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A Fundamental Protocol for Crop Health Status Evaluation Using Bio-Ecological Digital Sensors: A Technical Note

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ABSTRACT: BACKGROUND: There is a critical need for agricultural development to make a quantum leap and for rural development to ensure food security and self-sufficiency. Modern agricultural techniques can be seen as an effective way to extend agricultural production while battling poverty and nescience. OBJECTIVES: This technical scientific note briefly explains a suggested strategy for instructing plant protection experts in using digital tools to identify diseases, pests, and physiological disorders. RESULTS: For this study, an effective comprehensive/fundamental method applies which comprises: Android and computer programs coupled with a diagnostic pattern on measurements of temperature, humidity, irrigation water, and soil. This method also considers the growing media qualities from a chemical and physical standpoint, light intensities, and plant chemical analyses. CONCLUSIONS: Before describing the most effective integrated control plan, this process must be completed based on a suggested protocol. It is the most effective and thorough way to fully ascertain the root cause of the problem.

Keywords: Plant health, Sensors, Agricultural development, Growing media, Sustainability

INTRODUCTION

According to McCartney and Lefsrud [13], one of the most important technologies for mitigating the effects of environmental factors such as high temperature, heat stress, drought, salinity, cold, frost, light stress, and nutrient deficiency is vegetable cultivation under protection. The performance of tomato and pepper seedlings under simulated environmental stresses such as non-ideal temperatures, low humidity, close spacing, minimum light dose, nutrient-deficient water, and spraying a lower salicylic acid dosage during germination, cotyledon leaves, and the first set of true leaves can be evaluated to select crop varieties [11]. In this regard, integrated pest control and organic agriculture methods have evolved in tandem with their predecessors to produce environmentally and food-health-safe food. However, the most pressing question in this regard is how to conduct open cultivation while managing climate change factors and plant resistance via integrated pest management methods.

Drought stress affects plants when water delivery to the roots becomes difficult or the plant's transpiration rate becomes extremely high [15]. The abiotic pressures of rising temperatures, reduced irrigation water supplies, and salinity are the major limiting factors in maintaining and improving vegetable output. Extreme weather patterns

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can also reduce soil fertility and worsen erosion. Additional fertilizer application or improved crop nutrient-use efficiency will be required to maintain productivity [15]. Plant vulnerability in the face of environmental conditions will result in plants with poor health and susceptibility to infection with various pests and diseases such as fungi, viruses, bacteria, nematodes, weeds, and insects, affecting both quantity and quality of production. The main determining factor and driving force for the dynamic mechanism of the interrelationship between environmental and biological factors (abiotic versus biotic stresses) is drought stress for plants and its consequence of nutrient feeding for plants. Gray leaf spots on pepper plants caused by a fungus known as (*Stemphylium solani*) have previously been documented [6]. This disease may be brought on by a complex interplay between potassium shortage and drought stress [10]. The Royal Horticultural Society [3] reported tomato disorder in which the stem end of the ripening fruit has a ring of unripe flesh around it that distinguishes the tomato greenback symptoms. The damaged flesh is green or yellow. Although low amounts of potassium and phosphorus may be at play, high temperatures and strong sunshine are probably the most crucial. This demonstrates that the hidden connections between abiotic conditions and pest infection include drought stress and nutritional deficiencies. The amount of nitrogen and potassium depends on the type of soil. Symptoms of these two nutrient deficiencies often appeared in light, sandy soils as opposed to clay-rich soils [3]. This illustrates the direct relationship between nutrient uptake and soil moisture availability. Sandier soils consume less water and require irrigation more frequently than clay-heavy soils [9]. As a result, this technical note aims to highlight the role of agricultural extension education in training plant protection doctor students to use modern electronic sensors in a comprehensive and accurate schedule to evaluate plant health status.

MATERIALS AND METHODS

Electronic sensors are taught to plant protection students within agricultural extension academic courses. The reference readings most suitable for tomato and pepper growth were reviewed and compared with those that were measured in practical teaching for comparison purposes of potting mix, water, spraying solutions, and weather conditions.

1-To train students, a 5 cm-diameter container receives 900 mL of sterilized potting mix prepared and placed in lab conditions.

2-A digital soil tester analyzer (thermometer) called Luster-leaf Rapitest brand (1835) was used to measure soil temperature. To convert to °C, the following formula used: (°F − 32) × 5/9 = 0°C.

