

(19)



(11)

**EP 4 047 541 A1**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:

**24.08.2022 Bulletin 2022/34**

(51) International Patent Classification (IPC):

**G06Q 50/02** <sup>(2012.01)</sup>

(21) Application number: **21158673.0**

(52) Cooperative Patent Classification (CPC):

**G06Q 50/02**

(22) Date of filing: **23.02.2021**

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB  
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO  
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

**BA ME**

Designated Validation States:

**KH MA MD TN**

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(54) **CONTROLLING STEMPHYLIUM VESICARIUM IN ALLIUM CROPS**

(57) The present invention is concerned with the technical field of crop protection. The present invention relates to a method, system, a kit and a computer program product for controlling *Stemphylium vesicarium* in *Allium* crops.

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## Description

[0001] The present invention is concerned with the technical field of crop protection. The present invention relates to a method, a system, a kit and a computer program product for controlling *Stemphylium vesicarium* in *Allium* crops.

[0002] *Stemphylium vesicarium* causes the fungal disease Stemphylium Leaf Blight on a wide range of crops such as onion, garlic, asparagus, tomato, soybean, leek, pear and mango. The symptoms of the disease on each host are different, but what they have in common is that the initial symptoms appear on the leaves as small white spots that later develop, become brown and coalesce. In garlic and onion, infection usually remains restricted to the leaves and does not extend to the bulb scales. In other crops, young stems (asparagus, pear) and fruits (pear, tomato and mango) are also infected.

[0003] The life cycle of the pathogen is characterized by the production of sexual and asexual inoculum. During the sexual stage (*Pleospora allii*), the pathogen reproduces through ascospores that are released from pseudothecia mainly developed on crop debris in winter. The ascospores maturation takes one to six months and the pseudothecia releases the ascospores in spring infecting the new foliage of crop plants in a primary infection cycle. During the asexual stage (*Stemphylium vesicarium*), the pathogen reproduces through conidia on leaves lesions causing several cycles of secondary infections in spring and summer. Therefore, ascospores are considered the primary inoculum and are dispersed in the early part of the cropping season, whereas conidia are considered the secondary inoculum and are dispersed later in spring and summer. As for other foliar pathogens with airborne inoculum dispersal, it is also known that the temporal dispersal pattern of ascospores and conidia is associated with environmental factors such as precipitation, temperature and relative humidity (see e.g. Misawa, T. and Yasuoka, S., 2012. The life cycle of *Stemphylium vesicarium*, the causal agent of Welsh onion leaf blight. *Journal of General Plant Pathology* 78: 18-29.)

[0004] Stemphylium Leaf Blight can lead to severe yield losses at harvest and, therefore, it is necessary to improve the disease management by avoiding or minimizing infections e.g. applying preventive measures and/or treating the disease with fungicides or other appropriate control agent(s).

[0005] Different control agents have been suggested and used for the management of Stemphylium Leaf Blight on different *Allium* crops. In particular, various preventive fungicides have been described. In Canada, fluopyram plus pyrimethanil is registered to control Stemphylium Leaf Blight on onion (Luna Tranquility®, Bayer CropScience Inc., Canada).

[0006] For the control of *Stemphylium vesicarium*, the availability of a control method as efficiently as possible is important in order to preserve human health and the environment, to save costs, and/or to secure a high harvest quality.

[0007] The object to provide such a control method is achieved by the subject matter of the independent claims. Preferred embodiments are found in the dependent claims and in the present description and the drawings.

[0008] A first subject of the present invention is a method for controlling *Stemphylium vesicarium* on an *Allium* crop, comprising the steps of:

- (A) installing a temperature- and wetness sensor,
- (B) providing a prediction model, wherein the prediction model predicts an aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,
- (C) measuring temperature and wetness values at measurement time points,
- (D) linking the temperature and wetness values to the measurement time points,
- (E) calculating an infection rate on the basis of the temperature and wetness values and the measurement time points with the aid of the prediction model,
- (F) comparing the infection rate with a threshold value, wherein the threshold value specifies an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on an *Allium* crop,
- (G) outputting a message in case the calculated infection rate reaches and/or is higher than the threshold value.

[0009] A second subject is a system comprising:

- a sensor unit having a temperature- and a wetness sensor and a transmitting unit, and
- a computer system having a receiving unit
- wherein the sensor unit is configured to record temperature- and wetness values using the temperature- and wetness sensor at measurement time points,
- wherein the sensor unit is configured to send the temperature- and wetness values using the transmitting unit,
- wherein the computer system is configured to receive the temperature- and wetness values using the receiving unit,
- wherein the computer system is configured to calculate a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the aid of a

prediction model of the temperature- and wetness dependent infection rate of *Stemphylium vesicarium* and to compare the calculated value with the threshold value,

- wherein the prediction model predicts an infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,
- wherein the temperature- and wetness dependent parameter is an infection rate,
- wherein the threshold value is an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on the *Allium* crop,
- wherein the computer system is configured to generate a message when the calculated infection rate reaches and/or is higher than the threshold value.

**[0010]** A third subject is a computer program product comprising a program code which is stored on a data carrier and which causes a computer system comprising a main memory to execute the following steps when the program code is loaded into the main memory,

- receiving temperature- and wetness values which have been recorded at measurement time points,
- calculating a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the aid of a prediction model of the temperature- and wetness dependent infection rate of *Stemphylium vesicarium*,
- wherein the prediction model predicts an infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,
- wherein the temperature- and wetness dependent parameter is an infection rate,
- comparing the calculated temperature-dependent parameter with a defined threshold value,
- wherein the threshold value is an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on the *Allium* crop,
- generating a message when the temperature- and wetness dependent infection rate reaches and/or is higher than the defined threshold value.

**[0011]** A fourth subject is a kit comprising the computer program product and a control agent against *Stemphylium vesicarium*, preferably a fungicide and/or a sensor unit with a temperature- and wetness sensor and a transmitting unit.

**[0012]** The invention will be more particularly elucidated below without making a distinction between the subjects of the invention (system, method, computer program product, kit). The following elucidations are intended to apply analogously to all the subjects of the invention, irrespective of in which context the elucidations are made.

**[0013]** If, in the present description or in the claims, steps are mentioned in a sequence, this does not necessarily mean that the invention is restricted to the stated sequence. It is conceivable that the steps can be executed in a different sequence as well or in parallel to one another as well; an exception is if one step builds on another step, this making it absolutely necessary for the building step to be executed in a subsequent manner (this, however, being clear in individual cases). The stated sequences are thus preferred embodiments of the present invention.

**[0014]** The present invention provides means for the efficient control of *Stemphylium vesicarium*, a fungal pathogen causing important diseases in *Allium* crops. The term "*Stemphylium vesicarium*" is herein used to refer to *Stemphylium vesicarium* (conidia) as well as to *Pleospora allii* (ascospores).

**[0015]** A major element of the method/system is a temperature sensor. It is used to measure the temperature of the air in proximity to the *Allium* crop and preferably near the plants canopy (e.g. within a distance of 0.5 m to 20 m or 1 m to 10 m) to the *Allium* crops that can be potentially infected by *Stemphylium vesicarium*.

**[0016]** Another major element is a wetness sensor which measures the wetness duration on leaves. Leave wetness sensors are known to the skilled person in the art (see e.g. Leaf Rainfall Sensor from Decagon Devices, Inc.).

**[0017]** The temperature- and wetness sensor are installed in proximity to the *Allium* crop, preferably near the plants canopy (e.g. within a distance of 0.5 m to 20 m or 1 m to 10 m of the plants canopy).

**[0018]** Preferably, the temperature- and wetness sensor is a component of a sensor unit which records temperature- and wetness values automatically after the starting-up and transmits the data to a computer system by means of a transmitting unit.

**[0019]** The system according to the invention can comprise one or more temperature- and/or wetness sensors. The system according to the invention can comprise one or more sensor units. One sensor unit can comprise one or more temperature-and/or wetness sensors.

**[0020]** Preferably, the sensor unit has a unique identifier. The unique identifier can be a number or an alphanumeric code or a binary code or the like. The unique identifier serves for the identification of the sensor unit when it is registered.

