

PLANT GROWTH PROMOTER

BACKGROUND

1. Technical Field

5 **[0001]** The present disclosure relates to a plant growth promoter for promoting plants' growth by applying an electric field to roots of the plants in hydroponic culture, and a technique for realizing a reduction in the cost of cultivating plants by miniaturizing a power supply that applies the electric field.

10 2. Description of the Related Art

[0002] Plant cultivation by hydroponic culture has become an important technique to solve food problems in recent years. Plant cultivation by hydroponic culture can be controlled in a controlled space of a factory or the like, but in order to disseminate the hydroponic culture, it is essential to reduce the
15 cost of growing plants by shortening cultivation period or reducing operation running costs such as equipment depreciation expenses.

[0003] In order to shorten the cultivation period, apparatuses for promoting cultivation by giving electrical stimulation to the roots of plants via culture solution used in hydroponic culture are known (for example, Yamada, "Growth
20 Control of Lettuce by Pulsed Electric Field Aiming at Application to Plant Factory", Basic Conference of Electrical Engineers of Materials and Common Division, March, 2015, see p.325).

[0004] FIG. 7 is a diagram showing the structure of a plant growth promoter in the related art. In FIG. 7, panel 51 on which plant 50 is disposed
25 is placed in cultivation container 53 containing culture solution 52, an electric field is generated between parallel plate electrodes 55 output from power supply 54, and electric stimulation is given to the roots of plant 50 via culture

solution 52.

SUMMARY

[0005] To achieve the above object, the plant growth promoter according to
5 one aspect of the disclosure includes a container for placing the roots of a plant
in culture solution for cultivating the plant, a circulator for circulating the
culture solution, a power supply for applying a voltage, at least a pair of
electrodes disposed opposite to each other for applying the voltage by the power
supply in the culture solution, and a voltage controller for controlling applying
10 of the voltage. The pair of electrodes have no moving part at a part in contact
with the roots of the plant, and at least one of the pair of electrodes applies a
voltage in a direction of water flow in which the culture solution circulates by
the circulator while sequentially changing an application area.

[0006] With this configuration, it is possible to apply an electric field with
15 small current and low voltage without stressing the roots with scratches or
breaks.

[0007] Therefore, according to the plant growth promoter according to the
above aspect of the disclosure, it is possible to promote growth of the plant with
a compact power supply of small current and low voltage, thereby reducing
20 facility cost. In addition, since it is possible to narrow the space between the
electrodes, it is possible to reduce the amount of the culture solution.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a configuration diagram of a plant growth promoter of a
25 first exemplary embodiment;

FIG. 2 is a configuration diagram of a plant growth promoter of a
second exemplary embodiment;

FIG. 3 is a configuration diagram of a plant growth promoter according to a third exemplary embodiment;

FIG. 4A is a diagram for explaining an operation of the plant growth promoter according to the third exemplary embodiment;

5 FIG. 4B is a diagram for explaining an operation of the plant growth promoter according to the third exemplary embodiment;

FIG. 4C is a diagram for explaining an operation of the plant growth promoter according to the third exemplary embodiment;

10 FIG. 5A is a diagram for explaining an application example of the plant growth promoter according to the third exemplary embodiment;

FIG. 5B is a diagram for explaining an application example of the plant growth promoter according to the third exemplary embodiment;

FIG. 6 is a configuration diagram of a plant growth promoter according to a fourth exemplary embodiment; and

15 FIG. 7 is a diagram showing a configuration of a plant growth promoter in the related art.

DETAILED DESCRIPTION

[0009] Prior to the description of exemplary embodiments, problems in the related art will be briefly described.

[0010] It is effective to reduce the distance between one electrode and another electrode in order to reduce a power supply designed for small current and lower voltage in a promoter that promotes growth of a plant by giving an electric field to the roots of the plant in hydroponic culture. However, when
25 the electrode is miniaturized, it is impossible to apply an electric field to the entire roots.

[0011] Here, in the plant growth promoter shown in FIG. 7, it is possible to

apply an electric field to the entire roots by moving electrodes. However, as an electrode moves in the area where the roots are present, the electrode strikes the roots, causing breaks or scratches of the roots.

[0012] An object of the disclosure is to provide a plant growth promoter which can promote growth with a compact power supply of small current and low voltage and can reduce facility cost.

[0013] Hereinafter, an exemplary embodiment will be described with reference to the drawings.

10 Exemplary Embodiment

[0014] FIG. 1 is a block diagram of the plant growth promoter of the first exemplary embodiment, and the configuration of the plant growth promoter will be described below.

