

### Example 3

A substrate V is prepared, as in the previous examples, formed from a felt of glass fibres having a density of  $25 \text{ kg/m}^3$ . The total thickness of the substrate is 75 mm. It includes two layers distributed as follows from top to bottom: a layer having a weight per unit area of  $600 \text{ g/m}^2$  containing glass fibres having an average diameter of  $4 \mu\text{m}$  and a layer having a weight per unit area of  $1200 \text{ g/m}^2$  containing glass fibres having an average diameter of  $5.6 \mu\text{m}$ .

The curves showing the hydroretention of substrate V and substrate VI of identical structure inverted with respect to one another, are given in Fig.

5. It is established that, for a depression of 10cm of water, the water retained by substrate V represents more than 60% of the substrate and the water retained by the substrate VI represents more than 45% of it.

5 It may be noted that, when the finest layers are in the upper part of the felt, the hydroretention of the substrate is higher.

10 Having studied the above-mentioned curves, it may be said that in order to obtain a higher retention of water, it is preferred that the average diameter of the fibres increases in the direction of gravity (curves I, III and V).

In the previous examples, the volume percentage of water retained in the whole substrate has been given.

15 In the following example, the volume percentage of water retained by each layer of the fibres forming the substrate is determined in order to show that it is possible, in accordance with the invention, to control the water content within the substrate and to obtain a  
20 constant hydroretention over its whole thickness, by creating, within its thickness, a hydroretentivity gradient.

#### Example 4

##### Substrate A : Reference

25 A substrate having a total thickness of 100 mm is prepared by superimposing four layers of glass fibres 25 mm thick and of similar density. The four layers contain fibres of the same average diameter, 8  $\mu$ m, there is thus obtained a substrate having an analogous  
30 structure to the conventional substrates, i.e. displaying neither a density gradient, nor a gradient in fibre fineness.

Substrate A is immersed in water, then the water is allowed to escape, by natural drainage, for 10  
35 minutes.

The volume percentages of water contained in each of the layers after drainage are indicated in the following table.

| 5  | Substrate | Layers | Fibre Diameter  | Water retention(%) |
|----|-----------|--------|-----------------|--------------------|
|    | A         | 1      | 8 $\mu\text{m}$ | 36.5               |
|    |           | 2      | 8 $\mu\text{m}$ | 77.8               |
|    |           | 3      | 8 $\mu\text{m}$ | 96.8               |
| 10 |           | 4      | 8 $\mu\text{m}$ | 98.2               |

It is noted that as the average diameter of the fibres is the same over the whole substrate, the retention of water is greater in the lower layers.

15      Substrate B

A substrate B is prepared, analogous to substrate A, but in which the first layer (layer 1) contains fibres having an average diameter of 4  $\mu\text{m}$ .

The volume percentages of water retained by  
20 substrate B are indicated below:

|    | Substrate | Layers | Fibre Diameter  | Water retention(%) |
|----|-----------|--------|-----------------|--------------------|
|    | B         | 1      | 4 $\mu\text{m}$ | 99                 |
| 25 |           | 2      | 8 $\mu\text{m}$ | 57                 |
|    |           | 3      | 8 $\mu\text{m}$ | 97.6               |
|    |           | 4      | 8 $\mu\text{m}$ | 99.5               |

The three last layers 2, 3 and 4 of this  
30 substrate B, having similar density and containing fibres of the same diameter, form a part of the substrate which

does not display either a density gradient nor a fineness gradient, and which therefore has a structure corresponding to that of the conventional substrates. It also displays disadvantages in that the water accumulates 5 by gravity in the lower layers which contain more water than the upper layers.

The layer (1) containing the finest fibres (4  $\mu\text{m}$ ) permits there to be created a layer having high water retention at the surface.

10            Substrate C

Substrate B is compared to a substrate C having a total thickness of 100 mm obtained by superimposing 4 layers of glass fibres 25mm in thickness, which are arranged in the following order from top to bottom.

