

PLANT GROWTH PROMOTER AND METHOD

BACKGROUND

1. Technical Field

5 **[0001]** The present disclosure relates to a plant growth promoter and a method for promoting growth of plants by applying an electric field to the roots of the plants in hydroponic culture.

2. Description of the Related Art

10 **[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 cost of cultivating plants by shortening cultivation period or reducing operation running costs.

15 **[0003]** In order to shorten the cultivation period, apparatuses for promoting growth by applying an electric field to the roots of plants via culture solution used in hydroponic culture are known (for example, Yamada, "Growth Control of Lettuce by Pulsed Electric Field Aiming at Application to Plant Factory", Basic Conference of Electrical Engineers of Materials and Common Division, 20 September 2015, see p.325). FIG. 6 is a diagram showing the structure of a plant growth promoter in the related art. In FIG. 6, panel 51 on which plant 50 is disposed is placed in cultivation container 53 containing culture solution 52, a voltage is applied by connecting power supply 54 and a pair of electrodes 55 to each other, and an electric field is applied to the root of plant 50 via 25 culture solution 52.

SUMMARY

[0003a] According to an aspect of the present disclosure, there is provided a plant growth promoter comprising:

a container that contains culture solution for cultivating a plant;

electrodes that are divided into a plurality and disposed opposite to
5 each other in the container;

a power supply that applies a voltage to the electrodes; and

a current measurer that measures a current value between the
electrodes,

wherein the plant growth promoter further includes a voltage
10 application controller that applies a voltage to a part of the electrodes that are
divided into a plurality and disposed opposite to each other, determines
presence or absence of roots of the plant based on a current value between the
electrodes to which the voltage is applied, and applies a voltage of promoting
growth of the plant in a case where the roots of the plant are present.

15 [0003b] According to an aspect of the present disclosure, there is provided a
method for promoting growth of a plant for in which an electric field is applied
to roots of the plant, the method comprising:

a step of applying a voltage to a part of electrodes that are divided into a
plurality and disposed opposite to each other in a container in which a culture
20 solution for cultivating the plant is contained,

a step of determining presence or absence of the roots of the plant based
on a current value between the electrodes to which the voltage is applied, and

a step of applying a voltage of promoting growth of the plant while
sequentially switching connection to each of the electrodes, in a case where the
25 roots of the plant are present.

[0004] A plant growth promoter according to an embodiment of the present
disclosure includes a container that contains culture solution for

cultivating a plant, a pair of electrode groups that are disposed opposite to each other in the container and have a plurality of electrodes, and a power supply that applies a voltage between the pair of electrode groups, a current measurer that measures a current value between the pair of electrode groups, and a
5 voltage application controller that applies a voltage between a part of the plurality of electrodes, determines presence or absence of roots of the plant based on a current value between the part of electrodes to which the voltage is applied, and apply a voltage of promoting growth of the plant in a case where the roots of the plant are present.

10 [0005] In addition, a method for promoting growth of a plant according to another embodiment of the present disclosure is a plant growth promoting method for in which an electric field is applied to roots of the plant, in which the method includes applying a voltage between a part of electrodes among a pair of electrode groups that are disposed opposite to each other in a container in
15 which a culture solution for cultivating the plant is contained and have a plurality of electrodes, determining presence or absence of the roots of the plant based on a current value between the part of electrodes to which the voltage is applied, and applying a voltage of promoting grow of the plant while sequentially switching connection to each of the plurality of electrodes in a case
20 where the roots of the plant are present.

[0006] According to the plant growth promoter and the method according to the embodiments of the present disclosure, it is possible to promote growth of plants by energy saving, and reduce running cost. Further, since a voltage can be applied by switching the electrodes, the current flowing through the pair of
25 electrodes can be reduced. In this way, it is possible to reduce the size of the

power supply, and reduce facility cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a configuration diagram of a plant growth promoter
5 according to an exemplary embodiment;

FIG. 2 is a flowchart showing an operation of the plant growth promoter according to the exemplary embodiment;

FIG. 3 is an electrode configuration diagram in a case where an electrode group is evenly divided in the plant growth promoter according to the
10 exemplary embodiment;

FIG. 4 is an electrode configuration diagram in a case where an electrode group is unevenly divided in the plant growth promoter according to the exemplary embodiment;

FIG. 5A is a diagram showing an example of a current waveform when
15 current is measured in a state in which roots are not present in the plant growth promoter according to the exemplary embodiment;

FIG. 5B is a diagram showing an example of a current waveform when the current is measured in a state in which roots are present in the plant growth promoter according to the exemplary embodiment; and

20 FIG. 6 is a diagram showing a configuration of a plant growth promoter in the related art.

DETAILED DESCRIPTION

[0008] Prior to the description of exemplary embodiments, problems in the
25 related art will be briefly described.

