

METHOD AND DEVICES FOR CULTIVATING PLANTS

The invention relates to a method and a device for cultivating, in particular for rotation-mediated modification of, at least one plant which is rotated at least temporarily during a growth phase, wherein rotation takes place about a longitudinal axis or a transverse axis extending in the main direction of extension
5 of the plant.

For many years, various systems for automated plant cultivation have been known, which, particularly in recent decades, have become intensively used cultivation systems, especially for greenhouse crops such as tomatoes, cucumbers
10 and lettuce. The mass production of agricultural products in fully climate-controlled buildings under strict control of external influences is also referred to as so-called “indoor farming”.

In this context, AT 250728 discloses a special greenhouse designed in the form of a tower greenhouse in which the plants to be cultivated are moved during their
15 growth phase. An essential feature of the technical teaching described is that the height of a building is utilized in order to realize a conveying path for plant cultivation. The greenhouse described has a plurality of serpentine-arranged conveyor belts for transporting the plants, wherein the conveyor belt is designed as a circulating path and has upper and lower deflection rollers, so that the plants
20 can be moved vertically in different directions. Suitable fluorescent tubes are provided between the vertically arranged conveyor belts in order to ensure effective illumination.

A further technical teaching for automated plant cultivation is described in US 2012/0279122 A1. The described installation has a conveyor belt arranged in a serpentine manner and extending partially in the vertical direction. Corresponding deflection rollers are provided for deflecting the conveyor belt. Furthermore, special containers are provided for transporting the plants, in which carrier material for receiving seeds or plants is located and which are hooked into the circulating conveyor belt by means of special hook elements. The described containers for receiving the plants extend across the entire width of the conveyor belt and can each receive a plurality of plants next to one another.

Despite the increased energy demand, the known automated systems for plant cultivation have a number of advantages over conventional agriculture in fields. In addition to complete independence from weather conditions, the climatic conditions inside the greenhouse can be optimally adapted to the respective plants over the entire period, thus allowing constant plant growth to be achieved. Owing to special water recovery systems, significantly less water is required for growing the plants than for cultivating fields outdoors. In addition, comparatively little fertilizer is required and pesticide-free plant cultivation becomes possible by virtue of plant cultivation in fully climate-controlled spaces.

A problem with the known systems for automated plant cultivation in fully climate-controlled rooms is often that the installations used can only be adapted to different plants with comparatively great effort. When the plants to be cultivated are changed, it must be taken into account that the size of different

plants changes to different extents and over different periods during the growth phase. Adaptation of the known systems for automated plant cultivation to the respectively changed conditions is only possible with difficulty.

Nevertheless, the known systems, with which plants are often cultivated on
5 several levels (so-called vertical farming systems), have made it possible to multiply the plant yield per available cultivation base area in comparison with classical plant production on one level. However, due to limitations in technical process control, only smaller plants, usually having a growth height of less than 1 m, have so far been cultivated in vertical farming systems. Larger plants, in
10 particular highly profitable medicinal plants, such as cannabis, have so far only been produced comparatively inefficiently on one level or on very few levels in high-bay rack systems with a low total number of plants per available cultivation base area. It has thus not yet been possible to use the full spatial potential in the vertical direction efficiently for plant production. In addition, the production of
15 larger plants on very few high-bay rack levels is associated with various disadvantages. Thus, accessibility, monitoring and harvesting of the individual plants as well as compliance with the necessary climatic cultivation conditions pose considerable challenges. Moreover, there is a technical problem in changing the phenotype of a plant simply and efficiently in order to increase the plant yield,
20 beyond the approach of plant density per available cultivation base area, also on an individual-plant basis, for example by increasing the number of lateral shoots or by increasing plant biomass.

A known possibility for changing the phenotype of a plant consists in the use of classical breeding approaches. More recently, specific gene editing has also been carried out. However, these approaches are time-consuming and difficult, particularly when, in addition to the size- and yield-specific characteristics, 5 complex active ingredient/secondary metabolite combinations of a plant line also have to be taken into account for the crossing. In addition, gene-edited plants are regarded in various countries as genetically modified organisms (GMOs), with the result that they are treated in accordance with the GMO Directive and are subject to complex approval procedures.

10 Furthermore, chemicals are sometimes used to reduce plant growth height and to increase the number of lateral shoots, but these are undesirable in many applications and may have adverse effects on plant health. It is also known that, in controlled indoor cultivation systems, specific cultivation parameters, such as the use of certain artificial light wavelength ranges or fertilizer compositions, can 15 have an influence on the size and yield of a plant.

All these approaches are already used for phenotype adaptation, but are not suitable for simple and efficient modification of the phenotype.

Furthermore, a clinostat is a device with which the growth of plants can be influenced by specifically modifying the effect of gravity. By suitable rotation of 20 the plant, a clinostat makes it possible to eliminate the effects of gravity on plant growth (gravitropism) and development (gravimorphism).

A single-axis or horizontal clinostat has a disk connected to a motor. The disk is arranged vertically and rotated by means of an electric motor at a rotational speed of approximately one revolution per minute. At the same time, a plant is attached to the disk so that it is aligned horizontally. Due to the slow, continuous rotation, the plant experiences an attractive force averaged over 360 degrees, which approximates a weightless environment. If, by contrast, the clinostat is at an angle to the horizontal, a net gravitational force acts on the plant, the magnitude of which depends on the angle of inclination.

Proceeding from the systems for automated plant cultivation known from the prior art and the problems explained above, the invention is based on the object of providing a system for plant cultivation by means of which plant growth can be influenced in a targeted and effective manner. Here, it should be possible in a comparatively simple manner to specifically modify the phenotype of a plant. Furthermore, the technical teaching to be specified should be usable in enclosed spaces and should also permit comparatively simple integration into an automated process which may extend from the application of a seed to the harvesting of the fully matured plant. Furthermore, the supply of the plants to be cultivated with water and nutrients should be ensured.

The above object is achieved by a method for cultivating at least one plant according to claim 1 and by a device having the features specified in claim 11. Advantageous embodiments of the invention are the subject matter of the

dependent claims and are explained in more detail in the following description with partial reference to the figures.