3-Air humidity and temperature for air were measured through several devices: a hygro-thermometer clock (EXTECH 445702) and a weather station (SWS 5051). It can be used in open fields, greenhouses, gardens, laboratories, and growing chambers. Soil and air temperature and humidity measurements help explain the incidence and severity of infections caused by plant diseases and insects. To bind measurements with plant protection forecasting, electronic applications can be used (such as PLANTIX, GPS, and Excel 365).

4-Soil chemical traits and digital sensing: two devices were used to determine soil acidity (pH) and (N-P-K) content. One is traditional, with a pointer (Luster-leaf Rapitest brand 1818), and the other is digital (Luster-leaf Rapitest brand (1835)). The two devices need to be soiled with distilled water.

5-Water acidity: a distilled water sample was collected. Three devices were used to measure acidity. Pancellent brand (calibrated previously using buffers of points: 6.86, 4.01, and 9.18 respectively). Another device is VWR pH/CO 1030, and its calibration buffers are used for the same purpose. Acidity can be measured also with the HORIBA Laqua Twin pH meter (11) calibrated at two levels of buffers (7, 4).

6-Soil and water salinity: researchers and field extension specialists also make use of the Pancellent brand's salinity sensor, which is a soil sensor, and irrigation water sensor. Readings are given in mg/L or µs/cm of electrical conductivity. Each µs/cm is equivalent to 0.641 mg/L. Also, every 1000 µs/cm is 1 dS/m. In the case of measuring soil salinity, 30 mL of the pot mix was added to 60 mL of distilled water and mixed until homogeneity was achieved.

7-Soil moisture content and digital sensing: plant health is primarily determined by soil moisture content. The moisture content of the soil determines whether the plant receives nutrients. It is also a determining factor for the impact of abiotic stresses (drought, heat, salinity, and nutrient deficiencies). In this field, all types of electronic sensors aid in determining irrigation amounts and times. A dry potting mix (weight is 447 gm) was fully saturated with tap water and left to drain for 24 hours to determine water weight at field capacity (100% moisture content)

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and permanent wilting point (60%). After several weeks, tap water added to a potting mix equals 12 grams of water to maintain a consistent 60% moisture level (final water weight is 188 gm). This conventional method employs sensitive electronic scales (dyras DSFC-780WH/G) to calculate the required added amount. This amount of water (60% or 188 gm of water) can be translated using one of two types of electronic sensors. The traditional one of the Luster-leaf Rapitest (1818) (track 3) and the electronic one used by horticulturists and gardeners (Luster-leaf Rapitest 1825). Crop experts and agronomists employ a professional electronic soil moisture sensor (EXTECH MO750). Volume percentage is used in the latter device to calculate moisture by multiplying the result with the ideal soil bulk density (1.3 g /cm^3). A moisture level of (17.1%) was recorded (corresponds to 22% as a volume percentage). This sensor detects the texture of the soil.

8-Light intensity meter: Luster-leaf Rapitest (1818) (track 2) was used for this purpose. The photocell on the tester's top was pointed directly at the light source while the tester was held at leaf level. No hands, bodies, or objects were being tested between the light source and the plant position. The record was multiplied by 1000, and the time of day was collected. This was practiced three times a day (9 AM, 1 PM, and 5 PM). The number of hours is multiplied by the resultant value. After which they were totaled together to create a daily foot candle hour. An electronic auto-timer switcher (Type: Nedis-Programme, Time 02/Time 02 E) was used to program the light source. Total daily foot candle hours were measured as a total for the three period times.

9-Chemical composition of foliar spray solutions and plant sap: a spraying trial for tomato and pepper seedlings in the growing chambers with distilled water as a spray solution was done. A measurement procedure employing three HORIBA Laqua twin sensors (calcium, potassium, and nitrate) for spraying solution before spraying and for the plant sap after spraying. Each sensor was calibrated twice before use (150, and 2000 mg/L). In addition, the chlorophyll content before and after spraying was determined using a SPAD index sensor (Konica Minolta SPAD-502 Plus, Japan). Distilled water had 10 mg/L calcium, 0 potassium, and 7 mg/L nitrate.