15            Layer (1) comprises fibres having an average diameter of 4  $\mu\text{m}$ ;

Layer (2) contains fibres having an average diameter of 5.6  $\mu\text{m}$ ;

20            Layers (3) and (4) contain fibres having an average diameter of 8  $\mu\text{m}$ .

As in the case of substrate B, the volume percentages of water contained in each layer of substrate C are evaluated after a period of natural drainage of 10 minutes. The results are indicated in the following 25 table.

| Substrate | Layers | Fibre Diameter    | Water retention(%) |
|-----------|--------|-------------------|--------------------|
| 30        | 1      | 4 $\mu\text{m}$   | 97.7               |
|           | 2      | 5,6 $\mu\text{m}$ | 92.4               |
|           | 3      | 8 $\mu\text{m}$   | 93.5               |
|           | 4      | 8 $\mu\text{m}$   | 97.6               |

It is established that substrate C is distinguished from substrate B in that it includes in layer (2) fibres of smaller diameter ( $5.6\text{ }\mu\text{m}$  instead of  $8\text{ }\mu\text{m}$  in substrate B). In substrate C, the average diameter 5 of the fibres increases in the direction of gravity, in accordance with the invention. It is noted that by using such a substrate, a hydroretention is obtained which is approximately constant over the whole thickness of the substrate.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A substrate for soil-free culture of plants formed from a felt of mineral fibres, suitable for the supply of water or an aqueous nutrient solution to the plants, wherein the substrate comprises a heterogeneous fibrous structure displaying a hydroretentivity gradient such that the hydroretentivity decreases in the direction of gravity.
2. A substrate according to Claim 1, in which the hydroretentivity gradient is achieved by means of a density gradient over the thickness of the mineral fibre felt.
3. A substrate according to Claim 1, in which the hydroretentivity gradient is achieved by means of a gradient in the fineness of the fibres across the thickness of the felt of mineral fibres.
4. A substrate according to Claim 1, in which the hydroretentivity gradient is achieved by means of gradients in density and fineness across the thickness of the felt mineral fibres.
5. A substrate according to Claim 3 or 4, in which the diameter of the fibres increases in the direction of gravity.
6. A substrate according to any one of Claims 3 to 5, in which the average diameter of the fibres is between 2 and 12  $\mu\text{m}$ .
7. A substrate according to Claim 2 or 4, in which the density decreases in the direction of gravity.
8. A substrate according to any one of Claims 2, 4 or 7, in which the density is between 15 and 60  $\text{kg/m}^3$ .
9. A substrate according to Claim 6, comprising in its upper part fibres of an average diameter between 2  $\mu\text{m}$  and 5  $\mu\text{m}$ .
10. A substrate according to Claim 8, having in its upper part, a density between 30 and 60  $\text{kg/m}^3$ .
11. A substrate according to any one of Claims 1 to 10, in which there are several layers of fibres.
12. A substrate according to any one of Claims 1 to 11, comprising glass fibres.
13. A substrate for soil-free culture of plants substantially as hereinbefore described with reference to any



one of the foregoing examples.

14. A substrate for soil-free culture of plants substantially as hereinbefore described with reference to any one of the accompanying drawings.

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Dated this 12th day of September, 1991

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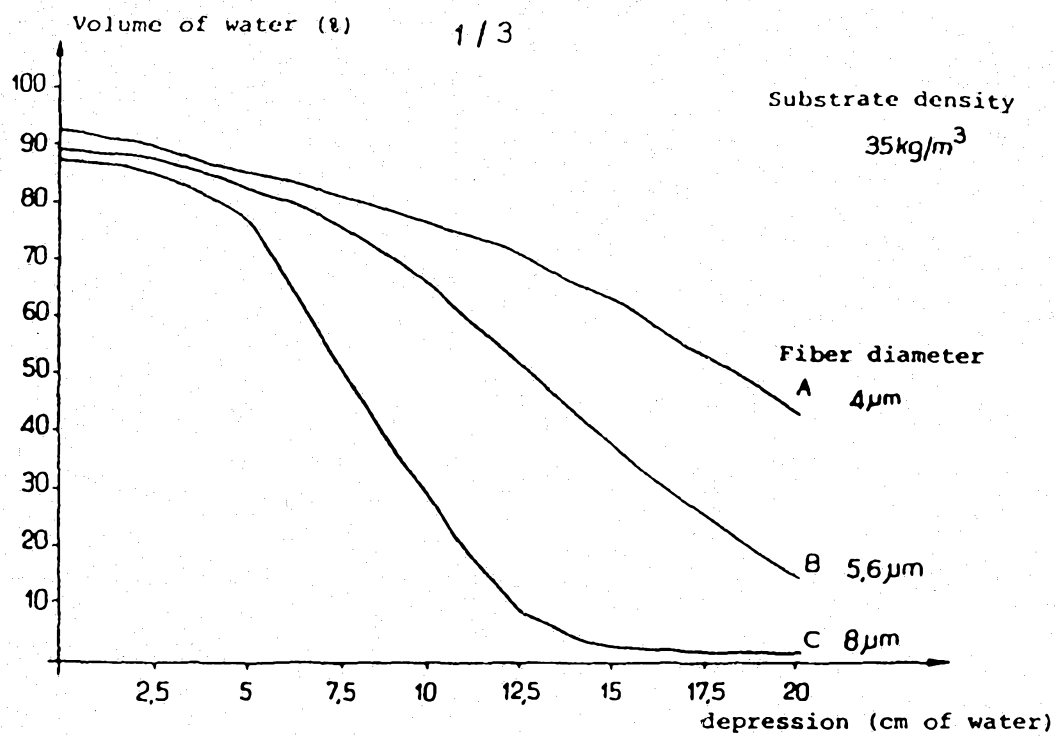