The invention relates to a method for cultivating at least one plant which is rotated at least temporarily during a growth phase. The method according to the invention
5 is characterized in that the plant is rotated discontinuously, wherein the plant is rotated during a rotation phase about a longitudinal axis of the plant extending in the main direction of extension and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, and the plant is, during a non-rotation phase in which the rotational speed is at least temporarily reduced to 0
10 (zero), at least temporarily arranged such that the longitudinal axis of the plant is inclined relative to a direction of gravity at the location of the plant and in a plane spanned by the direction of gravity and the longitudinal axis.

The term “direction of gravity” means the local direction of gravitational acceleration, which is perpendicular to the equipotential surfaces of the earth’s
15 gravitational field in the direction of the resultant of the earth’s gravitation and the centrifugal force due to the Earth’s rotation. As a simplifying assumption, it may be assumed that the direction of gravity is directed from a point above the earth’s surface toward the center of the Earth. The direction of gravity therefore extends vertically relative to the earth’s surface or to the ground at the location
20 where the plant to be cultivated is positioned. Furthermore, it is essential that the rotation of the plant takes place discontinuously, i.e. that rotation phases, in which the plant is rotated about its longitudinal axis and/or about a transverse axis

extending perpendicular or obliquely to its longitudinal axis, and non-rotation phases, in which no rotational movement takes place at least temporarily and the rotational speed is thus reduced to 0 (zero), are initiated.

By means of the invention, the plant to be cultivated can be stimulated during growth so as to achieve rotation-based modification of the plant phenotype. It is essential that the plant grows outside the direction of gravity relative to the earth's gravitational field, i.e. that gravity acts on the plant at different angles and, due to the discontinuous rotation of the plant about its longitudinal axis extending in the main direction of extension and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, different stem sides of the plant are alternately oriented toward the earth's gravitational field. The rotation takes place discontinuously and is thus stopped during the non-rotation phases, whereby at least one of the following plant phenotypes can be induced in comparison with the growth of a plant without the rotation provided according to the invention:

- shorter growth height with a predominantly straight stem
- shorter growth height with a wavy stem
- reduced internode spacing
- higher number of internodes
- more lateral shoots
- greater stem thickness
- more leaf biomass

- more root biomass
- more flower formation sites

The invention is based on the finding that a plant reacts to gravity only if the gravitational stimulus is maintained for longer than a critical period of time, the
5 so-called minimum presentation time (MPT). In many plant organs, the MPT is between 10 and 200 seconds. The non-rotation phases are therefore selected in an advantageous manner when implementing the method according to the invention such that a gravitropic reaction is achieved in the at least one plant which is rotated at least temporarily. It can be taken into account here that the presentation time is
10 cumulative, so that, in the case of repeated interruption of the rotational movement in the same position, even if the non-rotation phase is very short, a gravitropic reaction can be induced if the interruption of rotation in the same position is repeated sufficiently often. In contrast to the growth of a permanently statically aligned plant with a permanently induced gravitropic reaction, the invention
15 enables a directed, discontinuous gravitropic reaction in different plant regions, which leads to the unexpected phenotypes described above.

According to a particular embodiment of the invention, provision is made that the at least one moved plant is rotated discontinuously according to the invention about its longitudinal axis and/or a transverse axis extending perpendicular or
20 obliquely to the longitudinal axis.

In this way, rotation and/or movement of the plant in at least one plane can advantageously be realized. The rotational movements and/or linear movements

carried out in different planes may take place at least partially simultaneously or at different points in time or over different periods. In general, the radius selected for the rotational movement on the circular path on which the rotational movement takes place is irrelevant.

- 5 It is particularly preferred that the movement which causes rotation of the plant about a transverse axis extending perpendicular or obliquely to the longitudinal axis takes place on a specific section of a conveying path, for example at a reversal point or turning point of an otherwise at least partially rectilinear conveying path along which a conveyor belt is moved. Thus, for example, it is conceivable that
- 10 the plant, while being rotated discontinuously, i.e. at generally freely selectable time intervals, about its longitudinal axis extending in the main direction of extension of the plant, so that overall rotation phases and non-rotation phases are provided, is moved along a conveying path and is at least temporarily rotated about a transverse axis extending perpendicular or obliquely to the longitudinal
- 15 axis. Particularly preferably, the transverse axis extends at least substantially perpendicular to the longitudinal axis of the plant.

In a specific embodiment of the invention, provision is made that, at least temporarily during a growth phase of the moved plant, the non-rotation phases of a rotational movement about the longitudinal axis extending in the main direction

20 of extension of the plant and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis are at least as long as the rotation phases. Here, the non-rotation phases are again periods in which the rotational speed of

the rotational movement is lowered to 0 (zero). Furthermore, it is also conceivable that the non-rotation phases are longer than the rotation phases, for example assuming a 2- to 4-fold or even greater value.

Furthermore, in an advantageous embodiment of the invention, provision is made
5 that a first side of a main stem extending in the main direction of extension of the plant is aligned in the same way relative to the direction of gravity in at least two non-rotation phases. The main stem is thus aligned in at least two non-rotation phases, which are preferably interrupted only by one non-rotation phase, in such a way that different main stem sides face the ground or the earth's surface or the
10 center of the Earth.

According to a particularly suitable embodiment of the invention, provision is made that a first side and a second side of a main stem extending in the main direction of extension of the plant, which are arranged opposite one another on the main plant stem, are rotated such that, in a second non-rotation phase
15 following a first non-rotation phase with a rotation phase interposed therebetween, the first side assumes the position that the second side occupied in the first non-rotation phase. According to this embodiment, opposite sides of the main stem are thus aligned such that opposite main stem sides alternately face the ground or the earth's surface or the center of the Earth.

20 In a further embodiment, both plant stems of a pair of plant stems branching off at opposite locations from a main stem extending in the main direction of extension of the plant are each aligned in their main direction of extension in the

direction of gravity in different non-rotation phases. Thus, for example, it is conceivable that, in a first non-rotation phase, the first stem of the pair of plant stems is arranged in the direction of gravity, preferably hanging in the direction of the ground, and, in a second non-rotation phase, the second plant stem of the pair of plant stems is arranged in the direction of gravity, preferably hanging in the direction of the ground. Thus, plant stems arranged opposite one another on a main stem and branching therefrom are alternately arranged in the direction of gravity.