[0009] In the plant growth promoter shown in FIG. 6, the roots are present unevenly in an electric field application area in the culture solution, but an

electric field is applied to the portion where the roots are not present, and energy is wasted. The waste of energy is directly linked to an increase in running cost, and energy saving by applying an efficient electric field becomes a big problem.

5 **[0010]** An object of the present disclosure is to solve the above problem by providing a plant growth promoter and a method capable of promoting growth of plants by saving energy and reducing running cost.

[0011] Hereinafter, an exemplary embodiment will be described with reference to the drawings.

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Exemplary Embodiment

[0012] FIG. 1 is a configuration diagram of the plant growth promoter according to the exemplary embodiment, and the configuration of the plant growth promoter will be described below.

15 **[0013]** The plant growth promoter includes container 103, electrode group 115, power supply 104, current measurer 108, and voltage application controller 109.

[0014] In container 103, culture solution 102 for cultivating plant 101 is placed.

20 **[0015]** The plant growth promoter is provided with two electrode groups 115 corresponding to a positive electrode and a negative electrode. Here, two electrode groups 115 correspond to a pair of electrodes relating to the present disclosure.

[0016] Each of two electrode groups 115 includes a plurality of electrodes
25 105. In other words, each of two electrode groups 115 is divided into a plurality of electrodes 105. For example, in FIG. 1, each of two electrode groups 115 includes four electrodes 105. In other words, each of two electrode

groups 115 is divided into four electrodes 105.

[0017] In FIG. 1, the sizes of the plurality of electrodes 105 are equal to each other. In other words, in FIG. 1, two electrode groups 115 are equally divided.

5 [0018] Two electrode groups 115 are disposed opposite to each other in container 103. That is, the plurality of electrodes 105 constitutes a plurality of pairs of electrodes disposed opposite to each other. For example, in FIG. 1, the plurality of electrodes 105 constitute four pairs of electrodes.

[0019] Power supply 104 applies a voltage between two electrode groups
10 115. That is, power supply 104 applies a voltage between the plurality of electrodes 105 having two electrode groups 115.

[0020] Current measurer 108 measures a current value between two electrode groups 115. That is, current measurer 108 measures a current value between the plurality of electrodes 105 having two electrode groups 115.

15 [0021] Voltage application controller 109 applies a voltage to a part of electrode group 115 (that is, a part of the plurality of electrodes 105) divided into a plurality of electrodes and disposed opposite to each other, determines presence or absence of root 101a of plant 101 based on the current value between electrodes 105 to which a voltage is applied, and applies a voltage for
20 promoting growth of the plant in a case where root 101a of plant 101 is present.

[0022] In FIG. 1, root 101a of plant 101 is present in container 103 containing culture solution 102, and it is possible to apply an electric field necessary for promoting growth of the plant via electrode 105 in culture solution 102 by power supply 104. A plurality of sets of the plurality of
25 electrodes 105 are disposed opposite to each other. Electrode group 115 is divided into a plurality of electrodes 105 by insulator 106. At this time, in order to effectively apply an electric field to electric field application area 110

formed between electrode 105 and opposing electrode 105, inter-electrode distance L3 with opposing electrode 105 is set to be longer than 0 cm and not more than five times the length of the short side of electrode 105. Here, the short side of electrode 105 is a shorter side of electrode lateral width L1 and
5 electrode height L2 of electrode 105.

[0023] In a case where inter-electrode distance L3 is extremely small as compared with the length of the short side of electrode 105, the electric field between the electrodes can be considered to be uniform. However, in a case where inter-electrode distance L3 becomes too large as compared with the
10 length of the short side of electrode 105, the electric field is not uniform. In general, in an electrostatic field, the distribution of electric field intensity can be obtained by using Poisson equation, as a preferable condition under which a uniform electric field can be applied, inter-electrode distance L3 with respect to opposing electrode 105 is set to be longer than 0 cm and not more than 5 times
15 the length of the short side of electrode 105. In other words, it is preferable that two electrode groups 115 are opposed to each other with a distance of more than 0 cm and not longer than 5 times the length of the short side of electrode 105.

