International Journal of Computer Applications (0975 – 8887)
Volume 186 – No.10, February 2024

An Intelligent System for Optimizing Irrigation Water Usage for Cucumber Crop in Egypt

Nevien Moawad
Researcher at Agricultural Research Center (ARC)
Cairo Univ.Street, Giza, Egypt

Tarek Heggi
Researcher at Agricultural Research Center (ARC)
Cairo Univ.Street, Giza, Egypt

Susan F. Ellakwa
Researcher at Agricultural Research Center (ARC)
Cairo Univ.Street, Giza, Egypt

Manal M.H. Gad El-Moula
Prof Dr. Agricultural Research Center (ARC)
Cairo Univ.Street, Giza, Egypt

Ayman Mohamed
Assistant Prof. at NUB Univ., Researcher at ARC
Cairo Univ..Street, Giza, Egypt

ABSTRACT
Nowadays, Egypt is confronting many challenges in providing fresh water per capita. According to CAPMAS (the Central Agency for Public Mobilization and Statistics), Egypt's yearly water share per person fell to 570 m^3 in 2018, while the global average is 1000 m^3 annually. There are multiple reasons that cause Egypt's lack of water, including but not limited to climate changes such as the temperature increase, low rate of rainfall, increase in population, and the unplanned management of the existing resources, such as Ethiopia's building of the Grand Renaissance Dam without arranging with the affected countries.

This article aims to build a web application using an irrigation expert system to reduce the quantity of cucumber irrigation water. It serves the designers of an irrigation expert system to facilitate the rapid development of an irrigation component by offering a template that can be easily filled. It also helps growers save irrigated water. The system has been applied to the cucumber crop in the greenhouse. It is among the most significant crops in Egypt. The outcomes of the experiment show a highly significant impact in calculating the needed irrigation water requirements, and there are two effective outcomes. The first outcome is achieving 20 reductions in the quantity of irrigation water used. The second outcome is the capability of using the expert system for irrigation in locations that have a shortage of experts in this domain. In addition to that, other related irrigation parameters, such as nutrition elements, should be considered in future research.

General Terms
Applications of Computer Science in Modeling, Expert, Agents, Diagnostic and Decision Supporting Systems, Reasoning, Knowledge Extraction and Knowledge Management

Keywords
Expert System ES, Artificial Intelligent, and Irrigation Timetable.

1. INTRODUCTION
Cucumber is one of the most important vegetable crops, it is a member of the Cucurbitaceae family, which comprises 118 genera and 825 species [1]. It contains 2.8% carbs, 0.4% protein, 0.3% minerals, 0.1% fat, and 96.4% moisture [2]. It is cultivated either in open fields or under protected cultivation all over the world. Nowadays, Egypt has a lot of potential for greenhouses, and in recent years, the area has grown rapidly. Cucumber was ranked the first order as a cash and commercial crop of vegetables grown under the greenhouse for the local market. It is estimated that there are 51663 greenhouses overall, each with an area of 4413 feddans (one feddan equals 0.42 hectare), of which 25787 were planted with cucumber plants, occupying 2132 feddans in total, with an average productivity of 11.16 kg/m2 based on statistics of Ministry of Agriculture and Land Reclamation (2017). Egypt is in an arid part of the world, it has a severe water shortage, and about 81.6% of Egypt's water supply is used by the agricultural sector, so it is crucial to use contemporary irrigation systems to maximize productivity while minimizing water use [3]. The effective utilization of water resources in compliance with designated agricultural plans and the nation's economic sustainability are two of the primary goals of the national water supplies and agricultural strategy [4]. The main resources of fresh water in Egypt indicated in Fig.1 consist of the River Nile which provides 55.5 BCM/year, groundwater which provides 1.65 BCM/year, rainfall provides Egypt 1.05 BCM/year, and desalination provides Egypt 0.1 BCM/year.