10-The agricultural extension expert in the field of integrated pest control and management requires some software applications in the field to ensure plant health in a comprehensive protocol. The following applications were used in students' training:

10.1-PLANTIX application (3.6.7, 227-R PRO) for pests and diseases diagnosis and addressing. Help to diagnose infections by understanding weather conditions.
10.2-GPS (Global Positioning System) (2.4.05.254) for location weather data and soil traits. It aids in determining the geographical locations of specific infection severities, specific disorders (especially related to nutrient deficiency, and soil types), and integrated control measures.
10.3-EXCEL (365) for regression and correlation analyses of plant protection forecasting. It aided in linking weather factors to locations and the severity of pest infestations via mathematical models to forecast and integrate pest management procedure building-up.

11-A primitive and simple microscope is required for the initial definition of pest symptoms, and other abiotic/biotic disorders by an agricultural extension agent working in the field of integrated pest control. A pocket microscope with a magnification of 120X is recommended. Carson Micro Brite LED pocket microscope model MM-300 (60X-120X).

RESULTS AND DISCUSSION

1-Soil temperature, air temperature, and air humidity: the laboratory potting mix temperature was 16.66℃. According to the technical leaflet attached to the soil temperature sensor, tomato seeds require 10 to 37℃ to germinate, while peppers require 15.55 to 32.22℃. The ideal germination (or emergence) temperature is 26.66 ℃ for both. The temperature of the soil to transplant tomato seedlings is 15.55℃ while it is 18.33℃ for pepper seedlings. Mulvihill [14] reported that tomatoes and peppers' soil planting temperature must be 15℃, the best for growing is 15-32℃, and for germination is 15-30℃.

The lab air humidity of 51% and temperatures of 17.5°C (EXTECH 445702). However, the other device showed humidity of 54% and temperatures of 17 to 17.3°C. Zeidan [20] detailed the ideal humidity for tomato growth of 65-85% and ideal growth temperatures of 21-24℃ (maximum is 32℃). Through scientific experiments on tomato plants, [19] demonstrated that the ideal conditions for seedling growth in germination incubators are temperatures of 30℃ during the day while maintaining a constant level of relative humidity of 75%. Sanjuan-Martnez [17] on the other hand, experimented with (*Capsicum annuum*) plants grown at 25℃ and 85%-90% relative humidity for ideal growth. The recorded air humidity was not suitable for growing tomatoes and peppers.

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2-Soil fertility: the result showed that soil fertility is at the minimum for (too little) scale. Based on the scientific leaflet attached to this device, nitrogen and potash levels are lower than 50 mg/L, while phosphorus levels are lower than 4 mg/L. The digital sensor of (Luster-leaf Rapitest 1835) is more accurate, the fertility level is 3 (unitless scale) equal to minimum ideal levels of (N-P-K) which correspond to (50-4-50) mg/L. The following information was reported on the two leaflets of both devices: if the tester reads (too little), liquid feeds the plant within 3 weeks of planting or pot and repeats every month when watering. If the tester reads (ideal), water once a month with a plant-specific soluble fertilizer. Finally, if the tester reads (too much. i.e., 200-14-200 and more), thoroughly water greenhouse plants to allow excess nutrients to leach out and not fertilize.

3-Soil acidity: the pH of the soil influences macronutrient and micronutrient absorption. Except for molybdenum, micronutrient uptake capacity decreases as pH rises [4]. Conversely, as soil acidity rises, the absorption and uptake of other nutrients (macronutrients and secondary nutrients) increase such as nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium, to varying degrees and limits. As a result, trace elements (micronutrients) such as iron, manganese, boron, copper, and zinc are less effectively absorbed. The ideal soil acidity for tomatoes is (5.5-7.5). But pepper requires (5.5-7), while sweet pepper requires more than 7 (almost up to 8.5) [8]. The acidity measured in this technical note equal to 7.3 is not suitable for hot peppers (but suitable for both tomatoes and sweet peppers). However, Sainju [16] reported that the normal pH range for optimum tomato growth is 5.5 to 7.0. While Massimi and Radócz [10] reported that the ideal soil pH for peppers should be (5.5- 6).

4-Water acidity: the water acidity device after calibration gave a result of 6.40 acidity for distilled water using a Pancellent device, and an average value of 6.50 using HORIBA Laqua twin pH (11) meter. However, VWR pH/CO 1030 records an acidity of 6.54 for a distilled water sample. Water pH affects macronutrient and micronutrient absorption (like soil). This device is also used to adjust the pH of the solutions sprayed on plants, especially within foliar nutrition and pest management practices. These three devices can be ignored by taking a sample of the soil to which irrigation water (not distilled water) was added and calculating the acidity and fertility of the soil mix using a digital tool namely Luster-leaf Rapitest 1835. Generally, water acidity did not depend on water-dissolved salts as stated by [12].