Furthermore, it is advantageously conceivable that the discontinuously rotated plant is at least temporarily arranged such that the longitudinal axis extending in the main direction of extension forms an angle α with the direction of gravity, wherein the following applies to the angle α : $-90^\circ < \alpha < 90^\circ$. According to this embodiment, the longitudinal axis of the plant is arranged horizontally, i.e. at least substantially parallel to the ground or the earth's surface, when $\alpha = 0^\circ$, whereas, at an angle α for which $-90^\circ < \alpha < 0^\circ$, the plant tip is inclined toward the ground and, at an angle for which $0 < \alpha < 90^\circ$, the plant tip is aligned obliquely upward. Essential to the invention is always that the longitudinal axis of the plant to be cultivated is, during non-rotation phases, at least temporarily inclined relative to the direction of gravity in a plane spanned by the direction of gravity and the longitudinal axis, the longitudinal axis thus not being arranged vertically relative to the ground or the earth's surface.

In a further specific embodiment of the method according to the invention, the plant is at least temporarily arranged during the non-rotation phases with its longitudinal axis extending in the main direction of extension perpendicular to the direction of gravity. This means that the longitudinal axis extends in the horizontal
5 direction and thus at least substantially parallel to the ground or to the earth's surface.

Furthermore, in a specific further development of the method according to the invention, provision is made that a non-rotation phase is at least partially 10 to 200 s. A time span lying within the interval mentioned above offers the advantage
10 that a gravitropic reaction can be generated effectively in the plant.

The method described above in its general form or at least one of the specific further developments described above is particularly suitable for cultivating a medicinal plant, a food plant, a fodder plant, an ornamental plant and/or a woody plant. Preferably, a plurality of such plants are at least temporarily cultivated
15 simultaneously by the method according to the invention.

The method according to the invention, or at least one of its specific further developments described above, is particularly preferably suitable for cultivating a medicinal plant or a plurality of medicinal plants belonging to the family Cannabaceae.

20 In addition to a method, the invention also relates to a device for carrying out the method according to the invention and/or its further developments, wherein the device has at least one fastening device for releasably fastening the plant to be

cultivated and a drive unit which is connected at least indirectly to the fastening device for initiating a movement of the fastening device. According to a specific further development of the device, the fastening device and/or the drive unit are configured to move the plant to be cultivated in at least two planes, wherein these
5 planes are arranged neither identically nor parallel to one another.

In general, it is conceivable here that the fastening device serving to fasten the plant to be cultivated is linearly movable and/or rotatable.

According to a specific embodiment, a nutrient medium supply is further provided, by means of which the plant to be cultivated can be supplied with a
10 nutrient medium. Here, the nutrient medium supply has the suitable elements for receiving, storing, conveying and dispensing the required nutrient medium in the direction of the plant which is rotated at least discontinuously about its longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis.

15 Furthermore, it is advantageous if a light source is provided in order to irradiate the plant to be cultivated at least temporarily with photons. According to this embodiment, sunlight or at least one lighting unit is provided as a light source, by means of which the plant is irradiated in a targeted manner. Shading elements may be provided which effect targeted darkening of the plant, or the irradiation may
20 be switched on and off in a targeted manner, for example in order to define a day-night rhythm.

A further embodiment of the device according to the invention provides for the use of a climate control device in order to set the plant to be cultivated and/or an atmosphere surrounding the plant as required, in particular to cool and/or dehumidify it relative to the surroundings.

5 Furthermore, it is conceivable that the invention, which is based on the discontinuous rotation of a plant to be cultivated about a longitudinal axis extending in the main direction of extension of the plant and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, is combined with a device for promoting the growth of plants, in particular for automated plant
10 cultivation, having a conveyor belt movable along a conveying path for transporting plants at least in sections. The plants transported in this way are preferably at least temporarily illuminated during movement along the conveying path and are supplied with nutrients and water by a nutrient supply, and during their transport along the conveying path are moved at least approximately
15 horizontally in at least one first section and at least approximately vertically in at least one second section. During this alternating horizontal and vertical movement, the plants are also rotated discontinuously about their longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis. This embodiment of the invention is characterized in that the
20 plants are at least temporarily fixed relative to the conveyor belt during transport along the conveying path such that roots of the plants extend at least partially into an area arranged below an underside of the conveyor belt, while leaves and/or

fruits of the plants extend at least partially into an area located above an upper side opposite the underside, wherein a nutrient medium supply is arranged below the conveyor belt so that the plants fixed on the conveyor belt, in particular the roots below the conveyor belt, are supplied aeroponically with nutrient medium.

- 5 By means of the conveyor belt, rotation of the plant to be cultivated about the transverse axis extending perpendicular to the longitudinal axis of the plant can thus take place in the region of deflection points with a horizontal axis of rotation. In principle, a combination is also conceivable, so that discontinuous rotation of the plant about its longitudinal axis can also be effected on the conveyor belt.
- 10 Clinostats are, however, particularly suitable for discontinuous rotation of a plant about its longitudinal axis.

- In this context, essential features of the invention are that the plants are fixed on the conveyor belt during their growth phase, are continuously moved in one direction, and are rotated discontinuously about their longitudinal axis and/or
- 15 about a transverse axis extending perpendicular or obliquely to the longitudinal axis. Preferably, the plants are at least temporarily transported along a light source. Furthermore, it is conceivable that a nutrient medium supply, in particular with spray nozzles, is arranged at a distance from the underside of the conveyor belt, which ensures an aeroponic supply of the plants with nutrient medium in this
- 20 area. Furthermore, the root region is supplied with nutrients during movement, preferably continuously. Owing to the special arrangement of the conveying path according to this embodiment with sections extending at least approximately

vertically upward and downward, between which reversal points of the conveying path are arranged, the plants are not only rotated discontinuously about their longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, but in particular in the region of the reversal
5 points there is rotation about the transverse axis then extending perpendicular or obliquely to the longitudinal axis, wherein the longitudinal axis of a plant is preferably arranged perpendicular to the transverse axis.