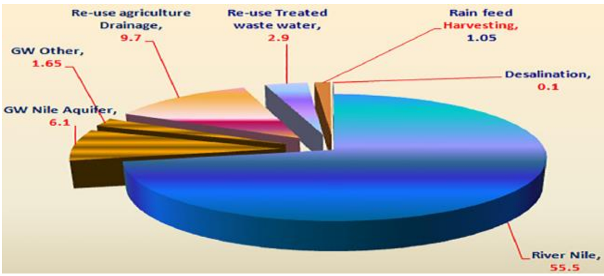

Fig. 1. Egypt's water resources (water distribution according to ministry of water resources and irrigation, MWRI [5])

To conserve irrigation water, contemporary technologies such as expert systems must be used. It's an artificial intelligence application. Owing to the shortage of irrigation specialists and the difficulties in obtaining them, expert systems might offer a helpful option for irrigation water management. Farmers can employ expert systems to gain expertise and be able to water their crops similarly to irrigation specialists [6]. Expert systems can serve as a substitute for human experts since they can provide farmers with the precise amount of water needed at the right moment to maximize irrigation water usage. Effective expert systems mimic the reasoning of human specialists in specific scenarios, enabling non-experts to handle problems more effectively. They can also be used by professionals as knowledgeable assistants [7]. The expert system was compared with actual experts, the expert system is simple and inexpensive to use but relatively expensive to design. Additionally, expert systems enable automation of certain jobs that human experts are unable to execute efficiently [8]. An irrigation expert system's main objective is to create a timetable of irrigation for a specific crop on a specific farm. The end product is a timetable outlining the amount and timing of water to be applied.

Ayman [6] created a general design for a tree irrigation expert system, it assists in optimizing agricultural water use. It applied on a mango crop, it seeks to equip farmers with irrigation knowledge to estimate the exact amount of water needed at precise times according to the needs of the crop and external variables that affect things like temperature, the kind of soil, water availability, and others. Maryam [9] developed a general design of an irrigation expert system for crop. It calculates the precise irrigation operations for a crop using irrigation experience. It depends on several environmental factors and the cultivated crop parameters. It is experimented on fababean crop. That using this general design in this application and apply it on a cucumber crop.

This study attempts to assess if lowering irrigation levels can maximize cucumber water use efficiency, as well as its effect on the production, quality, and storability of cucumber fruits by using expert system technology, the expert system automates calculating irrigation timetable, simulates the thought process of a human expert and solves shortage of experts in irrigation. An expert system design for a cucumber watering timetable is given in this study that gives farmers access to irrigation expertise to calculate the precise amount of water needed at the precise moment based on climate and environmental data.

The Agricultural Research Center (ARC) in Egypt provided the professionals with the expertise that was required to construct this design. The Common-KADS knowledge engineering methodology [10] is used in the construction of this design. The NASA Langley Research Center is the source of the climate data. It has an earth science research program that uses research and satellite systems to provide crucial data for understanding climate processes. NASA has models for understanding the changes on the earth system for optimizing the prediction methods, and deducing the impact on Earth life.

The paper is arranged as follows: The Materials and Methods are explained in Section 2. The results are discussed in Section 3. The Conclusion is introduced in Section 4.

2. MATERIALS AND METHODS

2.1 Cucumber Irrigation Timetable Expert System

Determining the optimal (water quantity and duration) timetable for a cucumber crop is the primary goal of the suggested system, the Cucumber Irrigation Timetable Expert System. The cucumber type, soil, water, climate, and farm data are the factors that determine the amount of water required, and these factors are used to determine the timetable. A general agricultural irrigation expert system design in [9] is the foundation of the paper system. To create the Cucumber Irrigation Timetable Expert System, that using CommonKADS. Six models comprise CommonKADS. The expertise model is the main model. The expertise model comprises three types of knowledge: domain, inference, and task.

2.1.1 Domain knowledge of the Cucumber Irrigation Timetable Expert System

Domain knowledge is factual information about the application domain. Domain knowledge consists of domain ontology and domain model. Domain ontology defines the concepts (domain words) that can be utilized in the domain; soil and plant are two examples of such terms. domain typology, which includes concepts, attributes, relations, and values, and domain taxonomy, which is a hierarchy of terms that describe the kinds of information that these terms include. A collection of assumptions about a domain that offer a particular viewpoint on the domain knowledge and qualify it for problem-solving tasks is called a domain model. The expert system of cucumber irrigation timetable comprises of four models. The models are: "et0 ", "Etcrop", "water needed quantity", and "Irrigation Timetable ". The relationships between the ontology are represented by these models. The following subsections provide descriptions of these models.

Et0 Model

The Penman technique [11] is used to calculate crop evapotranspiration (Et0), which is a measure of how weather affects crop water requirements.