FIG. 1

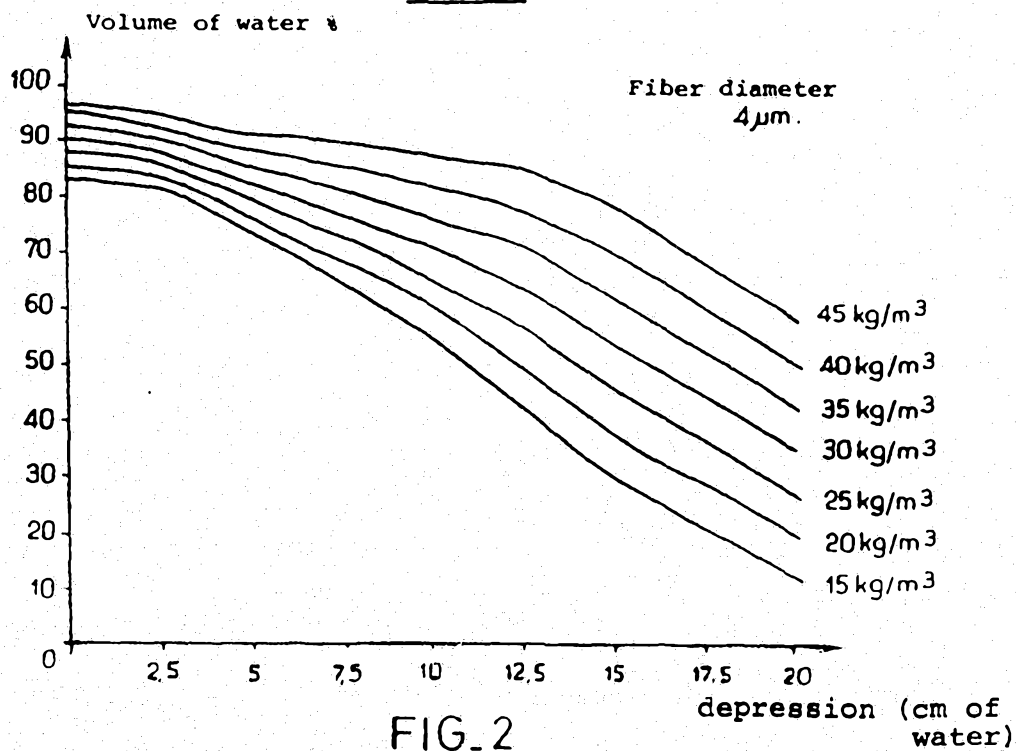