[0015] In FIG. 1, the roots of plant 101 are present in container 104 containing culture solution 103 via panel 102, and culture solution 103 circulates in the direction of water flow 106 in circulator 105. At this time, a pair of sequential electric field area variable type electrodes 107 (an example of a pair of electrodes according to the disclosure) are disposed opposite to each other in the same direction as water flow 106 of culture solution 103, and give electrical stimulation to the roots of plant 101 being present in electric field application area 108 between the sequential electric field area variable type electrodes 107 disposed opposite to each other, using power supply 109. Further, sequential electric field area variable type electrode 107 can apply an electric field while changing electric field application area 108 in the direction of water flow 106 in which culture solution 103 circulates by controller 110. In FIG. 1, both sequential electric field area variable type electrodes 107 opposed to the roots of plant 101 are controlled by controller 110, but among the pair of

electrodes, one of sequential electric field area variable type electrodes 107 may be controlled by controller 110, and the other opposing electrode may be a simple conductor flat plate. In this case, although the uniformity of the electric field applied to electric field application area 108 is lower than in the case of controlling both sequential electric field area variable type electrodes 107, it is a simple structure and it is possible to further reduce the facility cost.

[0016] FIG. 2 is a configuration diagram of the plant growth promoter according to the second exemplary embodiment. FIG. 2 is a promoter that performs area variable control of sequential electric field area variable type electrode 107 in FIG. 1 by mechanical electrode movement. In FIG. 2, using the controller 110, a pair of small electrodes 111(an example of a pair of electrodes according to the present disclosure) are moved by electrode moving mechanism 112 in a direction of electrode moving direction 113 parallel to water flow 106 in which culture solution 103 circulates, thereby applying an electric field while changing electric field application area 108. At this time, fixed plate 114 is disposed between small electrode 111 and plant 101. Fixed plate 114 described in FIG. 2 is described in a form in which conductor 114a is divided by insulator 114b. In a case where culture solution 103 is present between small electrode 111 and fixed plate 114, since small electrode 111 and conductor 114a of fixed plate 114 conduct through culture solution 103, in order to promote plant growth, it is not necessary to bring small electrode 111 and fixed plate 114 into contact with each other at the timing of applying an electric field to small electrode 111. Of course, small electrode 111 and fixed plate 114 may be brought into contact with each other. Further, in order to promote plant growth, at the timing of applying an electric field to small electrode 111, it is necessary to dispose the plane of small electrode 111 at a position opposed to the plane of conductor 114a of fixed plate 114. As in the first exemplary

embodiment, only one small electrode 111 of the pair of electrodes may be moved by electrode moving mechanism 112, and the other opposing electrode may be a simple conductor flat plate.

[0017] In fixed plate 114, in a case the conductivity of fixed plate 114 is equal to or more than twice the culture solution, as shown in FIG. 2, fixed plate 114 needs to be divided into a plurality of sections by insulator 114b. This is because when the conductivity of fixed plate 114 is high, the amount of current flowing through conductor 114a of fixed plate 114 increases. In other words, even in a case where the conductivity of fixed plate 114 is equal to or more than twice the conductivity of the culture solution, if fixed plate 114 is divided into a plurality of sections by insulator 114b, the above problem can be alleviated. Further, fixed plate 114 needs to have conductivity of 0.5 times or more the conductivity of culture solution 103. This is because the loss at fixed plate 114 increases as the conductivity is low. That is, by making the conductivity of fixed plate 114 equal to or more than 0.5 times the conductivity of culture solution 103, the loss at fixed plate 114 can be reduced. In a case where the conductivity of fixed plate 114 is in the range of 0.5 to 2 times the conductivity of culture solution 103, the electrical resistance of fixed plate 114 can be regarded as almost equivalent to the electrical resistance of culture solution 103, so fixed plate 114 does not need to be divided by an insulator.

[0018] FIG. 3 is a configuration diagram of the plant growth promoter according to the third exemplary embodiment. FIG. 3 is a plant growth promoter that enables electrode moving mechanism 112 in FIG. 2 by crawler mechanism 115. In FIG. 3, using controller 110, small electrode 111 is moved by crawler mechanism 115 in electrode moving direction 113 parallel to water flow 106 in which culture solution 103 circulates, applying an electric field while changing electric field application area 108. At this time, as shown in

FIG. 3, a rotation plane including roller rotation direction 117 of roller 116 in crawler mechanism 115 is perpendicular to a main surface of small electrode 111. That is, in the third exemplary embodiment, a mechanism for moving the electrode is crawler mechanism 115, the rotation plane of roller 116 in crawler
5 mechanism 115 is perpendicular to the main surface of small electrode 111, and a voltage is applied between two rollers 116 in crawler mechanism 115 by small electrode 111.