**[0021]** The sensor unit has a transmitting unit. It is also conceivable that multiple sensor units share a common transmitting unit. The recorded temperature values are transmitted to an external computer system via the transmitting unit. Preferably, transmission is done at least in part by wireless means. Transmission via Bluetooth, WLAN, a mobile

phone network, a low-power wide-area network (LPWAN or LPN) such as, for example, a NarrowBand IoT network, by cable (e.g. via a LAN) and/or the like is conceivable.

**[0022]** Preferably, a location is assigned in each case to the one or more sensor units belonging to the system according to the invention. Usually, the location is the position at which the sensor unit records temperature- and wetness values. However, it can also be a location in the surrounding area of the sensor unit, or the location can have a fuzziness, for example by specification of a region on the Earth's surface in which the sensor unit is situated (e.g. in the form of a circle having a defined radius).

**[0023]** In a preferred embodiment, the system according to the invention has means for the determination of the location of the one or more sensor units.

**[0024]** It is conceivable that the sensor unit has a GPS sensor (GPS: global positioning system) or some other sensor of a global navigation satellite system (GNSS) that makes it possible to ascertain the location of the sensor unit.

**[0025]** An advantage of location determination by means of a global navigation satellite system is the high accuracy. The disadvantages are the relatively high component costs and the comparatively high energy demand.

**[0026]** It is also conceivable that location determination is done via the radio cell to which the transmitting unit of the sensor unit is connected. Such a solution usually has a lower accuracy in location determination, but is associated with lower component costs and a lower energy demand.

**[0027]** In mobile communications, the simplest means of location determination is based on the cell in which a transmitting unit is situated being known. Since a switched-on mobile phone is associated with a base station, the position of the mobile phone can be assigned to at least one mobile radio cell (cell ID).

**[0028]** With the aid of GSM (global system for mobile communications), the location of a transmitting unit can be accurately determined to several hundred metres. In cities, the location can be accurately determined to 100 to 500 m; in rural areas, the radius increases to 10 km or more. If information about the cell ID is combined with the TA parameter (TA: timing advance), accuracy can be increased. The higher this value, the further away the transmitting unit from the base station. Using the EOTD method (EOTD: enhanced observed time difference), it is possible for a transmitting unit to be located even more accurately. In this case, the time differences of the signals between the transmitting unit and multiple receiving units are determined.

**[0029]** In a preferred embodiment, transmission of the temperature- and wetness values and location determination are done via the GPRS network.

**[0030]** It is also conceivable that the location of a sensor unit is recorded when the sensor unit is registered.

**[0031]** One registration step consists in the linking of sensor unit and location. It is conceivable that a user, by means of a (mobile) computer system, records the unique identifier of the sensor unit and links said identifier to location information. The record of the unique identifier can, for example, be done by input via an input means (e.g. a keyboard, a touchscreen, a mouse, a microphone (by speech input) or the like). Preferably, the unique identifier is present in the form of an optically readable code (e.g. a barcode or a matrix code or the like) or in the form of a wirelessly readable electronic memory (e.g. as an RFID tag) or the like. This has the advantage that the unique identifier can be read automatically and input errors (such as in the case of typing via a keyboard by a user) are avoided. The optical code can, for example, be recorded by using a camera, which can be a component of the (mobile) computer system. In a further step, the location is determined. It is conceivable that the means for location determination is provided by the (mobile) computer system of the user. The mobile computer system can, for example, be a smartphone which can be used to determine the location via the radio cell to which the smartphone is connected or via a GPS sensor belonging to the smartphone.

**[0032]** When the unique identifier is recorded and the location is determined, these items of information can be linked together. As a result of the linkage, a location is assigned to the sensor unit. It is conceivable that the linked items of information are transmitted to an external computer system via a network and are stored in said computer system. It is also conceivable that the linked items of information are stored on the (mobile) computer system of the user.

**[0033]** Preferably, during the registration, the unique identifier of the sensor unit is additionally linked to a unique identifier of the user, with the result that an individual sensor unit (or multiple sensor units) having a defined location is assigned to the user. Preferably, the user can, as a consequence of this linkage, only record temperature- and wetness values from the sensor unit assigned to him/her or access information based on temperature- and wetness values which were recorded by the sensor unit assigned to him/her.

**[0034]** After start-up, the sensor unit records temperature- and wetness values with the aid of the temperature- and wetness sensor(s) and transmits them to an external computer system by means of the transmitting unit. In this connection, the record of temperature- and wetness values and/or the transmission of temperature- and wetness values can be done regularly or irregularly. Preferably, the temperature- and wetness is measured multiple times during the day (including at night), preferably once every hour. The transmission of the temperature values can be done immediately after record of a temperature- and wetness value; however, it is also conceivable that the temperature and/or wetness values recorded within a defined period are transmitted together. Preferably, temperature- and wetness values are transmitted at least once a day.

**[0035]** Preferably, the individual temperature- and wetness values have assigned to them time points at which they were recorded (measurement time points). This assignment can be done during record or at a later time point. It can be done before or after transmission. In one embodiment of the present invention, a temperature- and wetness value is recorded, the particular measurement time point is determined and the recorded temperature- and wetness value is linked to the determined measurement time point. The linked data can then be transmitted together. In another embodiment, a temperature- and wetness value is recorded and transmitted. The linkage to a measurement time point is done on the external computer system. Then, for example, the arrival times of the transmitted data packets can be used as approximate values for the measurement time points. Further possibilities are conceivable.

On the external computer system, the infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop is modelled based on the transmitted temperature- and wetness values and the associated measurement time points.

**[0036]** Depending on the temperature- and wetness, an infection process (calculated as an infection rate) on the *Allium* crop plant and therefore the development of the fungal disease Stemphylium Leaf Blight on the crop plant is predicted.

**[0037]** The "infection rate" is preferably calculated as a function of recorded temperature- and wetness values and the measurement time points. Preferably, the infection rate is the sum of the infection risk values at different cycles of infection. Each infection cycle is calculated as a function of measured temperature and wetness (number of hours) values wherein a cycle is initiated with the first hour of wetness detected and is accumulated until a dry period occurs (i.e., a consecutive period of 24 hour in which no wetness is recorded), leading to the end of the infection cycle.

**[0038]** In another embodiment the crop that is used to model the infection rate of aerial inoculum of *Stemphylium vesicarium* is selected from the group of *Allium* spp. such as *sativum* (garlic), *Allium cepa* (onion), *Allium cepa* var. *aggregatum* (shallot), *Asparagus officinalis* (asparagus), *Glycine max* (soyabean), *Mangifera indica* (mango), *Pyrus communis* (European pear), and *Solanum lycopersicum* (tomato), *Allium ampeloprasum* (leek). In a particular preferred embodiment, the crop is *Allium sativum* (garlic).

**[0039]** In a preferred embodiment, the monitoring of temperature- and wetness (and the modelling with the prediction model) is started at the time point at which crop plants are planted.

**[0040]** The prediction model can, then, be configured such that it continuously calculates the infection rate on the basis of the transmitted temperature- and wetness values and the measurement time points and compares the calculated infection rate with a threshold value, wherein the threshold value specifies an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on the *Allium* crop. The threshold value is calculated by using a logistic equation with infection risk and accumulated infection risk as explanatory variables. By running this equation, the accumulated infection rate can be grouped into three infection risk groups (low risk of infection, moderate risk of infection and high risk of crop damage). Each group is associated with a certain accumulated infection rate value. A decision regarding the control of *Stemphylium vesicarium* on an *Allium* crop needs ideally be taken when the risk rises from moderate to high. However, the threshold value can also take into account the steepness of the accumulation of the infection rate value within a certain time period and can indicate that a decision in regard to the control of *Stemphylium vesicarium* on an *Allium* crop needs to be taken even though the value of a high infection rate risk has not yet been achieved.

**[0041]** The information provided by the prediction model will help growers to decide the best time for the application of a control agent - such as a fungicide - which effectively controls the *Stemphylium vesicarium*. According to the invention, a message is generated according the infection risk level. The message can indicate the change in the infection risk level helping the user to decide if an action to control *Stemphylium vesicarium* is needed.

**[0042]** For the prediction model, it is possible to use, besides the temperature- and wetness values and the associated measurement time points, further parameters, such as, for example, wind speed, solar radiation, the species of the cultivated crop plant. It is conceivable that the user of the computer program product according to the invention inputs such parameters into the computer program and/or that such parameters are read from a database. It is conceivable that, in such a database, such parameters have been deposited for a multiplicity of locations and/or regions. It is conceivable that one or more of the parameters are read from the database after the location of the sensor unit has been determined and linked to said sensor unit. It is conceivable that one or more of the parameters are recorded by one or more further sensors (such as sensors for wind, solar radiation and the like).

