RULE BASED RECOMMENDATION SYSTEM

TO SUPPORT CROP LIFECYCLE MANAGEMENT

Abstract: Crop lifecycle management is important for crop care and maintenance throughout its life. The existing recommendation and expert systems do not provide advice for the entire crop lifecycle. However, each stage of the crop's lifecycle necessitates a different set of recommendations. As a result, this paper proposed a recommendation system based on sensor data and rule-based extraction from expert people to provide crop management advice throughout its lifecycle. The proposed system's rules are built around IF-THEN situations. The proposed system will analyze the data by searching for relationships between input data and rule-based using a PHP script to define the best recommendation for farmers. This proposed system was put into action in a greenhouse dome in Chiang Mai, Thailand. Farmers were overwhelmingly pleased with it, giving it a 96% satisfaction rating.

Keywords: Scrop lifecycle, crop lifecycle management, recommendation system, expert system

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1. **INTRODUCTION**

Crop lifecycle is defined as the sequence of crop changes and crop growth from the start to the end of crop life [1]. The typical crop has four stages: seed, germination, seedling, and adult crop as shown in Figure 1. The seeds stage is the first stage of crop lifecycle by putting seeds in soil. The next stage is germination. The seeds require the proper conditions such as correct temperature, appropriate water, etc. for beginning to sprout. The seedling stage is the growing of a very young crop after germination that starts growing toward the sunlight. Crop requires water, sunlight, nutrients, and proper temperature to grow and to survive. The last stage is mature crop that has roots, leaves, stem, etc.

Crop lifecycle management refers to the methods or processes used to care for a crop during its life cycle. Farmers must manage the crop-care process at each stage of the crop's lifecycle. Irrigation, weed control, fertilizer application, disease control, pest control, and pruning are all part of the maintenance procedures. As a result, human knowledge is as valuable as the knowledge of an expert. However, it is not only expert knowledge that is required, but also smart farm technologies that are necessary for crop lifecycle management. Based on this, a recommendation system or expert system is critical for crop lifecycle management.

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12. LITERATURE REVIEW

Smart Farm (SF) refers to the incorporation of communication and information technologies into farm sensor devices and equipment. The Internet of Things (IoT) is a critical smart technology for SF applications. Farmers can now use IoTs to improve farm and crop management efficiency in areas such as fertilization, irrigation, disease control, soil, and so on. Soil mapping with variable rate pesticide application assists farmers in reducing pesticide use and costs by estimating the amount of pesticide spraying in each farm area [3][4][5][6]. To manage water resources for irrigation, the irrigation system-based Internet of Things (IoT) technology simulates crop and field water requirements using sensing data such as soil moisture, evaporation rate, air temperature, relative humidity, and so on. [7] [8] [9] [10] [11]. Robotic weed management detects and eliminates weeds in the field [12] [13] [14]. A survey robot with an electronic nose for soil sensing and a flying drone forecasts agricultural weather and monitors the farm to keep crop and farm conditions informed. Farmers can employ robots to detect soil nutrients and determine when to apply fertilizer and when to spray insecticides on crops. [15] [16].

Recommendation systems are machine learning systems that assist farmers in solving problems based on their information. In the agricultural sector, recommendation systems are used to provide solutions based on the system's data analysis. For example, an appropriate fertilizer identification-based random forest algorithm used three parameters to distribute the rating for fertilizer recommendation: market price of crop, year of crop cultivation, and yield/area ratio [17]. Data is analyzed using the K-Nearest Neighbor, CHAID, and Nave Bayes algorithms to advise farmers on chemical application to crops [18] [19].

An Expert System (ES) is described by Durkin as "a computer program designed to model the problem solving ability of a human expert" [20]. It is a system for making decision and solving problems. It is related to knowledge and procedures or rules to apply the knowledge. Both knowledge and logic are derived from the experiences of a subject matter expert [21]. ES in agricultural research is also focusing on crop management, crop diseases, and insect pest diagnosis [22] [23] [24] [25], as well as providing irrigation and fertilization advice based on rules [26]. Image processing is used to identify crop diseases and make recommendations based on expert knowledge [27] [28].