[0024] In addition, electrode switching unit 107 enables opening and closing
20 of a plurality of electric paths between electrode 105 and power supply 104, respectively, by the operation of electrode switching unit 107, by closing the electrical path only of a pair of electrode switching unit 107 to which the opposing pair of electrodes 105 and power supply 104 are connected and opening the other electrode switching unit 107, it is possible to apply an electric
25 field only to the electric field application area formed between the pair of electrodes 105. By switching electrode switching unit 107, it is possible to switch the electric field application area. In addition, current measurer 108

can measure the current value flowing in the electric field application area between electrodes 105. By measuring the current value, it is possible to determine whether or not root 101a of plant 101 is present in the electric field application area, and it is possible to control not to apply a voltage by power supply 104 in a case where root 101a is not present. This control is performed by voltage application controller 109 connected to power supply 104 and current measurer 108. In FIG. 1, electrode switching unit 107 is also controlled by voltage application controller 109.

[0025] Next, the operation of the plant growth promoter in FIG. 1 will be described with reference to the flowchart in FIG. 2. In FIG. 2, the operation of detecting presence or absence of root 101a of plant 101 between electrodes 105 and applying a voltage to electrode 105 which detects presence or absence of root 101a will be described.

[0026] First, in step S101, voltage application controller 109 is used to control electrode switching unit 107, and a part of electrode group 115 (that is, a part of the plurality of electrodes 105) divided into a plurality of electrodes and disposed opposite to each other, for example, a pair of electrodes 105 and power supply 104 are connected.

[0027] Next, in step S102, power supply 104 is controlled to apply a voltage waveform for detecting of presence or absence of a root.

[0028] Next, in step S103, the current between the pair of electrodes 105 is measured by current measurer 108.

[0029] Next, in step S104, the presence or absence of root 101a of plant 101 between the pair of electrodes 105 to which a voltage is applied by voltage application controller 109 is determined based on the current value of current measurer 108. In a case where it is determined that there is a root, a voltage for promoting grow of the plant growth is applied by power supply 104 in step

S105. The current value used for the determination will be described in detail with reference to FIGS. 5A and 5B. Thereafter, the process proceeds to step S106. If it is determined that there is no root, step S105 is not performed, and voltage application is ended in step S106.

5 [0030] Next, in step S107, voltage application controller 109 selects another pair of electrodes 105 to which a voltage is not applied yet.

[0031] In step S108, voltage application controller 109 determines whether or not application of a voltage to all electrodes 105 has ended. If the application of a voltage has not ended, the process returns to step S101, and
10 sequential connections are switched and a voltage is applied until the application of the voltage to all electrodes 105 is ended.

[0032] At this time, in the connection between the pair of electrodes 105 and power supply 104 in step S101, two or more pairs of electrodes 105 and power supply 104 may be connected at the same time as long as a pair of electrodes
15 whose distances therebetween are far apart enough not to erroneously determine the detection of root 101a.

[0033] Further, the voltage waveform for detecting presence or absence of a root in step S102 may be a DC constant voltage or a pulse waveform.

[0034] Furthermore, the voltage waveform in step S105 may be a DC
20 constant voltage or a pulse waveform.

[0035] In addition, the voltage application in step S102 or step S105 is preferable because the composition of culture solution 102 is not changed as long as the waveform does not cause electrolysis of culture solution 102. Specifically, if a voltage at which a theoretical limit voltage of water electrolysis,
25 1.23 V is not substantially involved, or is a short pulse waveform, since electrolysis of water does not occur, the composition of culture solution 102 is not changed.

[0036] Next, FIG. 3 shows an electrode configuration diagram in a case where electrode group 115 is evenly divided in the plant growth promoter of the present embodiment.

[0037] In a case where it is not possible to assume that root 101a of plant 101 is in advance or in a case where the probability of root 101a being present in each electrode 105 is unknown, it is preferable to divide electrode group 115 evenly. Here, as an example, electrode group 115 is evenly divided into four columns and five rows.

[0038] Next, FIG. 4 shows an electrode configuration diagram in a case where electrode group 115 is unevenly divided in the plant growth promoter of the present exemplary embodiment.