Et0 = Adiract *Wiegfact * Net_Rad + [(1 - Wiegfact) * Winfact * (Ea - Ed)]……………….. (1)

Equation 1 is to calculate Et0

Where

The adjustment factor for the effects of meteorological conditions is called Adiract.

The crop evapotranspiration is adjusted based on the solar radiation value and the farm location using an adjustment factor that is expressed as a rule-based relationship.

Wiegfact is the factor of weight between Altitudes and temperatures

Net_Rad = (0.75*Solar_Rad) - Long_Rad

The difference between the radiation entering from the sun and the radiation leaving the earth is called net_rad.

The long wave radiation is called Long Rad..

Solar _Rad = Rad * (0.25 + ((Act_Sun/ Abs_Sun) *0.5))

Act_Sun is the real hours of sunshine

Abs_Sun is component between the month and latitude

The radiation is called Rad.

Windfact = 0.27(1 + WindDay KM/100)

WindDayKM is the wind speed

Ed = Ea * Rh/100

Ed determines the air's mean real pressure of vapor.

At mean air temperature, Ea is the saturation pressure of vapor.

Rh is the humidity value mean

- **Etcrop Model**

Etcrop computes the crop evapotranspiration according to crop characteristics to calculate crop water requirements.

Etcrop = Ke * Et0

Where

Kc stands for crop coefficients.

Et0 is the evapotranspiration of the crop.

- **Water Needed Quantity model**

This model calculates necessary amount of water for each period (ten days) for growth stages of the cucumber crop. This calculation is based on the environmental data of a crop, soil leaching and irrigation system efficiency.

IrrQty = [(Etcrop- Rain_A/ IRReff)] * (1 + LeachR) * (Interval + 1) * A * 4.2…………………………….. (2)

Equation 2 is used to calculate Water Needed Quantity

Where

Etcrop is the crop evapotranspiration according to crop characteristics

The amount of rain is Rain A.

The irrigation system's efficiency is measured by IRReff

LeachR is the water quantity needed for leaching

LeachR = Etcrop /[Eciw/ IRReff * (2 * Ece * S)]
Eciw is salinity of irrigation water
Ece is the crop tolerance to soil salinity
S is the soil salinity
Interval is the frequency of irrigation processes in the same period (ten days)

Interval = RASW * (RD /Etcrop)

Where
RD is the crop depth of root
RASW is the easily obtainable soil water.
A is the farm area

- **Irrigation Timetable Model**

This model's goal is to allocate the amount of water needed for each irrigation operation over the course of the 10 days and at intervals.