5-Soil and water salinity: distilled water salinity equals 1 mg/L (almost 2 µs/cm) or (0.002 dS/m). However, the mix of pot soil with distilled water showed a salinity of 258 mg/L (402.3 µs/cm) equal to 0.4 dS/m. The salt content of the water and potting mix is significantly lower than the critical limit for tomato and pepper plants. Amacher [1] stated that plants draw less water from the soil as salinity levels rise, complicating drought stress conditions. Plants that have been exposed to salt are stunted, with dark green leaves that are thicker and more succulent than usual in some cases. The researcher concluded that when soil salinity is around 1.3 dS/m, peppers, and bell peppers start to lose their yield. Tomatoes, on the other hand, start to lose yield at a higher salinity threshold of 2.5 dS/m, indicating that peppers are more sensitive to soil salinity than tomatoes.

6-Soil moisture content: mathematical soil moisture content calculations are not economically feasible because they take a long time and rely on the weight of the water, which is calculated by subtracting the weight of the soil at 60% (permanent wilting point) moisture from the weight of the soil at 100% moisture content (field capacity). It was found that the water weight at field capacity was 314 gm and was 188 gm at the permanent wilting point. The water amount difference between the two points is known as the available water content in the soil for the plant (managed allowable depletion percent). After several weeks, the moisture content dropped 60%. It was found that the amount of tap water needed to be added to the potting mix equals 12 grams of water to maintain a consistent moisture level of 60% (water weight at this percent equals 188 gm) and the total weight of the potting mix (635 gm) without the weights of the pot and dish (67 gm). The overall weight is 702 gm. Only the weight of water is shown by the percentages of 100% and 60%. The percentage of permanent wilting goes to 42% when the percentage is calculated using the weights of the dry soil and the water. Although both results are valid in terms of science, the latter one (42%), which describes the wilting point of the potting mix, is more precise. Luster-leaf Rapitest (1825) illustrates this amount (i.e., 188 gm) as 4 (unitless scale indicates moisture level of 1-10 range). According to the scientific report attached to this electronic sensor, complete/permanent wilting of the pepper plant is (2-3), whereas tomatoes are (3-4). Thus, the amount of irrigation water added (12 grams) is appropriate for peppers but nearly appropriate for tomatoes. This means that the tomato plant should be irrigated as soon as possible to maintain a moisture level greater than 3. It is too early to re-irrigate and maintain a level of more than 2 if the cultivated plant is pepper. The leaflet that comes with this electronic sensor describes the irrigation frequency, which varies depending on the type of plant (either once every week, once every 5 days, or once every 3 days). Further, Luster-leaf Rapitest (1818) records the point of 2. Usually, vegetables require (2-3) in the case of this instrument. This is very close to the permanent wilting point of the two previous methods, but it is not exactly like a sensor of number (1825). Brouwer and Heibloem [2] reported that pepper requires 600-900 mm of irrigation

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during the growing season of 120-210 days, but tomato requirements are 400-800 mm over 135-180 days. Pepper plants have a shallow root system. A few major lateral roots can usually penetrate the soil to a depth of 2 m. Tomatoes, on the other hand, have a deep root system that can reach depths of up to 3 feet (90 cm) in extreme cases due to their taproot system. There is no clear explanation for pepper's relatively lower permanent wilting point in comparison to tomato. The pepper root is deeper than the tomato root, and this explains why pepper irrigation may occur reasonably soon after tomato irrigation (longer irrigation interval). Sensor (EXTECH MO750) translated the potting mix permanent wilting point percentage to 17.1% (moisture content on a dry weight basis). Thus, the texture is clay loam because 17.1% is multiplied by the means of ideal soil bulk density (1.3 g/cm^3) which gives 22% (moisture content on a volumetric basis) [9] and also in Saxton and Rawls [18].

7-The total daily foot candle for 12 hours measured was 36000-foot candle hours. 12000 for each period of day (mid-morning, 9 AM, average between 7-11 AM), (mid-afternoon, 1 PM, average between 11 AM-3 PM), and (early evening, 5 PM, average between 3-7 PM) (Table 1). Mulvihill [14] stated that both tomatoes and peppers are full-sun plants. Tomatoes require at least 6-12 hours of light per day, while peppers need around 8 to 10 hours of light. Thus, this training trial's light source is unsuitable for both plants in the summer season. Similar confirmations were reported by [11] who found in the multiple abiotic stresses test, that tomato and pepper plants were given artificial lighting suitable for photosynthesis only during the true leaf stage and a minimum of 7 hours.