**[0043]** The computer program according to the invention informs the user when the infection rate has reached the defined threshold value.

**[0044]** In a preferred embodiment, the user of the computer program according to the invention is informed, even before the defined threshold value is reached, that the infection rate is approaching the defined threshold value meaning that the user is enabled to act very early to control the pathogen. For example, it is conceivable that the user is, at one or more defined values of the ratio of the infection rate to the defined threshold value, sent one or more messages, for example when the infection rate has reached 80% and/or 90% and/or 95% or some other percentage of the defined threshold value.

**[0045]** In a preferred embodiment, the progress of the infection rate is continuously displayed for the user on a screen of the system according to the invention, for example in the form of a progress bar figure.

**[0046]** Messages about the threshold value being reached and/or other messages can be displayed for the user, for example via a screen, and/or communicated by voice message via a speaker. It is also conceivable that the user is alerted by a signal (e.g. a sound or a vibration alarm) to a new message, which is then displayed on a screen as a text message, possibly together with graphic elements. However, it is also conceivable that the user actively retrieves a message, for example by starting the computer program according to the invention.

**[0047]** Preferred embodiments of the present invention are:

1. Method for controlling *Stemphylium vesicarium*, comprising the further step of applying a control agent against the pathogen based on the infection rate and the threshold value, preferably applying a fungicide treatment.

2. Method, wherein the crop is selected from the group of *Allium spp.* specifically *Allium sativum* (garlic).

3. Method, wherein the steps of measuring temperature- and wetness values at measurement time points, linking the temperature- and wetness values to the measurement time points, calculating an infection rate, comparing the infection rate with a threshold value, outputting a message in case the calculated infection rate reaches and/or is higher than the threshold value and the potential further step of applying a control agent are repeated during the vegetation period of the crop planted in the ground.

4. Method comprising the following steps: providing a sensor unit comprising a temperature- and wetness sensor; introducing the temperature- and wetness sensor in proximity to the *Allium* crop; starting up the sensor unit; ascertaining the location of the sensor unit; ascertaining further location-dependent parameters such as, for example, wind, solar radiation, on the species of the cultivated crop plant; modelling the infection rate of aerial inoculum of *Stemphylium vesicarium* on the *Allium* crop on the basis of the temperature- and wetness values, the measurement time points and one or more of the further location-dependent parameters.

5. Method comprising the following steps: providing a sensor unit comprising a temperature- and wetness sensor; introducing the temperature- and wetness sensor in proximity to the *Allium* crop; starting up the sensor unit; ascertaining the location of the sensor unit; ascertaining a unique identifier of the sensor unit; linking the location of the sensor unit to the unique identifier; ascertaining user data; linking the user data to the unique identifier of the sensor unit; displaying the location of the sensor unit on a screen of the user.

6. Method comprising the following steps: providing a sensor unit comprising a temperature- and wetness sensor; introducing the temperature- and wetness sensor in the proximity to the *Allium* crop; starting up the sensor unit; ascertaining a unique identifier of the sensor unit; ascertaining user data; linking the user data to the unique identifier of the sensor unit; displaying the location of the sensor unit and/or displaying temperature- and wetness values which are recorded using the sensor unit and/or displaying a result of the modelling of the infection rate, which result is based on the temperature- and wetness values which are recorded using the sensor unit, on a screen of the user.

7. System comprising a sensor unit having a temperature- and wetness sensor and a transmitting unit, and a computer system having a receiving unit; wherein the sensor unit is configured to record temperature- and wetness values using the temperature- and wetness sensor at measurement time points; wherein the sensor unit is configured to send the temperature- and wetness values using the transmitting unit; wherein the computer system is configured to receive the temperature- and wetness values using the receiving unit; wherein the computer system is configured to calculate a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the aid of a prediction model of the temperature- and wetness dependent infection rate of aerial inoculum of *Stemphylium vesicarium* and to compare said parameter with a defined threshold value; wherein the computer system is configured to generate a message when the temperature- and wetness dependent parameter reaches and/or is higher than the defined threshold value.

8. System comprising a first computer system, and a second computer system; wherein the first computer system is configured to receive temperature- and wetness values and measurement time points, to calculate a temperature- and wetness dependent parameter, to compare the calculated temperature- and wetness dependent parameter with a defined threshold value and to then transmit a message to the second computer system when the temperature- and wetness dependent parameter reaches and/or is higher than the defined threshold value; wherein the second computer system is configured to receive the message and to display it to a user.

9. System comprising means for linking the sensor unit to a user; wherein the computer system is configured to display to the user only that information which is based on temperature- and wetness values which are recorded

using the sensor unit linked to the user.

10. System comprising means for determining the location of the sensor unit; a unique identifier, by means of which it is possible to identify the sensor unit; means for linking the location of the sensor unit to the unique identifier.

11. Computer program product comprising a program code which is stored on a data carrier and which causes a computer system comprising a main memory to execute the following steps when the program code is loaded into the main memory: receiving temperature- and wetness values which have been recorded at measurement time points; calculating a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the aid of a prediction model of the temperature- and wetness dependent infection rate of *Stemphylium vesicarium*; comparing the calculated temperature- and wetness dependent parameter with a defined threshold value; generating a message when the temperature- and wetness dependent parameter reaches and/or is higher than the defined threshold value.

**[0048]** The invention will be more particularly elucidated below on the basis of figures and examples, without there being any intention to restrict the invention to the features and combinations of features in the figures and examples.

**[0049]** Figure 1 shows schematically one embodiment of the system. The system comprises a sensor unit (10) and a computer system (20).

**[0050]** The sensor unit (10) comprises a control unit (11) for controlling the sensor unit (10). The control unit (11) controls, for example, the record of measurement values, the linkage of the measurement values to the measurement time points and the transmission of data.

**[0051]** The sensor unit (10) comprises a timer (13) which makes it possible to ascertain the current time (date, time).

**[0052]** The sensor unit (10) comprises a temperature sensor (15a) which makes it possible for the sensor unit (10) to measure temperatures at measurement time points. The sensor unit (10) comprises a wetness sensor (15b) which makes it possible for the sensor unit (10) to measure wetness at measurement time points. The control unit (11) links the measured temperature- and wetness values to the associated measurement time points. The sensor unit (10) further comprises a transmitting unit (12) which makes it possible to transmit the measured temperatures and the associated measurement time points to the computer system (20).

**[0053]** The computer system (20) comprises a control and processing unit (21) for controlling the computer system (20) and for carrying out calculations. The computer system (20) comprises a receiving unit (22) which makes it possible to receive temperature- and wetness values and the associated measurement time points that are transmitted by the transmitting unit (12). The computer system (20) has a permanent memory (23) in which data such as, for example, one or more defined threshold values and one or more models relating to the infection with *Stemphylium vesicarium* are stored. A component of the control and processing unit (21) is a main memory (24) into which it is possible to load data and models from the permanent memory (23) as well as the transmitted temperature- and wetness values and measurement time points. On the basis of the data and the transmitted values, the control unit calculates a temperature- and wetness dependent infection rate of *Stemphylium vesicarium* with reference to a prediction model and compares said infection rate with a threshold value. When the infection rate reaches and/or is higher than the threshold value, the control and processing unit (21) generates a message. Said message can be outputted to a user via an output unit (26). The output unit (26) has, to this end, one or more output means, such as, for example, a screen, a printer, a permanent memory, a speaker, a connection to a further computer system and/or the like.

**[0054]** A further component of the computer system (20) is an input unit (25) via which a user can input data and commands. The input unit (25) has one or more input means, such as, for example, a mouse, a touchscreen, a keyboard, a microphone and/or the like. The output unit (25) and the input unit (26) serve for the communication of the computer system (20) with a user.

**[0055]** Figure 2 shows schematically a further embodiment of the system. The system comprises a sensor unit (10), a first computer system (20) and a second computer system (30).