According to a review of the literature, smart farm is the use of smart devices and technologies such as sensors to collect, monitor, and control for crop management by setting threshold values for analysis and control. Meanwhile, recommendation systems make recommendations to farmers based on data from the systems (Content Base or Collaborative Filtering) and assess the situation using machine learning techniques. Furthermore, expert systems offer expert advice only in response to a farmer's question to the system. These systems and applications, on the other hand, do not manage crops based on their lifecycle.

As a consequence, managing crop lifecycles based on sensing data and expert knowledge to provide advice to farmers during crop lifecycles is extremely challenging. As a result, this paper aims to propose a recommendation system based on a combination of sensor data and expert rule-based to provide farmers with appropriate crop lifecycle management advice.

3. SYSTEM PROJECT PROPOSED

3.1. System Diagram

The proposed rule-based recommendation system recommends to farmers only five crop maintenance processes: fertilization, irrigation, pest control, weed control, and disease control. The proposed system analyzes sensor data with a rule base extracted from expert knowledge to provide appropriate suggestions to farmers.

Figure 2 illustrates the diagram of the proposed system comprising four components. The first part is input data using sensor devices such as soil sensor, humidity sensor, etc. to collect field environment data such as soil moisture, relative humidity, etc. as described in Table 1. The second part is inference engine using PHP script to analyze input data and rule base derived from expert knowledge to make appropriate recommendations to farmers. The third component is the rule-base, which is captured and created using the Knowledge Engineering (KE) technique based on the expert's knowledge extraction.

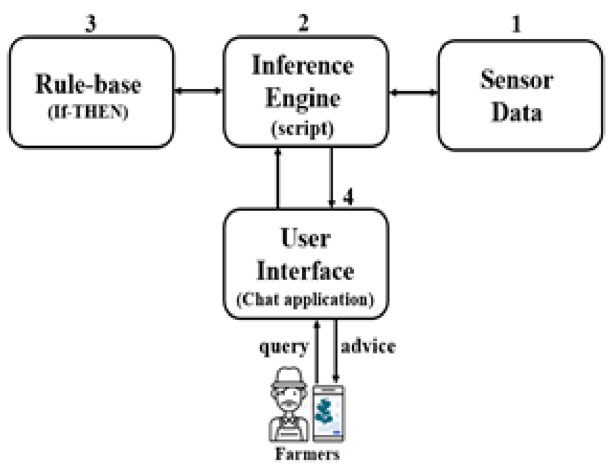

Figure 2: Proposed System Diagram

The 'IF-THEN' relationship situations serve as the foundation for the rules. The fourth component is the user interface, which serves as a medium of communication between farmers and the system via the Line application. Farmers can use the Line application to monitor the environment in their fields. Furthermore, farmers can send their queries to the system via the Line chatbox and receive recommendations from the system based on the input data and rule-base.

3.2. Data collection

3.2.1. Sensor Data

The sensors listed and described in **Table 1** are used to collect data relevant to the proposed system. These parameters and data play a significant role in crop lifecycle management. Soil moisture and temperature data have an effect on irrigation during the crop lifecycle. Water temperature, air temperature, and relative humidity (RH) data all have an impact on crop irrigation decision-making. The ph. of the soil, the ph. of the water, and the EC of the water all have an impact on crop fertilization. Crop growth is affected by light and UV data. Disease control, insect pest control, and weed control are all influenced by light, UV, air, and soil data. As a result, these parameters and data are taken into account when making recommendations for crop management throughout its lifecycle.

3.2.2. Expert's Knowledge

The expert knowledge relating to the proposed system is captured from five expert persons using the Knowledge Engineering (KE) technique by interviewing each expert person following the crop lifecycle questionnaire. The captured knowledge of each expert is extracted using a knowledge matrix, which is created by matching knowledge and parameters to define the knowledge conflict among five experts as shown in **Table 2**. The best practice among five experts is provided by the knowledge conflict. The rule-base is built using best practices.