8-Chemical composition trials: results were outlined in (Table 2). Also, the chlorophyll index was outlined for both plants twice (before spraying and after 8 days of spraying). Plant sap was collected at random from various parts of the plants. While the company only suggests collecting sap from plant petioles. According to the technical-scientific draft attached to those devices, the standard nitrate content during vegetative growth in peppers is (900-1200 mg/L) and (700-900 mg/L) in tomatoes. According to the company leaflet, nitrates in both plants are lower than recommended (Table 2). Spraying distilled water on tomatoes and peppers does not improve nitrate levels.

Table 1: Types of plants and light requirements (foot candle hours)

Season	Shade plants (Sh)	Partial shade plants (Psh)	Partial sun plants (Ps)	Full sun plants (Fs)
Spring (March-April-May)	0-10000	10001-20000	20001-35000	= or > 35000
Summer (June-July-August)	0-12000	12001-25001	25001-65000	= or > 65000

Furthermore, the potassium content of greenhouse tomato plants must be measured after transplanting (4500-5000 mg/L) [5]. During the vegetative growth stage, there are no specific standard ranges for potassium content in pepper plants. There are no specific numbers for the calcium content of either plant during the vegetative growth stage. These devices were designed to infer plant health and interpret physiological disorders associated with a nutrient deficiency if they appeared. Peppers, for example, have a higher potassium content than tomatoes (Table 2). It has previously been reported that a fungus known as (*Stemphylium solani*) is harmful to pepper plants and causes gray leaf spots [6]. A complex combination of potassium deficiency and drought stress may be responsible for this disease [10]. Further, tomato blotchy ripening occurs when random, distributed, hard, yellow, or green patches of tomato flesh remain unripe due to potassium deficiency. High temperatures and dry soil also play a role in this [3]. It should be noted that distilled water does not contain potassium. In contrast, the tomato plant after spraying contains more calcium (Table 2). Calcium deficiency is known to cause blossom end rot disease. Blossom end rot is a serious pepper and tomato disease caused by an environmental problem, most commonly uneven watering (drought conditions) and calcium deficiency [3]. Blossom end rot affects both green and ripe fruits, widening and maturing water-soaked areas on the bottom end into sunken, brown, leathery spots. Secondary pathogens, which appear as a black, fuzzy growth on the fruit, frequently invade the infected area and cause it to rot completely. Blossom end rot is not contagious and does not spread among plants. It can be concluded that foliar spraying with distilled water may provide calcium to the plant. The Royal Horticultural Society [3] reported another tomato disease. The tomato greenback is distinguished by a ring of unripe flesh around the stalk end of the ripening fruit. Green or yellow flesh has been affected. Low potassium and phosphorus levels may be involved, but the most important single factor is most likely hot bright sunlight.

The chlorophyll content of plant leaves is closely related to the plant's nutritional status. The chlorophyll content (as measured by the SPAD index value) will increase in direct proportion to the amount of nitrogen in the leaf as stated by Konica Minolta [7].

Table 2: Chemical composition of plants after spraying

Plant	Calcium mg/L	Potassium mg/L	Nitrate mg/L
Tomato	950	1395.33	213.11
Pepper	661.33	2230.70	712.67

Spraying distilled water causes positive SPAD results in tomato plants but negative results in pepper plants. SPAD value means the higher the better. Nitrate is a nitric acid salt with a high nitrogen content that plants can use. However, nitrite is a nitric acid salt in which nitrogen is not readily available to plants [3]. The nitrate record in (Table 2) was insufficient to express the nitrogen content of the leaves, as can be concluded. Table (3) summarizes all training outputs of this technical note as a detailed comprehensive plant health status evaluation. The kind of soil affects nitrogen and potassium levels. Lack of these two nutrients typically presented as symptoms in light, sandy soils rather than clay-rich soils [3]. According to review reports, soil texture can affect various soil characteristics, including drainage and water-holding ability. This demonstrates the indirect connection between soil moisture and nutrients. In comparison to clay-heavy soils, sandy soils use less water and require more frequent irrigation [9]. Correlations between soil type, water retention capacity, and nutrient deficiency disorders are essential. The suggested protocol is detailed in (Figure 1) in the form of checkpoints.