**[0056]** The sensor unit (10) in Figure 2 is similar to the one depicted in Figure 1.

**[0057]** The first computer system (20) serves for the modelling of the infection rate of *Stemphylium vesicarium*; it is preferably realized as a stationary computer system (server). The second computer system (30) serves for the communication with a user (client). It can be realized as a stationary and/or mobile computer system (30).

**[0058]** The first computer system (20) receives the temperature- and wetness values transmitted from the transmitting unit (12) and the associated measurement time points with the aid of a receiving unit (22). Loaded into a main memory (24) of the control and processing unit (21) is a prediction model which models the infection rate of *Stemphylium vesicarium*. The computer system (20) is configured such that it calculates a temperature- and wetness dependent infection rate of *Stemphylium vesicarium* on the basis of the received values and compares said development parameter with a defined threshold value. The computer system (20) is further configured such that it generates a message when the temperature- and wetness dependent parameter reaches and/or is higher than the defined threshold value. The computer

system (20) is further configured such that it transmits the message to the second computer system (30) via a transmitting unit.

**[0059]** The second computer system (30) receives the message with the aid of the receiving unit (32). Via the output unit (36), the message can be outputted to a user, for example by means of a display on a screen. The second computer system (30) further has an input unit (35), a control and processing unit (31) comprising a main memory (34), and a permanent memory (33).

**[0060]** Figure 3 shows a further embodiment of the system. The system comprises a sensor unit (10) having temperature- and wetness sensors (15a, 15b). Planted in the soil (2) are *Allium* crop plants (1) which can be infected by *Stemphylium vesicarium*. The sensor unit (10) has a housing (14) with control panel. Introduced into the housing (14) are a transmitting unit and a control unit (not shown). The housing (14) is mounted on a mounting unit (3). The housing (14) with control panel is mounted so as to be elevated with respect to the soil (2), with the result that a user can operate the instrument relatively easily. The system further comprises an external computer system (20) which is realized as a server. The external computer system (20) is connected to a database (23). The system further comprises a second computer system (30) which is realized as a smartphone. The sensor unit (10), the first computer system (20) and the second computer system (30) are connected to one another via a network (40). Via the network (40), temperature- and wetness values and measurement time points are transmitted from the sensor unit to the first computer system (30). There, an analysis of the values and a modelling of the infection rate of *Stemphylium vesicarium* take place. The results of the analysis and modelling are transmitted to the second computer system (30) via the network (40). It is also conceivable that the sensor unit (10) and the first computer system (30) are connected to one another via a first network, whereas the second computer system (30) and the first computer system (20) communicate with one another via a different, second network.

**[0061]** Figure 4 shows a further embodiment of the system. In contrast to the embodiment shown in Figure 3, the system shown in Figure 4 has only one computer system (30), which is realized as a smartphone (but which can also be realized as a table computer, desktop computer, smartwatch or the like). The computer system (30) receives the values recorded and transmitted by the sensor unit (10), models the infection rate of *Stemphylium vesicarium* and displays the result of the modelling preferably on a screen.

**[0062]** Figure 5 shows a further embodiment of the system. The system comprises a sensor unit (10), a computer system (20) and an application system (50). Temperature- and wetness values and measurement time points are transmitted from the sensor unit (10) to the computer system (20) via a network (40). On the basis of the transmitted values, the computer system (20) models the infection rate of *Stemphylium vesicarium*; more particularly, the computer system (20) calculates a temperature- and wetness dependent infection rate parameter of *Stemphylium vesicarium* and compares it with a defined threshold value. When the infection rate parameter reaches and/or is higher than the threshold value, the computer system (20) generates a message and sends it to the application system (50). The application system (50) applies a control agent for controlling the nematodes.

**[0063]** Figure 6 shows schematically one embodiment of a sensor unit (10). The sensor unit (10) has a housing (14) into which a transmitting unit and a control unit are introduced (not shown). The sensor unit (10) comprises a temperature sensor (15a) and a wetness sensor (15b). A switch (17) is used to switch on and switch off the sensor unit (10). A signal light (16) can display the status of the sensor unit (10). Situated on the housing (14) is an optically readable code (18) having a unique identifier.

**[0064]** Figure 7 shows schematically a registration procedure for registering a new sensor unit. By pressing the on/off switch (17), the sensor unit (10) is started up. It connects automatically to a server (20) via a network (40a) and transmits a unique identifier, by means of which the sensor unit (10) can be unambiguously identified. Furthermore, the location of the sensor unit (10) is ascertained in an automatic manner, for example via a GPS sensor, which can be a component of the sensor unit (10), or via the radio cell in which the sensor unit (10) is situated. The location of the sensor unit (10) is transmitted to the server (20), too. Unique identifier and location are stored together in a database (23). The signal light (16) indicates that the sensor unit (10) has been started up and location and unique identifier have been transmitted. From then on, the sensor unit records temperature- and wetness values and transmits them together with the associated measurement time points to the server (20).

**[0065]** In a further step, the sensor unit is linked to a user. In the present case, the linkage to the user is done by means of a second computer system (30) which is realized as a smartphone. The user starts the computer program. Said user is prompted to record the optically readable code (18) with the aid of the camera belonging to the smartphone; the screen of the smartphone displays a live image. The user holds the camera in front of the optical code and generates a recorded image (70) of the code. It is also conceivable that the recorded image is generated automatically once the smartphone has recognized that an optically readable code is represented on the sensor chip of the camera. The recorded image (70) is analysed and the optically readable code is interpreted. Said code comprises the unique identifier. The smartphone sends the unique identifier together with user data to the server (20) via a network (40b). The server stores the sent information in the database (23) in relation to the data already stored for the sensor unit (10). A location and a user are now assigned to the sensor unit.

[0066] Figure 8 shows a graph of a prediction model which models the infection rate of aerial inoculum of *Stemphylium vesicarium* on garlic. The prediction model calculates the infection rate on an hourly basis according to following equation of the formula (I):

$$INF = \frac{\frac{0.449+1}{0.449} \times 0.449^{\frac{1}{0.449+1}} \times e^{\frac{(T-20) \times 0.642}{0.449+1}}}{1 + e^{(T-20) \times 0.641}} \times \frac{1}{1 + e^{7.661 - 0.312 \times WD}} \quad (I)$$

wherein,

"T" stands for temperature (in °C),

"WD" stands for hours of wetness, preferably for hours of leave wetness,

"INF" stands for the infection rate.

[0067] The hours of wetness are taken into account by the prediction model if the rainfall is above 0.2 mm/m<sup>2</sup> in one hour. The "WD" value in the above equation according to formula (I) WD increases by 1 if wetness occurs in an hour and remains at the previous value when no wetness occurs in an hour.

[0068] Figure 9 shows that one cycle of infection rate calculation with the equation of the formula (I) as outlined in Figure 8 runs until the appearance of 24 hours of continuous dryness (preferably rainfall at or below 0.2 mm/m<sup>2</sup> in one hour). Then, the cycle is terminated and the calculation of the infection rate for this cycle stops.

[0069] Another cycle of infection rate calculation (2<sup>nd</sup> cycle of INF calculation) starts when it rains again (however, with at least 5 hours of difference with the previous cycle of infection rate calculation). Thus, several cycles of hourly infection rate calculations with the above formula can run at the same time. In this example, 3 cycles of INF calculation run in parallel until the WD value is 0 for a period of 24 hours.

[0070] If more than one cycle of infection rate calculations run in parallel all values of each hourly infection rate for each cycle are summed up to result in one value for a particular hour.

[0071] The INF (hourly infection rate) values as calculated according to the equation formula (I) are summed up over a period of time (this value is herein referred to as "Σ INF") such as over spring from February to August, or from March to July, or from May until to the end of June.

[0072] Figure 10 shows by way of example a screen display of the second computer system (30) realized as a smartphone and in operation after registration. In the lower area, an overview map of the environment in which the sensor unit is situated is displayed. A label (72) indicates the location of the sensor unit. In the middle and upper area, the temperature (70) and wetness (71) which is measured using the sensor unit is displayed as a function of time. In the present example, the individual temperature and wetness values, which have been recorded at individual measurement time points, are displayed as small circles; a spline function connects the points to one another. In the lower area, one virtual button (73), by means of which various models of the infection rate *Stemphylium vesicarium* can be started, are displayed.