4. IMPLEMENTATION AND RESULTS

In this paper, the proposed system project was implemented to Lettuce cultivation to manage its lifecycle during entire cultivation. The Lettuce is a well-known leafy vegetable with numerous applications ranging from salad to medicinal products. One of the most significant leafy vegetable crop in the world is Lettuce. [29][30]. Since the concept of green products has become popular around the world, lettuce has grown in popularity not only for food applications but also in a variety of forms with other specific applications [31].

Sensor	Data Collection	Description
Soil moisture	- Soil moisture - Soil temperature	- Measure the water content in soil in terms of percentage - Measure heat and cool in soil (%)
Soil ph	- Soil ph	Measure of the alkalinity and acidity in soil which effect to productivity and fertility of crop
Water EC and temperature	- Water Electrical Conductivity - Water temperature	- Measure the water's fertility which is relevant to fertilization - Measure hot and cool in soil which effect to crop's fertility
Water ph	- Water ph.	Measure of the alkalinity and acidity in water
Air temperature	- Air temperature - Relative humidity (RH)	Both temperature and RH impact to close and open of crop's leaves stomata
Light	- Light intensity	- Light intensity impact to photosynthesis of crop to generate food for itself - Measures to avoid crop burns
UV	- UV index	- UV influences to the lifecycle of crop, we measure it to avoid this issue.

Table 1: List of sensors and Data collection

According to Tridge based FAO data, the global production volume of lettuce increased from 22.58 million metric tons in 2005 to 29.13 million metric tons in 2019 [32]. As a result, the use case for this paper will be the management of the lettuce lifecycle. **Figure 3** depicts the lifecycle of lettuce. Sowing seeds in the soil is what the seeds stage entails. Water, warmth, and oxygen are required for seed germination. The stage at which the shoot reaches the surface is known as sprouting. The seedling has only two leaves, and their leaves are vulnerable to a variety of elements. Lettuce will grow to the third true leaf unfolded, a head will form, and 50% of the head size will be reached before we can harvest the crop. The total production lifecycle of lettuce is 45 days.

Management process	Crop lifecycle			
	Seed	**Germination**	**Seedling**	**Mature**
Irrigation	Irrigate 2 times a day	Irrigate 2 times a day, 50 ml/time	- Irrigate 2 times a day, 100 ml/time - If high temperature need to irrigate during day	- Irrigate 2 times a day, 150 ml/time - If high temperature need to irrigate during day
Fertilization	No fertilizer	No fertilizer	- Ph value should: 5-6.5 - If ph value is out of range , put fertilizer	Ph value should: 5-6.5 - If ph value is out of range , put fertilizer
Diseases Control	No disease	Spray Boron once a week	Spray calcium 2 times a week	Spray boron 2 times a week
Insect pest Control	No insects	No insect	If high temperature, might have insect, should cover by net	If high humidity, might have insect, should cover by net
Weeds Control	No weeds	Check weeds once a week	Check weeds every 3 days	Check weed every 2 days

Table 2: Sample of captured knowledge to manage general crop type in knowledge matrix

The implemented location is located in Chiang Mai province, Thailand (18.7453356, 98.9802234). As shown in Figure 4, the sensor devices (see **Table 1**) are installed in greenhouses for data collection. The expert's knowledge is captured using KE technique and extracted as illustrated in **Table 3**. The rule-based to manage Lettuce lifecycle is constructed based on the extraction results.

Figure 4 shows the sensor devices installed in the greenhouse for input sensing data collection. The soil sensors (moisture, ph, and EC) are installed into the Lettuce pots. The air sensors (humidity, temperature, light, and UV) are installed in the middle of the greenhouse. The water sensors (temperature, ph, and EC) are installed in the blue box outside the greenhouse. All input data collected are stored in the cloud database.