In a further specific embodiment of the invention, the conveyor belt has, at least in some regions, a carrier material in which the plants are fixed at least temporarily
10 during transport along the conveying path. Preferably, the carrier material is selected such that the seeds or plants find good support and, in addition, the material can conduct and at least temporarily store water and/or nutrient medium. The discontinuous rotation of the plant about its longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis then
15 preferably takes place at least partially together with the carrier material.

If, in addition to the discontinuous rotation about their longitudinal axes and/or about their transverse axes extending perpendicular or obliquely to the longitudinal axis, the plants are at least partially transported in an approximately vertical direction by means of a specially designed device, it is possible, according
20 to a particular further development of the invention, for the plants to be continuously transported during their growth phase along a natural or artificial light source and/or toward it, wherein illumination is particularly preferably

effected as soon as the plants are moved in the vertical direction. Advantageously, at the same time, a root region arranged on the underside of the conveyor belt is supplied aeroponically with nutrients and moisture. The aeroponic supply of the root region with nutrients also preferably takes place at least temporarily while

5 the plants are moved in the vertical direction. In this context, it is conceivable that an upper deflection point is provided between two vertically extending sections of the conveying path, so that the plants are moved with the conveyor belt vertically upwardly and subsequently, after passing around the deflection point, vertically downwardly. At this deflection point, in an advantageous manner, in

10 addition to the discontinuous rotation of the plants about their longitudinal axis, an additional rotation of the plant about a transverse axis of the plants extending perpendicular or obliquely to the longitudinal axis takes place. It is particularly advantageous if the plants are arranged with their longitudinal axis perpendicular to the direction of movement of the conveyor belt.

15 In general, it is conceivable that natural light and/or artificially generated light by means of a lighting unit, which has, for example, at least one fluorescent tube and/or one LED, is used for illumination. The provision of a lighting unit for generating light has the advantage that the illumination can take place in a targeted manner, in particular adapted to the plant species to be cultivated and/or

20 coordinated with plant growth, and can take place at any time if required. According to a particular further development of the invention, the illumination of the plants takes place only in certain areas of the conveying path, in particular

in selected areas in which the plants are moved in the vertical direction and particularly preferably in half of the overall vertical areas provided, so that a day-night rhythm can be imitated. Advantageously, the illumination takes place by means of vertically arranged LED panels or other lighting systems.

- 5 According to a specific further development, provision is further made that the lighting unit is designed such that illumination of the plants takes place in specifically selected sections of the conveying path. Advantageously, the illumination takes place while the plants, in addition to the discontinuous rotation about the longitudinal axis extending in the main direction of extension of the
- 10 plants and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, are moved continuously or likewise discontinuously upwardly on a vertically arranged section of the conveying path. Furthermore, it is advantageous that, after passing around the deflection point, in particular as soon as they are moved vertically downwardly, the plants are at least temporarily no
- 15 longer illuminated.

- In a particularly advantageous embodiment, the plants fixed on the conveyor belt, in particular the roots below the conveyor belt, are supplied aeroponically with nutrient medium as soon as they are moved in the vertical direction. If the conveying path also has a deflection point in the lower region between two at least
- 20 approximately vertically extending conveying path sections, it is conceivable that the plants, in particular the roots arranged below the conveyor belt, are moved at least partially through an immersion bath, so that a hydroponic nutrient supply of

the plants, in particular of the root system, takes place in this region. On the serpentine or meandering conveying path according to this specific embodiment with vertically extending path sections, between which lower and upper deflection points or regions are located, a continuous supply of the plants with nutrients and
5 moisture takes place in this way. A nutrient medium atomization installation is preferably used for the aeroponic watering of the root system of the plants.

By means of an automated system for plant cultivation designed as specified, it is possible in a preferred manner to provide continuous aeroponic watering of the roots on the underside of the conveyor belt, while in the region of the lower
10 deflection points a hydroponic bath of the plant carrier material is realized during passage through the trough phase of the conveyor belt.

By fixing the plants, which are rotated discontinuously about their longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, on the conveyor belt, permanent or at least long-lasting
15 aeroponic watering can be realized without unnecessarily wetting the foliage of the plant. In this way, diseases of the leaf mass are reliably prevented. The atmosphere located in particular below the conveyor belt on the vertical conveying path sections is monitored with regard to temperature and humidity by means of sensors and the values are regulated in a suitable manner via a central
20 control unit, so that excessively high humidity in this region can be reliably avoided.

Furthermore, as an alternative or in addition to the embodiment described above, it is advantageously conceivable to achieve the adaptation of a device for automated plant cultivation to the size requirements of the respective plants by changing the spacing of the points at which the individual plants are fixed on the conveyor belt and at which elements for the targeted and demand-based rotation of the plants about their longitudinal axes and/or about their transverse axes extending perpendicular or obliquely to the longitudinal axis are arranged. Preferably, mechanical elements are provided for this purpose, which ensure demand-based adjustment of the spacing of the individual fixing points and thus of the rotation elements provided in this area. Thus, for example, it is conceivable that the individual fixing points are moved further apart with increasing transport duration of a plant and the associated plant growth, wherein detent positions in different positions are conceivable. According to a further preferred embodiment of the invention, the conveyor belt has successive rigid lamellae or plates, which may be made of a wide variety of materials, such as polyvinyl chloride (PVC). Such lamellae or plates allow simple anchoring of the plants and at the same time are characterized by a high degree of flexibility, so that the conveyor belt can be guided over the deflection rollers.

By adapting the conveying path or the conveyor belt to the changing size of the plants, on the one hand the increasing space requirement of the plant is taken into account and, on the other hand, the use of material and energy is minimized. In this way, the installation is operated particularly effectively from both economic

and ecological points of view, since, for example, the expenditure in the young plant phase for watering and illumination is significantly reduced.