[0073] Figure 11 shows by way of example a screen display of the second computer system (30) realized as a smartphone and in operation after registration and of the pressing the virtual button (73) from Figure 9. As already depicted in Figure 9, an overview map of the environment of the sensor unit with a label (72) of the location of the sensor unit is displayed at the lower part of the screen. In the upper part of the screen (74) the comparison of the accumulated infection rate value (as calculated with a prediction model with the temperature- and wetness values obtained by the sensor) and a threshold value is shown. The threshold value is a predefined infection rate value. The accumulated infection rate values can be grouped into three risk groups (low risk, moderate risk and high risk). Each group is associated with a certain accumulated infection rate value (Σ INF value). Following group classifications can be made: the low risk group has a Σ INF value of between 0 to 0.5; the moderate risk group has a Σ INF value of between 0.5 to 1.5 and the high risk group has a Σ INF value of above 1.5. A decision in regard to the control of *Stemphylium vesicarium* on a crop needs ideally be taken when the risk rises from moderate to high and a control agent against *Stemphylium vesicarium* can be applied.

[0074] Instead of the graph (74) it is possible to show a progress bar which indicates at which percentage the accumulated temperature- and wetness dependent infection rate parameter has already reached the defined threshold value. It is conceivable that the colour of the progress bar changes when the bar is approaching the value of 100%. For example, it is conceivable that the bar is green so long as it is situated within the range of 5% to 80%. From 81%, it can have a yellow colour, from 91% an orange colour and from 95% a red colour. Other values and other colours for the colour

transitions are conceivable.

## Claims

1. Method for controlling *Stemphylium vesicarium* on an *Allium* crop, comprising the steps of
  - (A) installing a temperature- and wetness sensor,
  - (B) providing a prediction model, wherein the prediction model predicts an infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,
  - (C) measuring temperature- and wetness values at measurement time points,
  - (D) linking the temperature- and wetness values to the measurement time points,
  - (E) calculating an infection rate on the basis of the temperature- and wetness values and the measurement time points with the aid of the prediction model,
  - (F) comparing the infection rate with a threshold value, wherein the threshold value specifies an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on an *Allium* crop,
  - (G) outputting a message in case the calculated infection rate reaches and/or is higher than the threshold value.
2. Method according to Claims 1, comprising the further step of:
  - (H) applying a control agent against *Stemphylium vesicarium* if the infection rate reaches and/or is higher than the threshold value, preferably applying a fungicide.
3. Method according to one of Claims 1 to 2, wherein the crop is selected from the group of *Allium* spp. preferably *Allium sativum* (garlic).
4. Method according to any of Claims 1 to 3, comprising the further step of:
  - (I) repeating steps (C) to (G) or (C) to (H) during the current vegetation period of the crop planted in the ground.
5. Method according to any one of Claims 1 to 4, wherein step (A) comprises the following steps:
  - (a) providing a sensor unit comprising a temperature- and wetness sensor,
  - (b) introducing the temperature- and wetness sensor in proximity to the crop,
  - (c) starting up the sensor unit,
  - (d) ascertaining the location of the sensor unit
  - (e) ascertaining a unique identifier of the sensor unit
  - (f) linking the location of the sensor unit to the unique identifier
  - (g) ascertaining user data
  - (h) linking the user data to the unique identifier of the sensor unit
  - (i) displaying the location of the sensor unit on a screen of the user.
6. Method according to any one of Claims 1 to 5, wherein step (G) comprises displaying the location of the sensor unit and/or displaying temperature- and wetness values which are recorded using the sensor unit and/or displaying a result of the modelling of the infection rate of *Stemphylium vesicarium*, which result is based on the temperature- and wetness values which are recorded using the sensor unit, on a screen of the user.
7. System comprising
  - a sensor unit having a temperature- and a wetness sensor and a transmitting unit, and
  - a computer system having a receiving unit
  - wherein the sensor unit is configured to record temperature- and wetness values using the temperature- and wetness sensor at measurement time points,
  - wherein the sensor unit is configured to send the temperature- and wetness values using the transmitting unit,
  - wherein the computer system is configured to receive the temperature- and wetness values using the receiving unit,
  - wherein the computer system is configured to calculate a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the

aid of a prediction model of the temperature- and wetness dependent infection rate of *Stemphylium vesicarium* and to compare said parameter with a threshold value,

- wherein the prediction model predicts an infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,

- wherein the temperature- and wetness dependent parameter is an infection rate,

- wherein the threshold value is an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on the crop,

- wherein the computer system is configured to generate a message when the calculated infection rate reaches and/or is higher than the threshold value.

8. System according to Claim 7, wherein the crop is selected from the group of *Allium* spp. preferably *Allium sativum* (garlic).

9. System according to either one of Claims 7 and 8, comprising a first computer system, and a second computer system,

- wherein the first computer system is configured to receive temperature- and wetness values and measurement time points, to calculate a temperature- and wetness dependent parameter, to compare the calculated temperature- and wetness dependent parameter with a defined threshold value and to then transmit a message to the second computer system when the calculated temperature-and wetness dependent parameter reaches and/or is higher than the defined threshold value,

- wherein the second computer system is configured to receive the message and to display it to a user.

10. System according to any of Claims 7 to 9, comprising means for linking the sensor unit to a user,

- wherein the computer system is configured to display to the user only that information which is based on temperature- and wetness values which are recorded using the sensor unit linked to the user.

11. System according to any of Claims 7 to 9, comprising

- means for determining the location of the sensor unit,

- a unique identifier, by means of which it is possible to identify the sensor unit,

- means for linking the location of the sensor unit to the unique identifier.

12. Computer program product comprising a program code which is stored on a data carrier and which causes a computer system comprising a main memory to execute the following steps when the program code is loaded into the main memory,

- receiving temperature- and wetness values which have been recorded at measurement time points,

- calculating a temperature- and wetness dependent parameter on the basis of the received temperature- and wetness values and the measurement time points with the aid of a prediction model of the temperature- and wetness dependent infection rate of *Stemphylium vesicarium*,

- wherein the prediction model predicts an infection rate of aerial inoculum of *Stemphylium vesicarium* on an *Allium* crop,

- wherein the temperature- and wetness dependent parameter is an infection rate,

- comparing the calculated temperature-dependent parameter with a defined threshold value,

- wherein the threshold value is an infection rate which requires a decision in regard to the control of *Stemphylium vesicarium* on the crop,

- generating a message when the calculated temperature- and wetness dependent parameter reaches and/or is higher than the defined threshold value.

13. Computer program product according to Claim 12, wherein the content of the message is that the calculated infection rate reaches and/or is higher than the threshold value.

14. Computer program product according to either of Claims 12 and 13, comprising a program code which is stored on a data carrier and which causes a computer system comprising a main memory to execute one or more steps of

the method according to any of Claims 1 to 6 when the program code is loaded into the main memory.

- 5      15. Kit comprising the computer program product according to any of Claims 12 to 14 and a control agent against *Stemphylium vesicarium*, preferably a fungicide and/or a sensor unit with a temperature-and wetness sensor and a transmitting unit.

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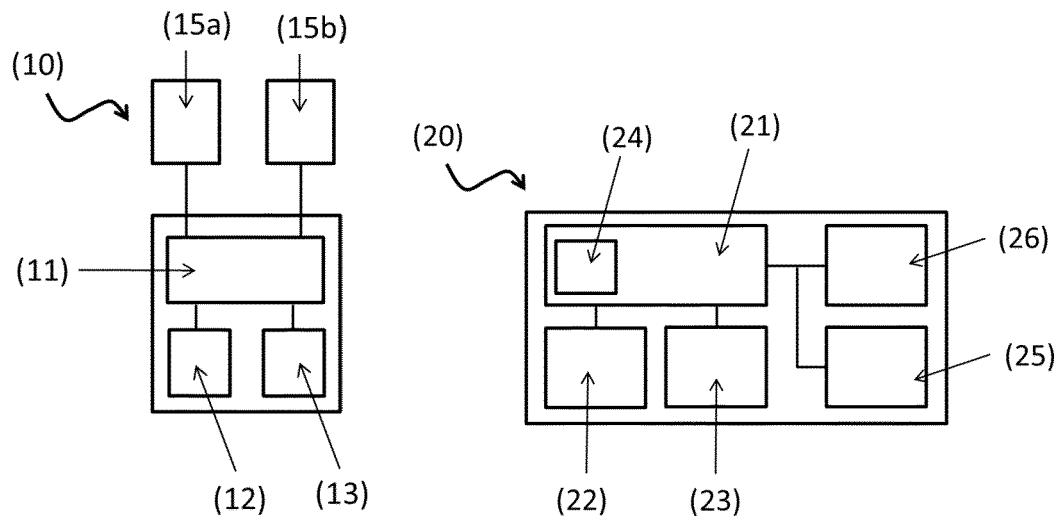