Table 3 depicts a sample of expert's knowledge relevant to Lettuce management during its entire lifecycle. In terms of irrigation, the Lettuce requires different amount of water for growing. Hence, farmers have to irrigate Lettuce in different amount of water. In addition, farmers need to control the field environment inside greenhouse to suitable for Lettuce cultivation. However, farmers need to monitor soil water content and weather inside the greenhouse to analyze an appropriate amount of water for irrigation. In terms of fertilizer application, farmers need to check soil ph and EC value for soil fertility monitoring and control for Lettuce growth. In terms of pest control, farmers have to know the weather conditions such as humidity, temperature, etc. that might impact to insect attack. In terms of diseases control, the weather conditions are very significant effecting to Lettuce diseases especially light intensity, temperature, and humidity. Hence, farmers have to know these value for decision-making to prevent Lettuce from the attack of insect pests. In terms of weeds control, the weather and irrigation method are impact to weeds occurring. Therefore, farmers

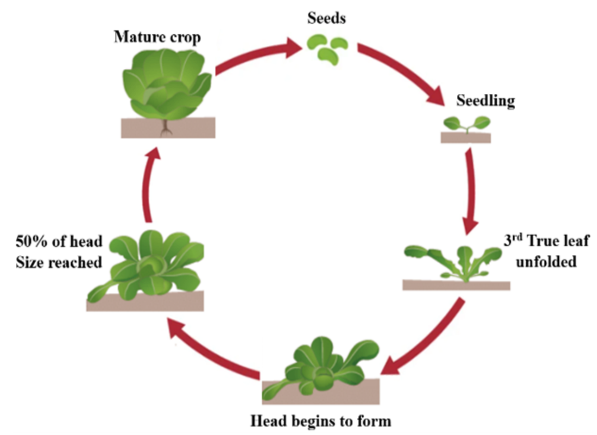

Figure 3: Lettuce lifecycle stages [33]

Figure 4: Sensors installation in greenhouse for data collection

have to the weather conditions and manage irrigation to avoid weeds occurrence. Based on the knowledge captured and extraction as shown in **Table 3**, the rule-base is constructed based on the expert's knowledge extraction and matching with parameter collected by sensor, for example;

Rule 1:
IF Soil moisture between 40% - 60% AND
Water Temperature between 15-25 °C
THEN no irrigation
Rule 2:
IF Soil Moisture less than 40% AND
Water Temperature between 15-25 °C
THEN Turn ON drip irrigation
Rule 3:
IF Soil PH is over than 7 AND
Water PH is over than 7
THEN Decrease soil PH and water PH by putting aluminum sulfate in soil and water
Rule 4:
IF Air Temperature between 18°C-25°C AND
Light Intensity over than 700
THEN Increase the dark by cover the Lettuce with the black shade
Rule 5:
IF Air Temperature is lower than 25°C AND
Relative Humidity is over 80%
THEN See field, if attacked by insects, spray Dimecron (0.05%) and malathion (0.05%)

The sensor data collected is analyzed rule-based to provide an appropriate recommendation to management during its lifecycle. Farmers can monitor sensor data and manage the lettuce lifecycle, such as irrigation, fertilization, etc., via the Line chat application. Based on the implementation, farmers are pleased with the proposed system for managing lettuce production, with a total satisfaction rate of 96%, as shown in **Table 4**.

Table 4 illustrates the satisfaction of three farmers after implementing the proposed recommendation system. This satisfaction survey has a rating scale of 5 to 1, with 5 representing very satisfied and 1 representing unsatisfied. The total score for each topic is 15 points. Based on the results, farmers are very satisfied with our proposed recommendation system with a 96% satisfaction rate because the system helps them to manage and to care for the lettuce during its lifecycle.