A further specific embodiment of the invention provides that the conveying path or the conveyor belt moved along the conveying path is moved on a closed
5 circular or oval path. Thus, two vertical sections and two horizontal sections are provided in the region of the deflection points, which connect the vertical sections to one another. By changing the length of the vertical sections of the conveyor belt, such an installation for plant cultivation can be built to virtually any height. Preferably, an internal aeroponic nutrient supply for cultivating the moved plants
10 is provided. Such an installation for plant cultivation is particularly suitable for the cultivation of herbs, leafy vegetables, fruit plants including grain legumes, fodder plants, ornamental plants, woody plants and/or medicinal plants, in particular those belonging to the family Cannabaceae. Also when moving along a closed circular or oval conveying path, the plants are likewise rotated
15 discontinuously about their longitudinal axis and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, so that the plants are at least partially aligned during the non-rotation phases such that their longitudinal axis does not extend in the direction of gravity.

Advantageous harvesting is possible if the harvesting of the plants or fruits takes
20 place in the region of the lower reversal point, in particular with the aid of an automatically operating harvesting machine.

With regard to fixing the plants in or on the conveyor belt, it is basically conceivable that the seeds and/or young plants are fixed directly or indirectly via a carrier material in or on the conveyor belt. It is always essential that elements are provided which permit the discontinuous rotation according to the invention
5 of the plants about their longitudinal axis and/or about a transverse axis of the plants extending perpendicular or obliquely to the longitudinal axis.

According to an alternative embodiment, the conveyor belt has suitable plant containers which can be equipped with plants and which are fastened to the circulating conveyor belt by means of fastening elements. In this context, it is
10 conceivable, for example, that the conveyor belt has at least one conveyor chain into which a hook of the plant container serving as a fastening element is hooked as soon as a plant is to be transported along the conveying path. If plant containers connectable to the conveyor belt are used accordingly, these are preferably released from the conveyor belt or the conveyor chain for the harvesting process,
15 cleaned after completion of the harvest and finally returned to the loading installation. After loading with a seed or a young plant, corresponding plant containers are in turn hooked into the conveyor belt or the conveying courses at the beginning thereof.

By means of the invention, cultivation of plants is made possible in which the
20 phenotype of a plant is modified during cultivation solely by changing the orientation of the plant, in particular of its main plant stem, relative to the earth's gravitational field. Here, the initial orientation of a plant with its main plant stem

extending in the direction of the plant longitudinal axis relative to the ground and thus to the earth's gravitational field is changed at least once during the cultivation period by discontinuous rotation in such a way that the time interval between the rotational movements, i.e. a non-rotation phase, is longer than the longest
5 rotational movement during a rotation phase. The change in the orientation of the plant with its main plant stem relative to the earth's gravitational field leads to different sides of the main plant stem facing the ground and can take place by rotation about the plant longitudinal axis extending in the main direction of extension and/or about a plant transverse axis extending perpendicular or
10 obliquely to the longitudinal axis.

During rotation about a plant transverse axis, preferably the opposite sides of the main plant stem are alternately aligned facing the ground. In the case of rotation about the plant longitudinal axis and/or about a transverse axis of the plant extending perpendicular or obliquely to the longitudinal axis, it is advantageously
15 possible to set the orientation of one side or one region of the main plant stem facing the ground as a function of the rotational angle used, wherein the preferred rotational angle of the rotational movement during a rotation phase is 180° in order thereby to be able to initiate technical features with a minimum number of rotations. During cultivation between the rotation phases, i.e. during the non-
20 rotation phases, the longitudinal axis of the plant to be cultivated is in a non-parallel orientation to the direction of gravity and thus extends in a direction different from the Earth's gravity vector. According to this embodiment, the

longitudinal axis of the plant to be cultivated and the gravity vector include an angle which is not equal to 0 (zero). The longitudinal axis of the plant to be cultivated is thus inclined relative to the gravity vector.

Surprisingly, when using the invention it has been observed that a changing
5 orientation of the plant longitudinal axis relative to the gravity vector, wherein, after movement of the plants, at least partially a different region of the main plant stem faces the ground, causes, compared with other cultivation methods, a shorter growth height, reduced internode spacing, a higher number of internodes, more lateral shoots, greater stem thickness, more leaf biomass, more root biomass
10 and/or more flower formation sites. These unexpected technical effects are all advantageous for increasing the plant yield per available cultivation base area or per available cultivation volume. Furthermore, it is advantageous that the technical effect is achieved purely physically by different sides, side surface areas or regions of a main plant stem being oriented toward the ground at least partially
15 in different periods. In particular, no breeding approaches or chemicals are required. In addition, the method according to the invention can be applied in addition to the use of specific cultivation parameters, such as certain artificial light wavelength ranges or fertilizer compositions.

On the basis of the invention, simple and rapid generation of plants with a specific
20 phenotype can take place, which is of overall interest for commercial plant production, especially in the field of vertical farming. Here, the invention opens up the possibility of efficient production of larger plants which have hitherto been

little or not at all suitable for vertical farming. In addition, the invention also offers the possibility of specifically adapting the standard phenotype of plants, whereby both plant quality and plant yield can be improved. The invention is particularly suitable for cultivating or producing lucrative medicinal plants which are large-
5 growing under standard conditions, such as medicinal cannabis. In addition, the invention can advantageously be used in the cultivation or production of food plants or ornamental plants.

Here, it is conceivable that the method according to the invention, which is based on suitable discontinuous rotation of plants to be cultivated about their
10 longitudinal and/or one transverse axis of the plants, is realized both on larger installations for plant cultivation which have conveyor belts or other conveying devices, and on installations such as those used in research and development and designed, for example, in the form of clinostats.

In the following, the invention is explained in more detail, without restriction of
15 the general inventive concept, by means of exemplary embodiments and with reference to the figures.

Figures

Fig. 1: Schematic illustration of the various possibilities for rotation and orientation of a plant arranged inclined relative to the direction of gravity in the earth's gravitational field during rotation about the transverse axis of the plant.

Fig. 2: Schematic illustration of the various possibilities for rotation and orientation of a plant arranged inclined relative to the direction of gravity in the earth's gravitational field during rotation about the longitudinal axis of the plant.