[0019] FIGS. 4A to 4C are diagrams for explaining an operation of the plant growth promoter according to the third exemplary embodiment. FIG. 4A is a
10 timing chart for explaining the operation. FIG. 4B is a diagram for explaining a position of small electrode 111 when the time is 0 second in FIG. 4A, and FIG. 4C is a diagram for explaining a position of small electrode 111 when the time is 2,000 seconds in FIG. 4A. In the case of FIGS. 4A to 4C, an electric field is applied by moving small electrode 111 in the direction of electrode moving
15 direction 113 with respect to the four rows of plant A row 118, plant B row 119, plant C row 120, and plant D row 121 using five crawler mechanisms 115. In plant 101, an electric field is applied to four rows of plant α row 122, plant β row 123, plant γ row 124, and plant δ row 125, which are orthogonal to electrode moving direction 113. 16 heads of plant 101 (4 rows $\times$ 4 rows) are subjects.

20 **[0020]** In addition, small electrode 111 divides one head of plant 101 into five areas and performs application operation. Small electrode 111 applies 100 shots (1 Hz) per area to promote growth of the plants, and moves in less than 1 second.

[0021] Now, the operation of small electrode 111 in FIGS. 4A to 4C will be
25 described. The operation of small electrode 111 is described in the timing chart shown in FIG. 4A. First, at the time 0 second which is immediately after the start, small electrode 111 is present at the position shown in FIG. 4B. As

shown in FIG. 4B, small electrode 111 applies 100 shots (1 Hz) to at the positions of plant A row 118, plant C row 120, plant α row 122 to promote growth of the plants. Small electrode 111 moves after 100 seconds after application of 100 shots is ended. Since the movement of small electrode 111 is possible in less than 1 second, and the electric field is applied to 5 areas for each head of plant 101, the application of the electric field to one head of plant 101 is ended after 500 seconds, and small electrode 111 moves to plant β row 123. After 1,000 seconds, small electrode 111 moves to plant γ row 124, and after 1,500 seconds, small electrode 111 moves to plant δ row 125. After 2,000 seconds, application of the electric field of plant A row 118 and plant C row 120 is ended, small electrode 111 moves to the opposite side of crawler mechanism 115, and small electrode 111 moves to the position shown in FIG. 4C. As shown in FIG. 4C, small electrode 111 is present at positions of plant B row 119, plant D row 121, and plant δ row 125. After 2,500 seconds, small electrode 111 moves to plant γ row 124, small electrode 111 moves to plant β row 123 after 3,000 seconds, and small electrode 111 moves to plant α row 122 after 3,500 seconds. After 4,000 seconds, application of the electric field of plant B row 119 and plant D row 121 is ended, and a series of operations are ended.

[0022] FIGS. 5A and 5B are diagrams for explaining an application example of the plant growth promoter according to the third exemplary embodiment. FIG. 5A is a diagram for explaining an example in which electrodes of all rows move, and FIG. 5B is a diagram for explaining an example in which one side electrodes are fixed. In FIG. 5A, there are five crawler mechanisms 115, whereas in FIG. 5B, only one small electrode 111 of the pair of electrodes is moved by crawler mechanism 115, the other opposing electrode is configured as a simple conductor flat plate, and only two crawler mechanisms 115 are sufficient. Therefore, the facility cost can be reduced.

[0023] FIG. 6 is a configuration diagram of the plant growth promoter according to the fourth exemplary embodiment. FIG. 6 shows a plant growth promoter that performs the area variable control shown in FIG. 1 by switch 126. In FIG. 6, conductor electrode 127 (an example of an electrode related to the disclosure) is divided into a plurality of sections by insulator 128, and installed in a manner to sandwich the roots of plant 101 in parallel with water flow 106 in which culture solution 103 circulates. Controller 110 is used to connect to conductor electrode 127 at switch 126. In other words, conductor electrode 127 is divided into a plurality of sections by insulator 128, and switch 126 is provided between each divided section of conductor electrode 127 and power supply 109. A plurality of switches 126 are provided corresponding to each of conductor electrodes 127 divided into a plurality of sections. By sequentially switching the connection of switch 126, an electric field is applied while changing electric field application area 108.

[0024] Only one conductor electrode 127 of the pair of electrodes may be divided into a plurality of sections by insulator 128 and the other opposing electrode may be a simple conductor flat plate.