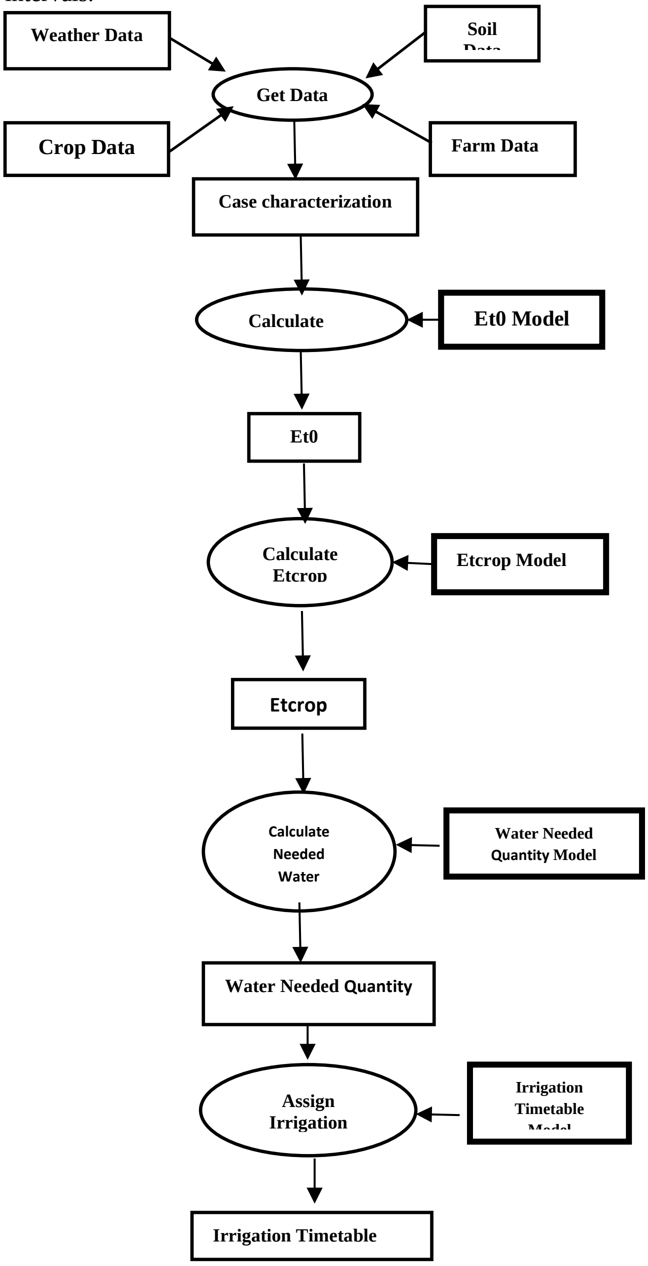

Fig2: Inference structure of cucumber irrigation timetable ES

2.1.2 Inference Knowledge of the Cucumber Irrigation Timetable Expert System

Inference knowledge is a sort of interface between domain knowledge and task knowledge, inference knowledge is the understanding of how to apply domain knowledge in the reasoning process. Information about inference abstracts from domain information and explains the fundamental inferences using domain knowledge. An inference can be generated after processing some incoming data, which produces an additional segment of information. When an inference is fully defined by its name, the internal behavior of the inference is uncontrollable. Inference knowledge contains inference structure and inference specification. An inference structure diagram is used to represent inference knowledge. The diagram uses three different kinds of components: static roles, dynamic roles, and inference steps. An inference step's input or output data is known as a dynamic role, and it is symbolized by a rectangle. A declarative specification of the directional relationship between the input and output roles is represented by an ellipse that is used to express an inference step. A bolded line rectangle designating a static role denotes a domain model; it is a component of domain knowledge that an inference step uses. The function of the inference step in problem solving is represented by the inference specification.

Inference knowledge of Cucumber Irrigation Timetable Expert System consists of the inference structure and inference specification. The inference structure involves five subtasks namely: Get Data, calculate *et0*, calculate *etcrop*, calculate needed qua qntity, and Assign Irrigation Timetable see Fig. 2.

- **Get Data Inference**

The goal of the Get Data inference is to gather and save all data related of the cucumber crop and its environment. Its input role is the soil data, weather data, cucumber data, and farm data. Its output is a case characterization. Fig.3 is specification of Get Data inference step.

```
INFERENCE    Get Data
        Input-roles: farm data, soil data, weather data, cucumber
                              data
        Output-roles: case characterization
SPESIFICATION
        Get farm data
        Get soil data
        Get weather data from NASA
        Get cucumber data
        Save case characterization
```

Fig.3: Specification of Get Data inference step.

- **Calculate Et0 Inference**

The goal of the Calculate Et0 inference is to compute crop evapotranspiration, which measures how weather influences the amount of water needed for a cucumber crop. The case characterization serves as its input, the Et0 Model is its static role, and Et0 is its output. Fig. 4 shows the Et0 inference formulation.

INFERENCE Calculate Et0
Input-roles: case characterization
Output-roles: Et0
SPESIFICATION
Get weather data from NASA
Get Et0 Model
Calculate Et0

Fig 4: Specification of Calculating Et0 inference

- **Calculate Etcrop Inference**

Reasoning the evapotranspiration of the crop for the cucumber crop is the aim of Etcrop inference. The Etcrop Model is its static role; the case characterization and the Et0 are its input roles; the etcrop is its output. Fig. 5 is the Etcrop inference specification.

INFERENCE Calculate Etcrop
Input-roles: Et0, case characterization
Output-roles: Etcrop
SPESIFICATION
Get Et0
Get case characterization
Get Etcrop Model
Calculate Etcrop

Fig 5: Specification of Etcrop inference

- **Calculate Water Needed Quantity Inference**

The objective of the Compute Water Needed Quantity inference is to calculate the amount of water needed for the cucumber crop at each growth stage for a ten-day period. Water Needed Quantity is its output, its static role is the Water Needed Quantity Model, and its input role is the etcrop, case characterization. The calculation of the Water Needed Quantity inference is specified in Fig. 6.