Fig. 3: Comparison of the mean plant heights of the fiber hemp varieties "Kompolti" and "Futura 75".

Fig. 4: Comparison of the mean number of internodes of the fiber hemp varieties "Kompolti" and "Futura 75".

Fig. 5: Comparison of the phenotypes of the fiber hemp varieties "Kompolti" and "Futura 75" with and without alternating inclination relative to the direction of gravity.

Fig. 6: Schematic illustration of an installation having an oval conveying path for automated plant cultivation with discontinuous rotation of the plants to be cultivated.

Fig. 7: Diagrams showing the comparison of the mean growth heights of the fiber hemp varieties "Kompolti" and "Futura 75" during a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field.

Fig. 8: Diagrams showing the comparison of the mean number of internodes of the fiber hemp varieties “Kompolti” and “Futura 75” after a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field.

- 5 Fig. 9: Fiber hemp phenotypes after a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field under identical indoor climatic conditions.

- Fig. 10: Comparison of the mean growth height, green biomass (fresh weight), root biomass (fresh weight) and number of lateral shoots of the fiber hemp variety
10 “Kompolti” after an aeroponic cultivation period of 21 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field.

- Fig. 11: Diagrams showing the comparison of the mean growth heights and stem thicknesses of the hemp variety “Finola” after an aeroponic cultivation period of
15 21 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field.

- Fig. 12: Diagram and photograph showing the comparison of the mean growth heights of the grain pea plants “Astronaute” and “Ostinato” after an aeroponic cultivation period of approximately 6 weeks with constant vs. alternating
20 orientation of the stem sides of the plant relative to the earth’s gravitational field.

Detailed Description of the Figures

Figures 1 and 2 show schematic illustrations of the various possibilities for rotation and orientation of a plant 8 to be cultivated in the earth's gravitational field, which is arranged inclined relative to the direction of gravity 27 in the earth's gravitational field. Here, the direction of gravity 27 extends vertically relative to the ground 30 at the location where the plant 8 is positioned or relative to the earth's surface in this region. By means of the schematically illustrated method for discontinuous rotation of a plant 8 to be cultivated, which is arranged inclined relative to the direction of gravity 27 at least in non-rotation phases, a specific phenotype modification of the plant can advantageously be induced.

The change in the orientation of the main plant stem, in particular of the longitudinal axis 28 of the plant 8 extending in the main direction of extension, relative to the earth's gravitational field can take place either by rotation about a transverse axis 29 of the plant 8 extending perpendicular or obliquely to the longitudinal axis, as shown in Fig. 1, or by rotation about the longitudinal axis 28 extending in the main direction of extension, as shown in Fig. 2.

It is always essential that, between two non-rotation phases, different stem sides of the plant 31 are aligned differently relative to the earth's gravitational field due to the intermediate rotation, wherein different side regions or side surface regions of the main stem 32 as well as the plant stems 33 arranged on the corresponding side 31 face the ground 30.

In the embodiment shown in Fig. 1, the plant 8 to be cultivated, which is in each case inclined differently relative to the direction of gravity 27 according to partial views a) to f), is rotated about its transverse axis 29, which is arranged perpendicular to the longitudinal axis 28 of the plant 8. In general, it is also
 5 conceivable in this context that the transverse axis 29 extends obliquely to the longitudinal axis 28. Here, the opposite stem sides of the plant 31 or side regions of the main plant stem 32 are alternately aligned facing the ground.

By contrast, Fig. 2 shows an embodiment of the method according to the invention in which the plants 8 to be cultivated, which are in each case inclined differently
 10 relative to the direction of gravity 27 according to partial views a) to f), are rotated during the rotation phases between two non-rotation phases about the longitudinal axis 28 extending in the main direction of extension of the plants.

In this embodiment, the orientation of the stem sides of the plant 31 or of the respective side region of the main plant stem 33 depends on the respective
 15 rotational angle through which the plant 8 has been rotated during a rotation phase.

The plant orientations shown by way of example illustrate the angle range effective for inducing specific phenotype modification of the plants, wherein the following applies to the angle α : $-90^\circ < \alpha < 90^\circ$. Within this angle range, gravity
 20 acts at least approximately laterally on the plant 8 and its plant stems along the gravity vector. The greatest lateral force of gravity acts in the case where $\alpha = 0^\circ$ is selected, the longitudinal axis 28 of the plant 8 to be cultivated thus being

aligned perpendicular to the direction of gravity in the plane spanned by longitudinal axis 28 and direction of gravity 27, as shown in each case in Figures 1c), 1d), 2c) and 2d).

Figure 3 shows, in a graphical representation, the comparison of the mean plant heights of the fiber hemp varieties “Kompolti” and “Futura 75” after a cultivation period of 36 days without or with alternating orientation of the stem sides of the plant relative to the ground or the earth’s surface under otherwise identical cultivation conditions.. By alternating the orientation of the plants to be cultivated relative to the direction of gravity, in which gravity acts, the growth height is reduced for Kompolti by 21.92% and for Futura 75 by 25.22%. The error bars represent the standard deviation (+/- 1 SD).

Figure 4 shows, in a graphical representation, the comparison of the mean number of internodes of the fiber hemp varieties “Kompolti” and “Futura 75” after a cultivation period of 36 days without or with alternating orientation of the stem sides of the plant relative to the ground or the earth’s surface under otherwise identical cultivation conditions.. By alternating the orientation of the plants to be cultivated relative to the direction of gravity, in which gravity acts, the number of internodes increases for Kompolti by 25.41% and for Futura 75 by 20%. The error bars represent the standard deviation (+/- 1 SD).