Table 3: Measured results comparisons with standard references using digital sensing

Sample	Measured	Sensor Used	Standard/ideal	
			Tomato	Pepper
Potting mix temperature	16.66°C [a]	Luster-leaf Rapitest (1835)	26.66°C ideal	
Air humidity	51% [a]	EXTECH 445702	75%	85-90%
Air temperature	17.5°C [a]		30°C	25°C
Air humidity	54% [a]	SWS 5051	75%	85-90%
Air temperature	17-17.3°C [a]		30°C	25°C
Potting mix fertility	Minimum too little [a] < (50-4-50) mg/L	Luster-leaf Rapitest (1818)	50-200 mg/L (N, and K), 4-14 mg/L (P) ideal	
	Minimum ideal 3 [a] ~ (50-4-50) mg/L	Luster-leaf Rapitest (1835)	3-7 ideal	
Potting mix acidity	7.3 [a] (not for hot)	Luster-leaf Rapitest (1835)	5.5-7.5	Hot (5.5-7) sweet (7-8.5)
Distilled water acidity	6.54 [a] (not for sweet)	VWR pH/CO 1030		
	6.50 [a] (not for sweet)	HORIBA Laqua twin pH (11)		
	6.40 [a] (not for sweet)	Pancellent (pH probe)		
Potting mix salinity	0.4 dS/m	Pancellent (TDS & EC probe)	2.5 dS/m	1.3 dS/m
Distilled water salinity	0.002 dS/m			
Potting mix tap water content	188 gm	dyras DSFC-780WH/G	~60% [c] (~P.W.P, within MAD)	
	4	Luster-leaf Rapitest (1825)		
	2	Luster-leaf Rapitest (1818)		
	17.1%(w%)~22(v%)	EXTECH MO750		
Light intensity	3000 FC/hr ~36000 [a] FC/hrs[12]	Luster-leaf Rapitest (1818)	= or > 65000 FC/hrs[12]	
Calcium cation content	950 [b] (tomato)	HORIBA Laqua twin (Ca^{+2})	Unknown	
	661.33 [b] (pepper)			
Potassium cation content	1395.33 [a] (tomato)	HORIBA Laqua twin (K^{+})	4500-5000 mg/L	Unknown
	2230.70 [b] (pepper)			
Nitrate ion content	213.11 [a] (tomato)	HORIBA Laqua twin (NO_3^{-})	700-900 mg/L	900-1200 mg/L
	712.67 [a] (pepper)			
SPAD before spraying	22.11 [a] (tomato)	Konica Minolta (SPAD 502 Plus)	-	
SPAD after spraying	26.10		+	
SPAD before spraying	26.63			+
SPAD after spraying	23.57 [a] (pepper)			-

a: Out, or nearly out of suitable range.

- (worse than +), + (better than -).

b: Unknown: need research (basically and relatively, the higher the better).

c: P.W.P: permanent wilting point (60% equals 188 gm of water only), parallel to 42% for potting mix 188 gm/447 gm.

MAD: managed allowable depletion.

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Air humidity	Air temperature	Soil temperature	1	Soil pH	Soil fertility	Soil salinity
2	Water pH	Water salinity	Water and soil mix fertility	3		
Soil texture	Soil moisture-Content	4	Light plant needs	5		
Foliar spray's pH, and chemical composition	6	Plant sap calcium				
Plant sap potassium	Plant sap nitrate	7				
Chlorophyll content	8	PLANTIX application				
GPS application	Excel interface	9				
Diagnosis, documentation, and report	10					

Figure 1: Plant protection doctor protocol using digital sensors and Android/computer applications for diseases, pests, or disorders diagnosis divided among 4 types (colors) of a total of 10 checkpoints.

CONCLUSIONS AND RECOMMENDATIONS

This study recommends training plant protection doctor students to analyze the environmental (soil, water, and growing media physiochemical traits) and biological system of the plant (biochemical or physiological system) in an integrated manner using electronic sensors before diagnosing diseases, pests, and physiological defects to find out the root cause of the problem and choose the most appropriate pest management method before resorting to chemical spraying. To maintain optimal plant health, integrated pest management (IPM) suggested protocols and agricultural extension must consider a variety of techniques (forecasting, preventive, technical, physical, and biological). Chemical control is the last solution and final option for plant protection.

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Authors' contribution
The authors have the same contribution.

Conflicts of interest
No conflict of interest.

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