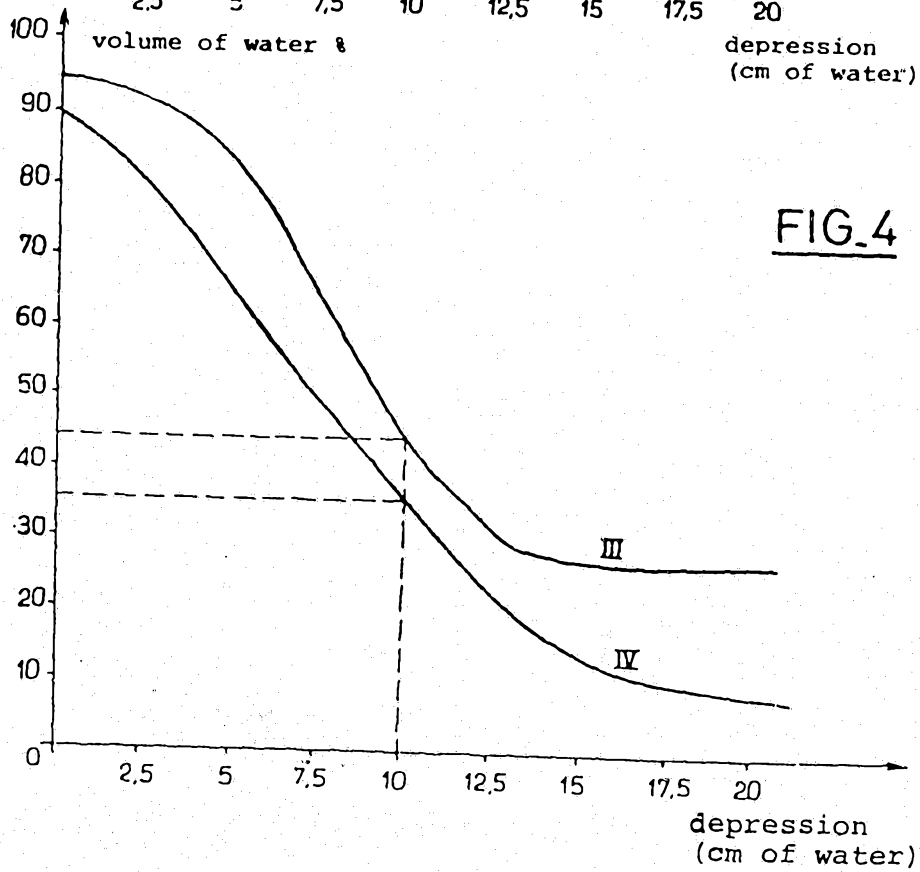
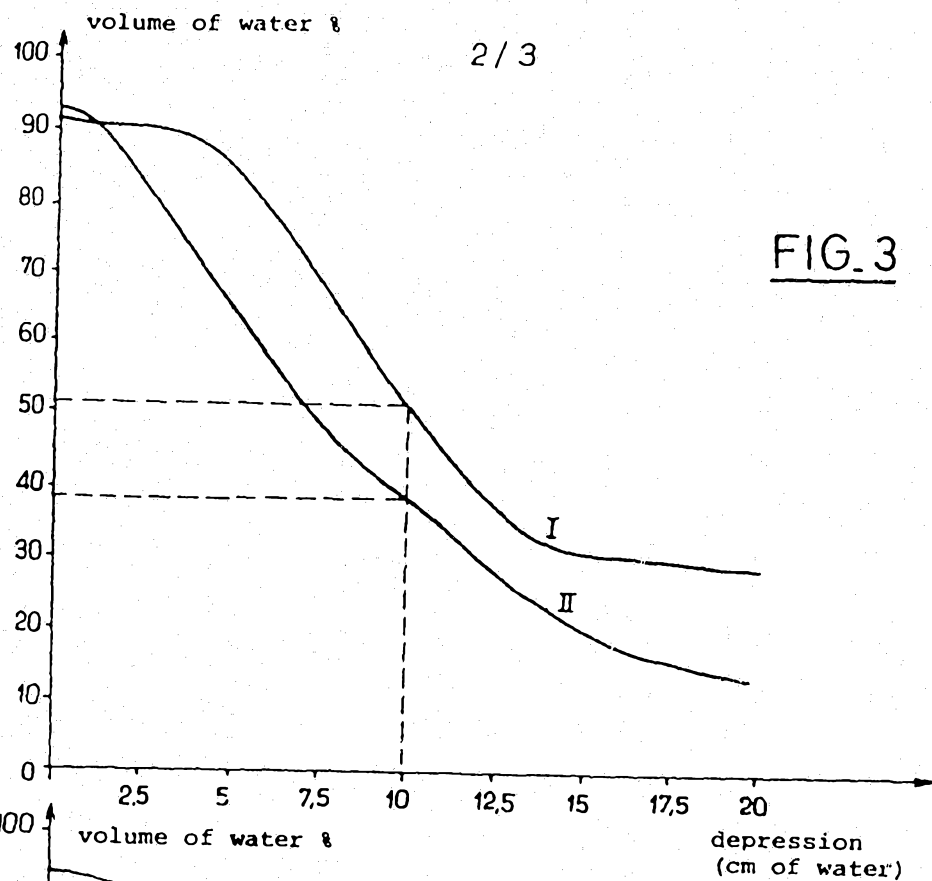