Figure 5 shows, in specific images, a comparison of the phenotypes of the fiber hemp varieties “Kompolti” and “Futura 75” after a cultivation period of 36 days without or with alternating orientation of the stem sides of the plant relative to the

earth's gravitational field under otherwise identical cultivation conditions.. Here, partial views a) and b) show the fiber hemp variety "Kompolti", in partial view a) without the orientation of the longitudinal axis 28 of the plant relative to the direction of gravity 27 having been changed and, in partial view b), after the orientation of the stem sides of the plant relative to the ground 30 had been changed during cultivation. In addition, partial views c) and d) show cultivation of the fiber hemp variety "Futura 75" in partial view c) without and in partial view d) with changed orientation of the stem sides of the plant relative to the ground 30 during cultivation. Alternating orientation of the stem sides of the plant relative to the ground, whereby in successive non-rotation phases different side regions of a main plant stem 32 or stem sides of the plant 31 are oriented toward the ground, results in a shorter growth height, a higher number of internodes with reduced internode spacing, more lateral shoots, more leaf biomass, greater stem thickness and more flower formation sites.

Figure 6 shows a specific installation for cultivation in which the plants 8 are fixed on a conveyor belt 2 and conveyed discontinuously on a closed oval path. Movement on a circular path is also conceivable. Optionally, one or a plurality of such installations can be operated simultaneously. Again, it is essential that the plants 8 to be cultivated are moved discontinuously so that, according to the embodiment shown in Figure 3, rotation about the transverse axis 29 of the plants 8 takes place in the rotation phases.

The installation shown in Figure 6 can furthermore be configured flexibly. According to the exemplary embodiment shown here, the discontinuously rotated plants are fixed in the conveyor belt such that their root system projects freely into an area below the conveyor belt. Here, the plants are supplied aeroponically with
5 nutrient medium by a nutrient medium supply 9a. Alternatively or additionally, a hydroponic nutrient medium supply 9b is also conceivable. Furthermore, lighting units 10 are provided outside the installation, which enable demand-based irradiation of the plants to be cultivated, in particular of the foliage.

An advantage of the installation shown is that even larger plants can be rotated
10 without problems and for this purpose can be deflected at the upper and lower deflection points.

In general, the installation shown in Figure 6 can be used to realize the method according to the invention with or without the embodiments described above. Thus, for example, it is conceivable to fix the plants 8 on the conveyor belt 2 and
15 to rotate them exclusively discontinuously about their transverse axis 29, or alternatively or additionally to initiate rotation about their longitudinal axis 28.

Such an installation for plant cultivation is particularly suitable for cultivating medicinal plants, fodder plants, ornamental plants and/or woody plants. Such an installation is particularly suitable for cultivating medicinal plants belonging to
20 the family Cannabaceae by utilizing the method according to the invention.

Food plants such as herbs, leafy vegetables and/or fruit plants including grain legumes can likewise be cultivated by means of the method according to the

invention using such an installation. Advantageous harvesting is possible if the harvesting of the plants or fruits takes place in the region of the lower reversal point, in particular with the aid of an automatically operating harvesting machine.

5 Reference Signs List for Figs. 1, 2 and 6

- 1 Conveying path
- 2 Conveyor belt
- 3 Receiving unit
- 4 Upper deflection point
- 10 5 Lower deflection point
- 6 Vertical path section
- 7 Horizontal path section
- 8 Plant
- 9 Nutrient medium supply unit
- 15 9a Aeroponic nutrient medium supply unit
- 9b Hydroponic nutrient medium supply unit
- 10 Lighting unit
- 11 Shading phase
- 12 Loading unit

- 13 Harvesting unit
- 14 Cleaning and sterilization unit
- 15 Conveyor chain
- 16 Transport belt
- 5 17 Elastic connecting elements
- 18 Carrier material
- 19 Area below the conveyor belt
- 20 Area above the conveyor belt
- 21 Adjustment unit
- 10 22 Electric motor
- 23 Worm gear
- 24 Spray nozzle
- 25 Nutrient medium tank
- 26 Central control unit
- 15 27 Direction of gravity
- 28 Longitudinal axis
- 29 Transverse axis
- 30 Ground

31 Plant stem side

32 Main stem

33 Plant stem

- 5 Figures 7 to 10 show cultivation experiments with the fiber hemp varieties “Kompolti” and “Futura 75” with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field – alternating orientation by rotation about the plant transverse axis.

Fig. 7 shows the comparison of the mean growth heights of the fiber hemp varieties “Kompolti” and “Futura 75” during a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field. After 36 days of comparative soilless cultivation under identical indoor climatic conditions, alternating orientation of the plant stems relative to the earth’s gravitational field resulted in a reduction in growth height of 21.92% for the fiber hemp variety “Kompolti” (upper diagram) and of 25.22% for the fiber hemp variety “Futura 75” (lower diagram). The error bars represent the standard deviation (± 1 SD).

Fig. 8 shows the comparison of the mean number of internodes of the fiber hemp varieties “Kompolti” and “Futura 75” after a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth’s gravitational field. After 36 days of comparative soilless cultivation under

identical indoor climatic conditions, alternating orientation of the plant stems relative to the earth's gravitational field resulted in an increase in the number of internodes of 25.41% for the fiber hemp variety "Kompolti" and of 20% for the fiber hemp variety "Futura 75" (lower diagram). The error bars represent the standard deviation (± 1 SD).

Fig. 9 shows the fiber hemp phenotypes after a cultivation period of 36 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field under identical indoor climatic conditions. Fiber hemp variety "Kompolti" after constant (A) vs. alternating orientation (B) of the stem sides of the plant relative to the earth's gravitational field. Fiber hemp variety "Futura 75" after constant (C) vs. alternating orientation (D) of the stem sides of the plant relative to the earth's gravitational field. Alternating orientation of the stem sides of the plant relative to the earth's gravitational field results in a shorter growth height with a straight stem, a higher number of internodes with reduced internode spacing, more lateral shoots, more leaf biomass, greater stem thickness and more flower formation sites.

Fig. 10 shows the comparison of the mean growth height, green biomass (fresh weight), root biomass (fresh weight) and number of lateral shoots of the fiber hemp variety "Kompolti" after an aeroponic cultivation period of 21 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field. The comparative cultivation was carried out under identical cultivation conditions (identical temperature and humidity conditions,

identical LED lighting modules with identical lighting times, identical fertilizer, pH and EC value, identical aeroponic nutrient supply and identical cultivation duration). (A) After 21 days of comparative cultivation, alternating orientation of the stem sides of the plant relative to the earth's gravitational field resulted in a
5 reduction in growth height with a straight stem of 30.61%, an increase in green biomass (fresh weight) of 35.56%, an increase in root biomass (fresh weight) of 78.11% and an increase in the number of lateral shoots of 38.57%. (B) and (C) show exemplary images of the fiber hemp plants after the 21-day cultivation period with constant orientation (in each case the hemp plant on the right in the
10 image) vs. alternating orientation (in each case the hemp plant on the left in the image) of the stem sides of the plant relative to the earth's gravitational field.