Fig. 1

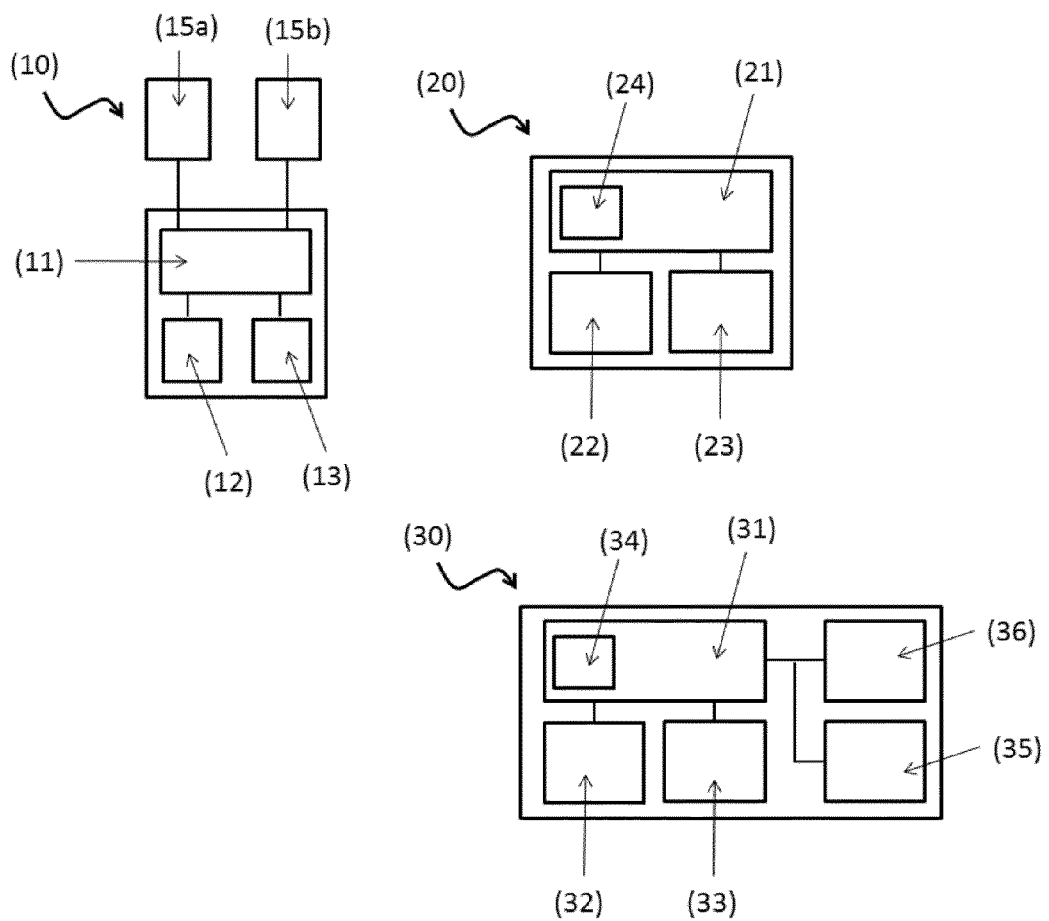


Fig. 2

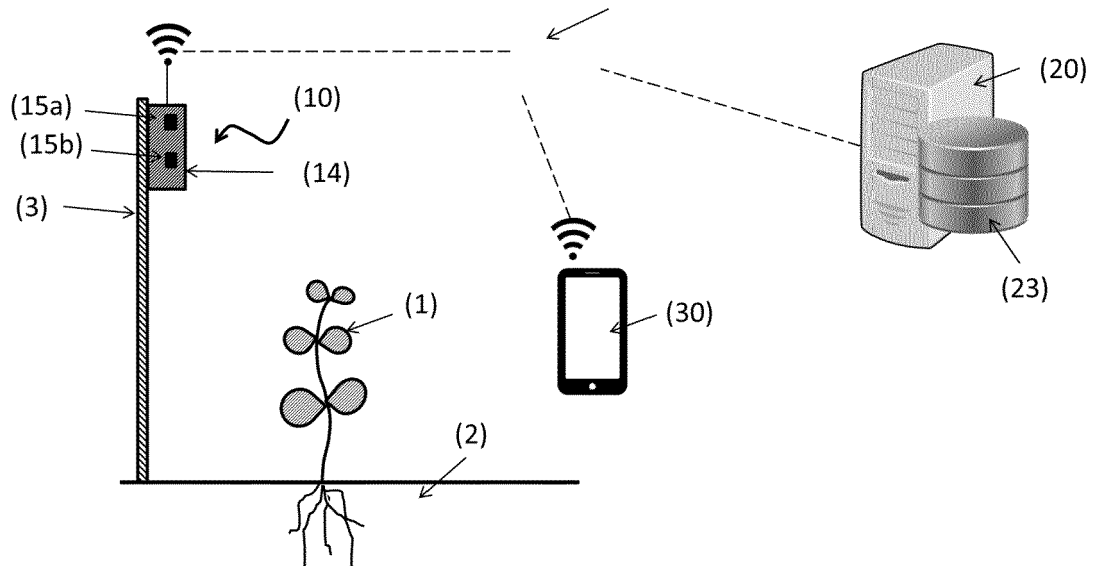


Fig. 3

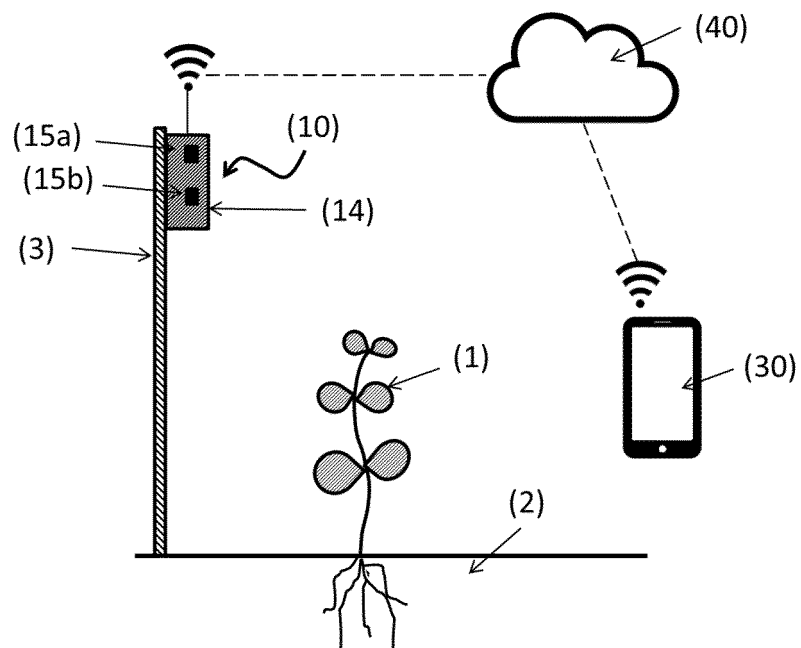


Fig. 4

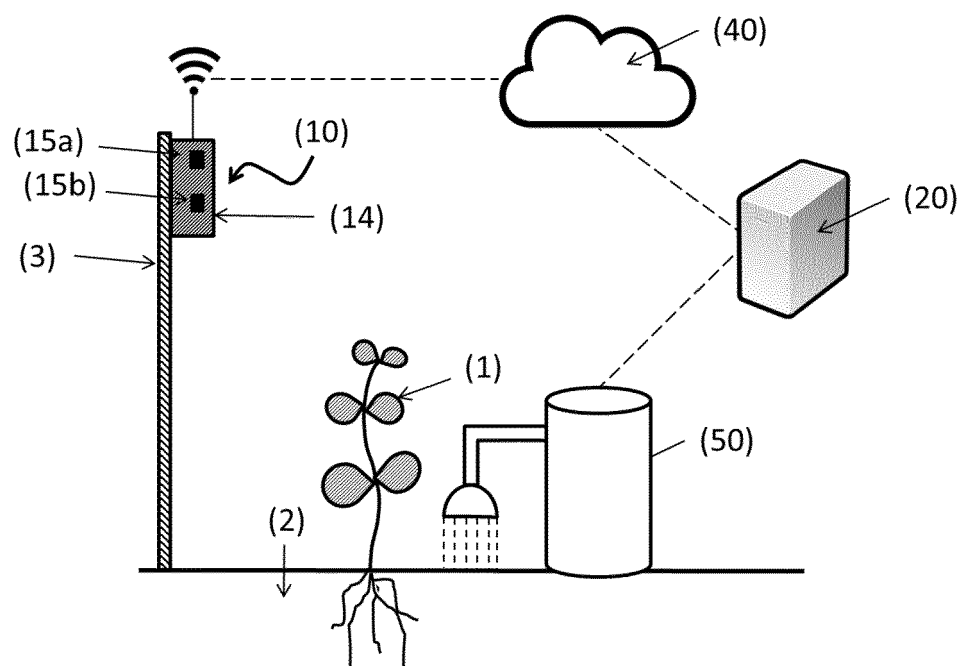


Fig. 5

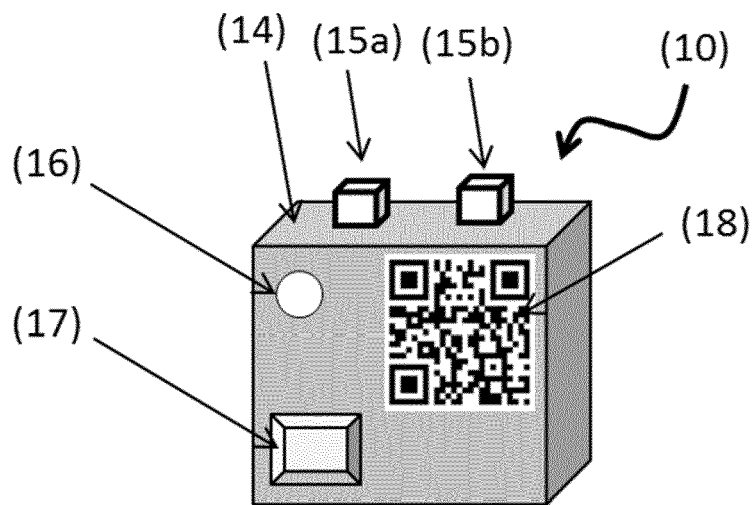


Fig. 6

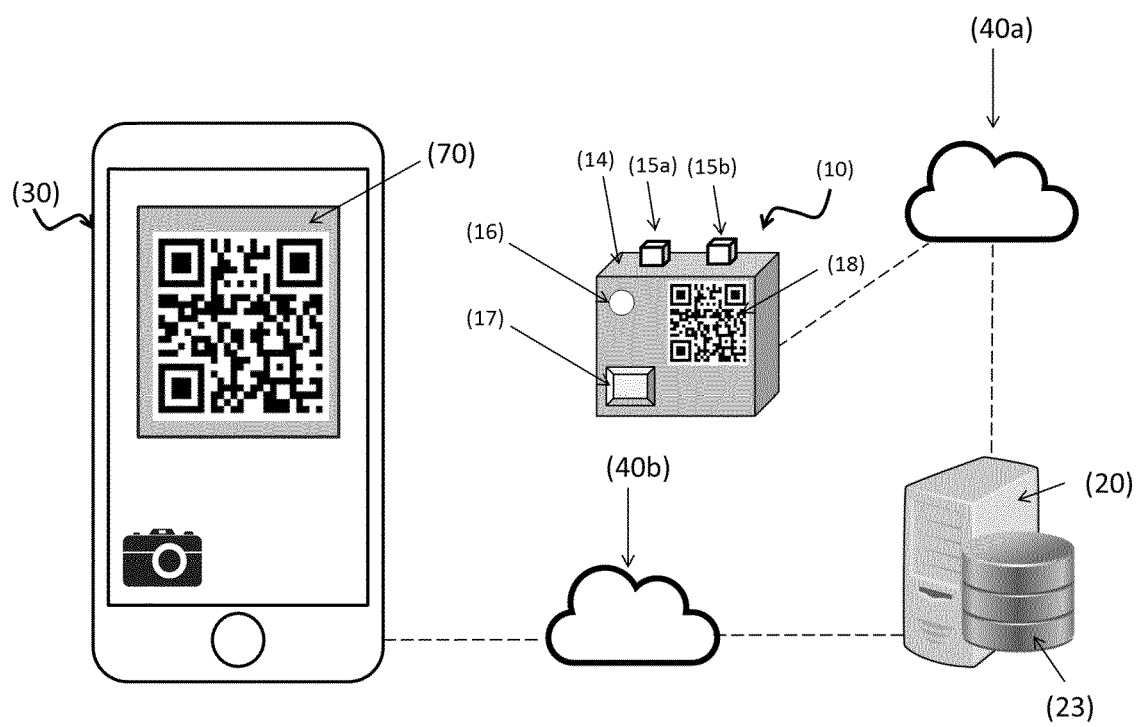


Fig. 7

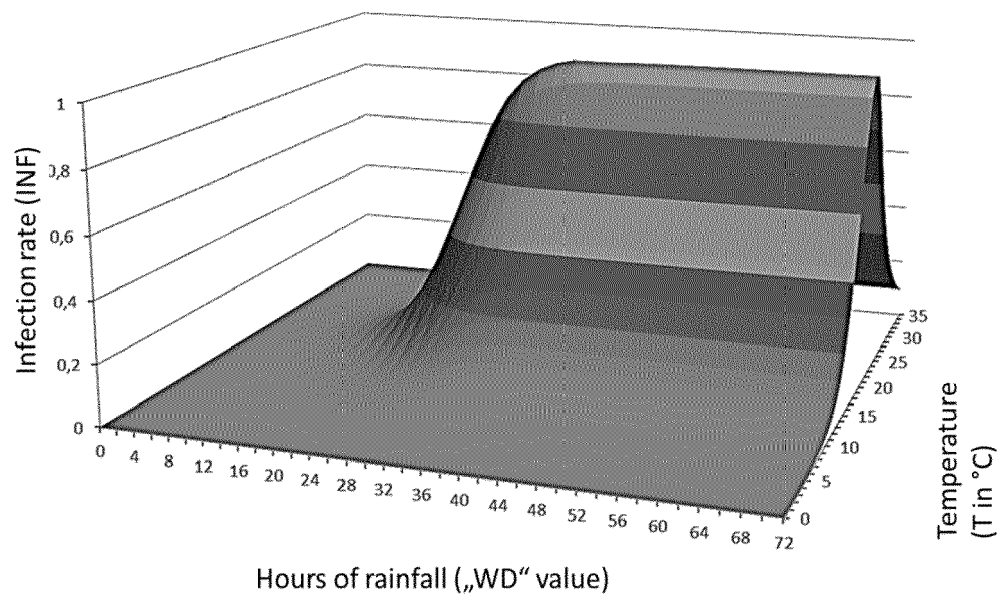


Fig. 8

| Time (plus 1 hour) | Hours of rainfall (WD) | 1st cycle of INF calculation | 2nd cycle of INF calculation | 3rd cycle of INF calculation | Σ INF                                                                                        |
|--------------------|------------------------|------------------------------|------------------------------|------------------------------|----------------------------------------------------------------------------------------------|
| 1                  | 1                      |                              |                              |                              | INF value from 1st cycle                                                                     |
| 2                  | 0                      |                              |                              |                              | INF value from 1st cycle / Sum of INF value of time 1 and time 2                             |
| 3                  | 1                      |                              |                              |                              | INF value from 1st cycle / Sum of INF value of time 1, 2 and time 3                          |
| 4                  | 1                      |                              |                              |                              |                                                                                              |
| 5                  | 0                      |                              |                              |                              |                                                                                              |
| 6                  | 1                      |                              |                              |                              | Sum of 1st (sum of INF values for time 1 to 5) and 2nd (INF value at time 6) cycle INF value |
| 7                  | 0                      |                              |                              |                              |                                                                                              |
| 8                  | 1                      |                              |                              |                              |                                                                                              |
| 9                  | 0                      |                              |                              |                              |                                                                                              |
| 10                 | 0                      |                              |                              |                              |                                                                                              |
| 11                 | 1                      |                              |                              |                              | Sum of 1st, 2nd and 3rd cycle INF value                                                      |
| 12                 | 0                      |                              |                              |                              |                                                                                              |
| 13                 | 1                      |                              |                              |                              |                                                                                              |
| ...                | ...                    |                              |                              |                              |                                                                                              |
| ...                | ...                    |                              |                              |                              |                                                                                              |
| ...                | ...                    |                              |                              |                              |                                                                                              |
| ...                | ...                    |                              |                              |                              |                                                                                              |
| ...                | ...                    |                              |                              |                              |                                                                                              |
| ...                | 24x the value of 0     | stop of INF calculation      | stop of INF calculation      | stop of INF calculation      | INF sum remains at the previous level                                                        |