[0039] In a case where it is possible to assume that root 101a of plant 101 is present in advance or in a case where bias is assumed to the probability of root 101a being present in each electrode 105, it is preferable to divide electrode group 115 unevenly. For example, in a case where it is assumed that there is a high probability of root 101a of plant 101 being present on the first day when an electric field is applied, as in the case of first electrode 105a (an example of an electrode relating to the present disclosure), electrode group 115 is divided so as to have the size of the area where root 101a is present. Further, according to a process of growing plant 101, for an area assumed to have a probability of root 101a being present, electrode group 115 is divided into small sections as in second electrode 105b (an example of an electrode relating to the present disclosure). On the contrary, even if plant 101 fully grows, for an area assumed to have a low probability of root 101a being present, electrode group 115 is divided into large sections as in third electrode 105c (an example of an electrode relating to the present disclosure). That is, if electrode group 115 is unevenly divided in areas where the probability of root 101a being present is

large and small (if sizes of the plurality of electrodes 105 are made different from each other), it is possible to operate the plant growth promoter efficiently.

[0040] Next, FIGS. 5A and 5B show examples of current waveform 112 in a state where root 101a is not present in electric field application area 110 and
5 current waveform 112 in a state where root 101a is present in electric field application area 110 when voltage waveform 111 is applied to electrode 105 with the plant growth promoter in the exemplary embodiment. FIG. 5A is a diagram showing current waveform 112 in the state where root 101a is not present. FIG. 5B is a diagram showing current waveform 112 in the state
10 where root 101a is present. When comparing current waveform 112 in the state where root 101a is not present and current waveform 112 in the state where root 101a is present, it is understood that the current value decreases in current waveform 112 where root 101a is present, and presence or absence of root 101a can be detected.

15 [0041] With the plant growth promoter described above, it is possible to promote growth of the plant by saving energy and reduce running cost by applying an electric field only to the area where root 101a is present.

[0042] According to the above embodiment, it is possible to apply a voltage for promoting growth of the plant only between electrodes 105 where root 101a
20 is present by switching the plurality of electrodes 105, applying a voltage for detecting presence or absence of root 101a, and measuring the current value between electrodes 105. Therefore, it is possible to promote growth of the plant by saving energy and reduce running cost. Further, since electrode group 115 is divided and a plurality of electrodes 105 can be switched to apply a
25 voltage, the current flowing through the pair of electrodes 105 can be reduced. In this way, it is possible to reduce the size of power supply 104, and it is possible to reduce the facility cost.

[0043] Any embodiment or modification example of the above-described 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
5 embodiments and the examples are possible, and combinations of features in different embodiments or examples are also possible.

[0044] According to the plant growth promoter and the plant growth promoting method relating to the present disclosure, since the electrodes can be divided and switched to apply a voltage, the current flowing through a pair of
10 electrodes can be reduced. Accordingly, it is possible to reduce the size of the power supply, and it is possible to reduce the facility cost. Since current can be reduced, safety measures are also easier, and the introduction of growth promotion technique by voltage application to hydroponic culture is accelerated. In this way, it is possible to shorten the cultivation period in hydroponic culture,
15 suggest plant cultivation cost, and contribute to solving food problems worldwide.

WHAT IS CLAIMED IS:

1. A plant growth promoter comprising:

a container that contains culture solution for cultivating a plant;

electrodes that are divided into a plurality and disposed opposite to each other in the container;

a power supply that applies a voltage to the electrodes; and

a current measurer that measures a current value between the electrodes,

wherein the plant growth promoter further includes a voltage application controller that applies a voltage to a part of the electrodes that are divided into a plurality and disposed opposite to each other, determines presence or absence of roots of the plant based on a current value between the electrodes to which the voltage is applied, and applies a voltage of promoting growth of the plant in a case where the roots of the plant are present.

2. The plant growth promoter according to Claim 1, wherein the electrodes that are divided into a plurality are disposed opposite to each other with a distance of longer than 0 cm and not more than 5 times a length of a short side of each of the electrodes.

3. A method for promoting growth of a plant for in which an electric field is applied to roots of the plant, the method comprising:

a step of applying a voltage to a part of electrodes that are divided into a plurality and disposed opposite to each other in a container in which a culture

solution for cultivating the plant is contained,

a step of determining presence or absence of the roots of the plant based on a current value between the electrodes to which the voltage is applied, and

a step of applying a voltage of promoting growth of the plant while sequentially switching connection to each of the electrodes, in a case where the roots of the plant are present.