5. DISCUSSION AND CONCLUSION

This paper proposed a recommendation system for crop lifecycle management that is based on sensor data and rules. Lettuce is the use case in this paper because its demand is increasing year after year, as are the global market's needs. Irrigation, fertilization, disease control, insect control, and weed control are the five processes used in this system to manage and care for the lettuce. Sensor data is collected by installing sensor devices in the greenhouse. Furthermore, the rule-based are created by extracting captured knowledge from experts. Three farmers in Chiang Mai, Thailand, are implementing the proposed recommendation system. According to farmer satisfaction results, we discovered that farmers are very satisfied with

Management process	Lettuce lifecycle	Knowledge
Irrigation	Seeds	Put water 2 times a day, 100 ml/time Soil moisture: 20-40%
	Seedling	Put water 2 times a day, 150 ml/time Soil moisture: 20-40%
	3 true leaf unfolded	Put water 2 times a day, 350 ml/time Soil moisture: 30-55%
	Head begins to form	Put water 2 times a day, 500 ml/time Soil moisture: 30-60%
	50% of head size reached	Put water 2 times a day, 700 ml/time Soil moisture: 35-65%
	Mature Lettuce	Put water 2 times a day, 1000 ml/time Soil moisture: 50-75%
Fertilizer application	Seeds	No fertilization Soil ph: 5.5-7
	Seedling	No fertilization Soil ph: 5.5-7
	3 true leaf unfolded	Put calcium to soil Soil ph: 5.5-7
	Head begins to form	Soil ph: 5.5-7 Soil EC: 1.0 – 1.2 ms/cm
	50% of head size reached	Soil ph: 5.5-7 Soil EC: 1.2 – 1.4 ms/cm
	Mature Lettuce	Soil ph: 5.5-7 Soil EC: 1.0 – 1.2 ms/cm
Insect pest control	Seeds	No insect attack
	Seedling	No insect attack
	3 true leaf unfolded	Need to check temperature, if too high, might be attacked, should cover by transparent net
	Head begins to form	Need to check temperature, if too high, might be attacked, should cover by transparent net
	50% of head size reached	Need to check temperature, if too high, might be attacked, should cover by transparent net
	Mature Lettuce	Need to check temperature, if too high, might be attacked, should cover by transparent net
Diseases Control	Seeds	No diseases
	Seedling	No diseases
	3 true leaf unfolded	If high temperature or light intensity, might be burned, should cover by shading
	Head begins to form	If high relative humidity or soil moisture, might be occurred diseases. Should control humidity.
	50% of head size reached	If high relative humidity or soil moisture, might be occurred diseases. Should control humidity.
	Mature Lettuce	If high relative humidity or soil moisture, might be occurred diseases. Should control humidity.
Weeds Control	Seeds	No need to check weeds
	Seedling	Check once a week
	3 true leaf unfolded	Check once a week
	Head begins to form	Check 2 times a week
	50% of head size reached	Check 3 time a week
	Mature Lettuce	Check everyday

Table 3: Sample of knowledge captured from expert relating to Lettuce lifecycle management

Topics	Score
Interaction ability of system between user and system	15
User friendly of the system	15
Usability of the system	15
Accessibility of system in everywhere and every time	14
The smoothness of interaction between users and system	15
Effectiveness of internet connection between user and system	13
Visibility and clearness of video, text, voice	14
Ability to support the decision of users for crop maintenance	14
Ability to support users for crop maintenance more effectively	15
Ability to response users requirement	14
Total Score	**144**
Total (%)	**96**

Table 4: Farmers' satisfaction to proposed recommendation system

our proposed recommendation system, with a 96 percent satisfaction rate.

However, this recommendation system only provides advice for one type of soil (mixed organic soil), which is a limitation of this system because there are several soil types. Furthermore, each soil type has a unique impact on crop management, particularly crop irrigation management. In the future, we will develop a rule based on different soil types for more general use by farmers. Moreover, we will analyze and compare the Lettuce yield and quality when the proposed recommendation system for Lettuce lifecycle management is implemented versus the conventional method for Lettuce lifecycle management.

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