[0025] With the plant growth promoter described above, it is possible to promote growth of plants with a compact power supply of small current and low voltage, and it is possible to reduce facility cost. In addition, since it is possible to narrow the space between the electrodes by the water flow in which culture solution 103 circulates, the amount of culture solution 103 can be reduced. For example, when lettuce is cultivated by hydroponics, the cultivation spacing is set to 15 cm, and in comparison with the case where the distance between the electrodes is set to 15 cm and the electrode width is set to 15 cm for one head of lettuce in the related art, according to any of the above exemplary embodiments, distance between the electrodes can be 3 cm which is

1/5 of the conventional one, electrode width can also be 3 cm which is 1/5 of the conventional one, a voltage can be 1/5 of the conventional one, current can be also 1/5 of the conventional one, and as electric power, a power supply of 1/25 can be used as compared with the conventional one.

- 5 In addition, in the space of 15 square cm which is a lettuce cultivation area, the usage of culture solution is proportional to the distance between the electrodes, which is a maximum of 1/5. By using any of the above exemplary embodiments, although the direction perpendicular to the water flow in which the culture solution circulates narrows the space in which the roots of the plant
- 10 can be present, since the direction of the water flow in which the culture solution circulates impose no physical restriction on the roots, plant cultivation becomes possible without giving stress to the roots and without hindering circulation of the culture solution.

- [0026]** Any embodiment or modification example of the above-described
- 15 various embodiments or modification examples may be appropriately combined to achieve the respective effects. In addition, combinations of the embodiments, combinations of the examples, or combinations of the embodiments and the examples are possible, and combinations of features in different embodiments or examples are also possible.

- 20 **[0027]** According to the plant growth promoter according to the above aspect of the disclosure, it is possible to apply an electric field with small current and low voltage without stressing the roots such as scratches or breaks. Accordingly, it is possible to reduce the size of the power supply, and it is possible to reduce the facility cost. In addition, by reducing the distance
- 25 between the electrodes, it is possible to reduce the amount of the culture solution. Generally, in cultivation containers used in hydroponic culture, the water flow direction generated by circulating the culture solution is long and

the orthogonal direction is shortened in dimension. In the plant growth promoter according to the above aspect of the disclosure, switching of the electric field area is performed in a direction in which the cultivation container, which is in the direction of the water flow, has a long dimension, and therefore
5 practical development thereof is easy. Since current can be reduced, safety measures are also easier, and the introduction of growth promotion technique by electric stimulation to hydroponic culture is accelerated. In this way, it is possible to shorten the cultivation period in hydroponic culture, reduce plant cultivation cost, and contribute to solving food problems worldwide.

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WHAT IS CLAIMED IS:

1. A plant growth promoter comprising:
 - a container for placing roots of a plant in culture solution for cultivating
 - 5 the plant;
 - a circulator for circulating the culture solution;
 - a power supply for applying a voltage;
 - at least a pair of electrodes disposed opposite to each other for applying
 - the voltage by the power supply in the culture solution; and
 - 10 a controller that controls applying of the voltage,
 - wherein the pair of electrodes have no moving part at a part in contact
 - with the roots of the plant, and at least one of the pair of electrodes applies a
 - voltage in a direction of water flow in which the culture solution circulates by
 - the circulator while sequentially changing an application area.
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2. The plant growth promoter of Claim 1, further comprising:
 - a mechanism that moves at least one of the pair of electrodes in the
 - direction of water flow in which the culture solution circulates; and
 - a fixed plate disposed between the pair of electrodes and the roots of the
 - 20 plant and made of a conductive material,
 - wherein the fixed plate has conductivity of 0.5 times or more
 - conductivity of the culture solution.
3. The plant growth promoter of Claim 2,
 - 25 wherein the fixed plate has conductivity of twice or more conductivity of
 - the culture solution, and
 - the fixed plate is divided into a plurality of sections by an insulator.

4. The plant growth promoter of Claim 2 or 3,

wherein the mechanism that moves at least one of the pair of electrodes is a crawler mechanism, and a rotation plane of each of rollers in the crawler
5 mechanism is perpendicular to a main surface of the pair of electrodes, and a voltage is applied between two rollers of the rollers in the crawler mechanism by the pair of electrodes.

5. The plant growth promoter of Claim 1,

10 wherein at least one of the pair of electrodes is divided into a plurality of sections by an insulator, and a switch is provided between each divided section of the at least one of the pair of electrodes and the power supply.