Fig. 9

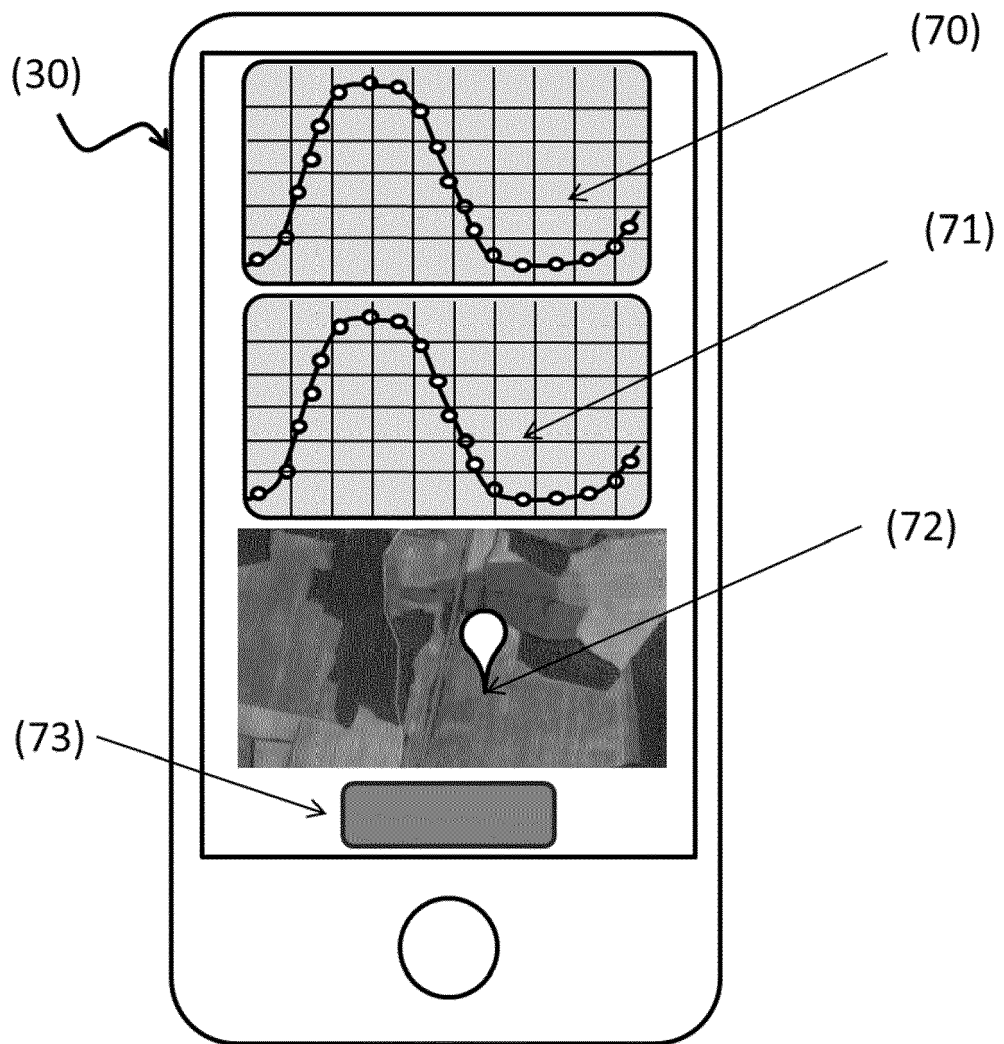


Fig. 10

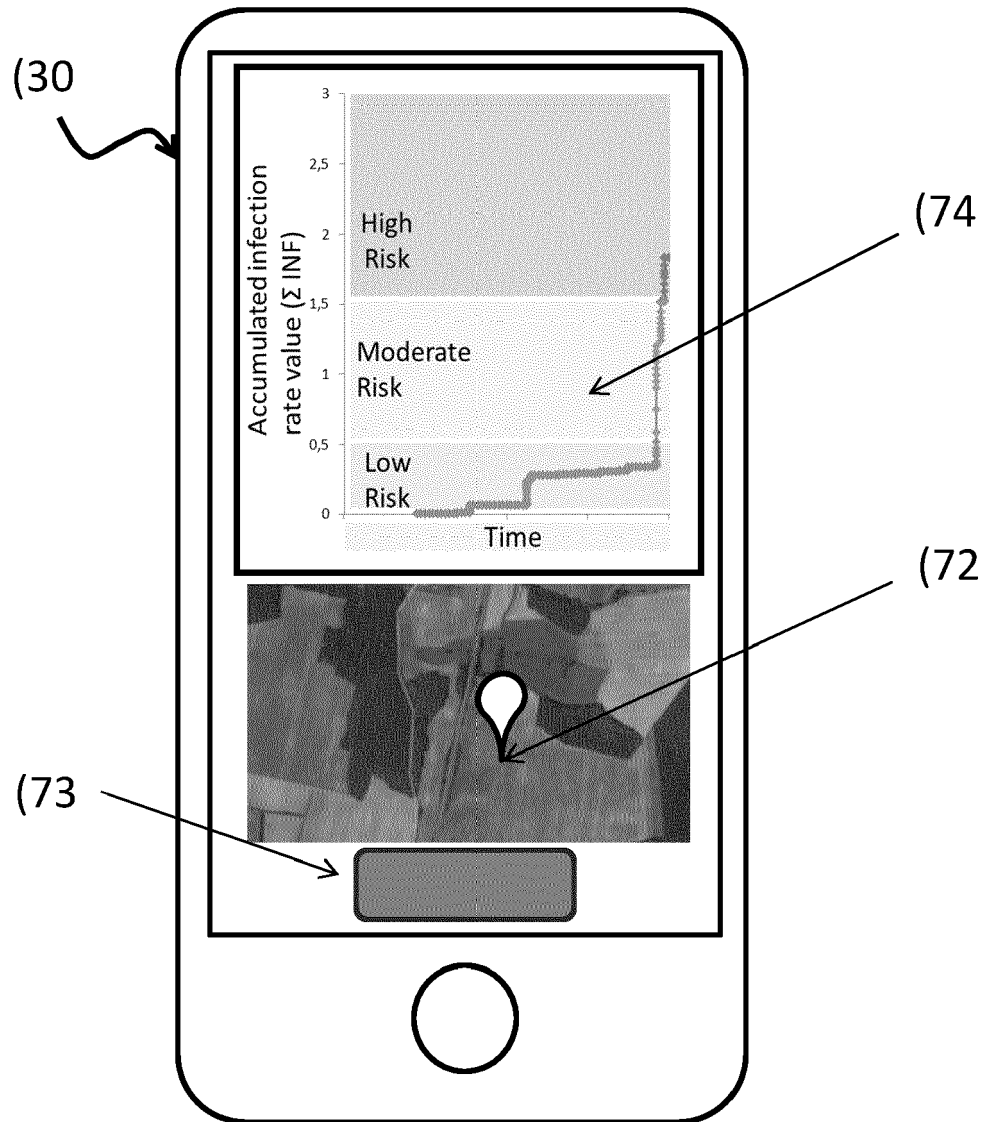


Fig. 11



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Application Number  
EP 21 15 8673

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                   |                                                  |                                         |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                   |                                                  |                                         |
| Place of search<br>The Hague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                   | Date of completion of the search<br>28 July 2021 | Examiner<br>Lozza, Mario                |
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The members are as contained in the European Patent Office EDP file on  
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