FIG. 2



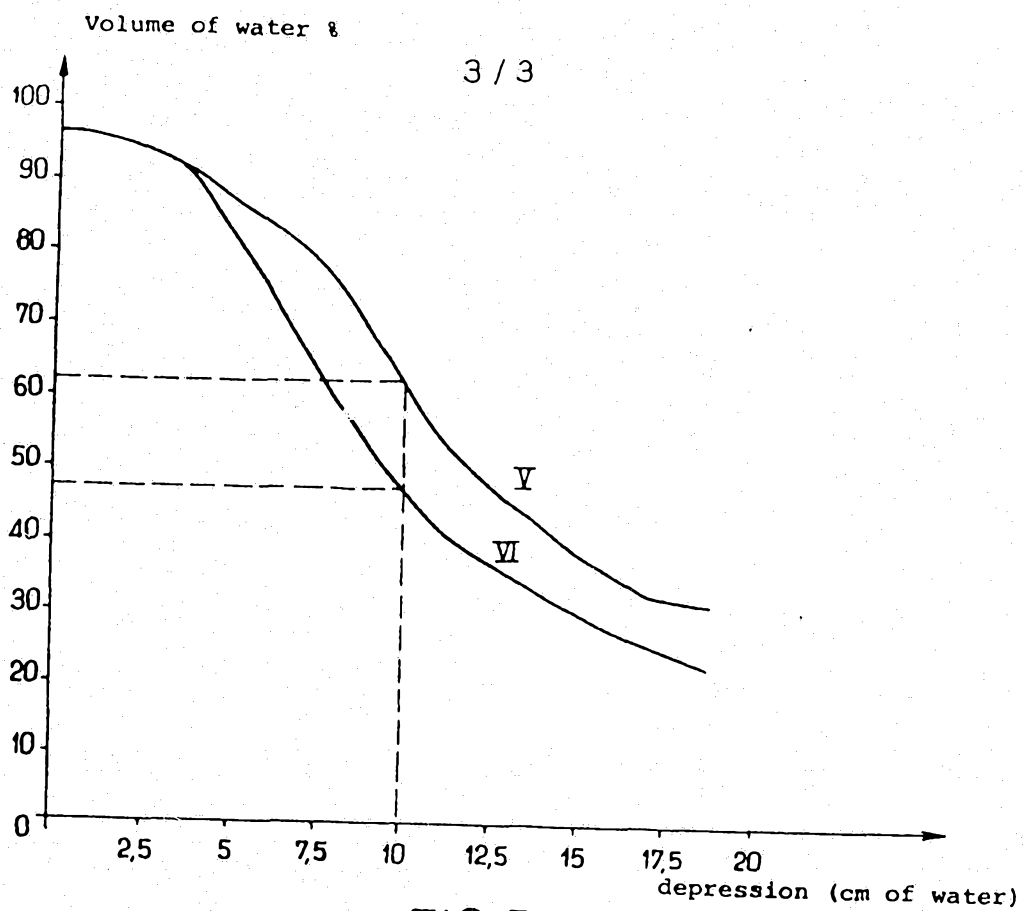


FIG. 5

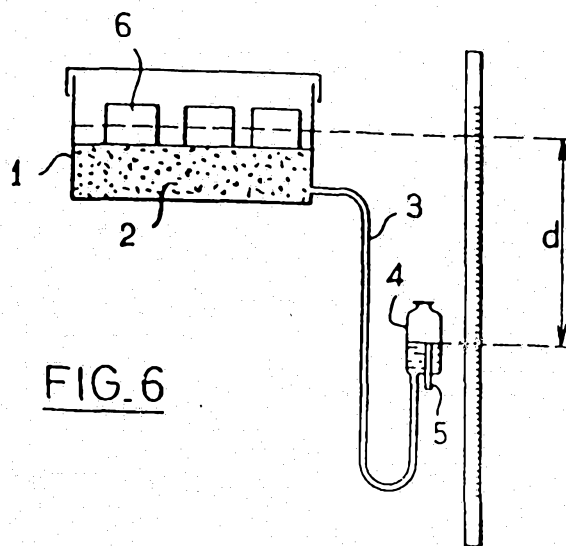


FIG. 6