Figure 11 shows cultivation experiments with the hemp variety "Finola" with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field – alternating orientation by rotation about the plant
15 longitudinal axis. In particular, Fig. 11 shows a comparison of the mean growth heights and stem thicknesses of the hemp variety "Finola" after an aeroponic cultivation period of 21 days with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field. The comparative cultivation was carried out in the same aeroponic cultivation system under
20 identical cultivation conditions (identical temperature and humidity conditions, identical LED lighting modules with identical lighting times, identical fertilizer, pH and EC value, identical aeroponic nutrient supply and identical cultivation

duration). After 21 days of comparative cultivation in the same cultivation system, alternating orientation of the stem sides of the plant relative to the earth's gravitational field resulted in a reduction in growth height with a curved stem of 55.80% (upper diagram) and an increase in stem thickness of 36.18% (lower diagram). The error bars represent the standard deviation (± 1 SD).

Figure 12 shows the cultivation of grain pea plants with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field (example of a reduction in growth height with a curved stem) – alternating orientation by rotation about the plant transverse axis. In particular, Fig. 12 shows the comparison of the mean growth heights of the grain pea plants “Astronauta” and “Ostinato” after an aeroponic cultivation period of approximately 6 weeks with constant vs. alternating orientation of the stem sides of the plant relative to the earth's gravitational field. The comparative cultivation was carried out under identical cultivation conditions (identical temperature and humidity conditions, identical LED lighting modules with identical lighting times, identical fertilizer, pH and EC value, identical aeroponic nutrient supply and identical cultivation duration). After approximately 6 weeks of comparative cultivation, alternating orientation of the stem sides of the plant relative to the earth's gravitational field resulted in a 3.7-fold reduction in growth height for the grain pea plant “Astronauta” and a 3.8-fold reduction for the grain pea plant “Ostinato” (upper diagram). The error bars represent the standard deviation (± 1 SD). The reduction in growth height is based on the multiple-curved stem of the grain pea

plants, wherein the stem bends are induced by the changes in direction of the stem sides of the plant relative to the earth's gravitational field (photograph).

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CLAIMS

1. A method for cultivating at least one plant, which is moved at least temporarily during a growth phase, characterized in that the plant is rotated discontinuously, wherein the plant is rotated during a rotation phase about a longitudinal axis of
5 the plant extending in the main direction of extension and/or about a transverse axis extending perpendicular or obliquely to the longitudinal axis, and the plant is, during a non-rotation phase in which the rotational speed is at least temporarily reduced to 0 (zero), at least temporarily arranged such that the longitudinal axis of the plant is inclined relative to a direction of gravity at the location of the plant
10 and in a plane spanned by the direction of gravity and the longitudinal axis.
2. The method according to claim 1, characterized in that the non-rotation phases are at least temporarily at least as long as the rotation phases.
3. The method according to one of the preceding claims, characterized in that a first side of a main stem extending in the main direction of extension of the plant
15 is aligned in the same way relative to the direction of gravity in at least two non-rotation phases.
4. The method according to one of the preceding claims, characterized in that a first side and a second side of a main stem extending in the main direction of extension of the plant, which are arranged opposite one another on the main plant
20 stem, are rotated such that, in a second non-rotation phase following a first non-rotation phase with a rotation phase interposed therebetween, the first side assumes the position that the second side occupied in the first non-rotation phase.

5. The method according to one of the preceding claims, characterized in that the plant is at least temporarily arranged during the non-rotation phases with its longitudinal axis at an angle α relative to the direction of gravity, wherein $-90^\circ < \alpha < 90^\circ$.
- 5 6. The method according to one of the preceding claims, characterized in that the plant is at least temporarily arranged during the non-rotation phases with its main direction of extension perpendicular to the direction of gravity.
7. The method according to one of the preceding claims, characterized in that a non-rotation duration lasts at least partially from 10 to 200 s.
- 10 8. The method according to one of the preceding claims, characterized in that at least one plant phenotype of the plant is induced in comparison with the growth of a plant that is not rotated discontinuously during growth, wherein the plant phenotype is selected from a group of phenotypes comprising shorter growth height with a predominantly straight stem, shorter growth height with a wavy
15 stem, reduced internode spacing, higher number of internodes, more lateral shoots, greater stem thickness, more leaf biomass and more root biomass.
9. The method according to one of the preceding claims, characterized in that a medicinal plant, a food plant, a fodder plant, an ornamental plant and/or a woody plant is cultivated.
- 20 10. The method according to one of the preceding claims, characterized in that a medicinal plant belonging to the family Cannabaceae is cultivated.

11. The method according to one of the preceding claims, characterized in that the plant is moved at least temporarily by means of a conveyor belt or a clinostat.
12. The method according to one of the preceding claims, characterized in that the plant is rotated during a rotation phase about a longitudinal axis of the plant
5 extending in the main direction of extension and about a transverse axis extending perpendicular or obliquely to the longitudinal axis.
13. A device for carrying out the method according to one of the preceding claims, comprising a fastening device for releasably fastening the plant to be cultivated, and a drive unit which is connected at least indirectly to the fastening device for
10 initiating a movement of the fastening device.
14. The device according to claim 13, characterized in that the fastening device is displaced linearly and/or rotated.
15. The device according to claim 13 or 14, characterized in that the fastening device and/or the drive unit are configured to move the plant to be cultivated in at
15 least one plane.
16. The device according to one of claims 13 to 15, characterized in that a nutrient medium supply for at least partially supplying the plant to be cultivated with nutrient medium, a light source for at least temporarily irradiating the plant to be cultivated, and/or a climate control device for setting an atmosphere surrounding
20 the plant as required, is provided.