INFERENCE Calculate Water Needed Quantity
Input-roles: Etcrop, case characterization
Output-roles: Water Needed Quantity
SPESIFICATION
Get Etcrop
Get case characterization
Get Water Needed Quantity model
Calculate Water Needed Quantity

Fig 6: Specification of calculate Water Needed Quantity inference step.

- **Assign Irrigation Timetable Inference**

The goal of the Assign Irrigation Timetable inference is to reason the water quantity for each watering process and number of intervals in each period (during ten days). Its static role is the Irrigation Timetable Model, its input role is the case characterization, Water Needed Quantity, and its output is Irrigation Timetable. Fig.7 is specification of Assign Irrigation Timetable Inference.

INFERENCE Assign Irrigation Timetable
Input-roles: Water Needed Quantity
Output-roles: Irrigation Timetable
SPESIFICATION
Get Water Needed Quantity
Get Irrigation Timetable Model
Assign Irrigation Timetable

Fig7: Specification of Assign Irrigation Timetable Inference

2.1.3 Task Knowledge of the Cucumber Irrigation Timetable Expert System

Task knowledge is the understanding of how to manage the process of reasoning in order to arrive at an efficient and successful answer. Task definition and task body are included in task knowledge. The goal, input/output roles, and task specification make up the task definition. A goal is an explanation of what can be accomplished by using the task at hand. Input/output roles are the definition of the dynamic knowledge roles that the task manipulates. The task specification outlines the logical relationships between the task's case roles.

Sub-goals, subtasks, and the task control structure are the several subparts that make up the task body. The sub-goals that can be produced by the job. The subtasks that accomplish the sub goals are called subtasks. Task control structure is an explanation of how to manage the smaller tasks (subtasks) that make up the larger task. There are three different types of tasks: composite task, primitive task and transfer task.

Composite task can be decomposed in sub-tasks. Primitive task is task is directly related to an inference. Transfer task is an interaction with the world.

Task
Task-definition: Compute Cucumber Irrigation Schedule
Goal: Irrigation Timetable
Input-role: case characterization
Output-role: Irrigation Timetable
Task-body
Type: Primitive
Subtasks: Get Data, calculate et0, calculate Etcrop, Calculate Needed Quantity, Assign Irrigation Timetable
Static-roles: Et0 model, Etcrop model, Water Needed Quantity Model, Irrigation Timetable Model
Control-structure:
Get case characterization
Save case characterization
Get Et0 model
Calculate Et0
Get Etcrop
Calculate Etcrop
Get water needed Quantity model
Calculate Water Needed Quantity
Get Irrigation Timetable Model
Assign Irrigation Timetable

Fig 8: Task knowledge of the cucumber irrigation schedule expert system

Fig. 8 is the specification of task knowledge of the Cucumber Irrigation Timetable Expert System. It consists of five primitive subtasks: Get Data, Calculate *Et0*, Calculate *Etcrop*, Calculate Water Needed Quantity, and Assign Irrigation Timetable.

2.2 Web Application

The suggested cucumber irrigation expert system is designed as a web-based tool to assist users (growers) in cultivating and irrigating a cucumber crop with the right amount of water to maximize yields. It has a user interface to enter all required data: farm data like its location, crop data like its variety, soil data like its salinity, and weather data like wind speed and temperature (see Fig. 9). The weather data is obtained from NASA, depending on the location of the farm. NASA provides the research application with a prediction of weather for the following ten days. These expectations help the system to predict the optimal irrigation timetable for the following ten days.

Fig 9: The proposed system User interface

To irrigating a cucumber crop with the right amount of water to maximize yields. It has a user interface to enter all required data. The output irrigation timetable of the application has the quantity of water needed for each interval and the number of intervals during ten days; this is repeated throughout the cultivation season of the cucumber crop.

Table1: Irrigation timetable under different irrigation levels

Period Date	Season 2023			
	Liter/m2/week			
	100%	80%	60%	Intervals
15/3/2023 - 24/3/2023	2.66	2.13	1.59	6
25/3/2023 – 4/4/2023	2.98	2.38	1.79	5
5/4/2023 – 14/4/2023	7.03	5.62	4.22	4
15/4/2023–24/4/2023	7.44	5.95	4.46	4
25/4/2023–4/5/2023	7.44	5.95	4.46	4
5/5/2023 – 14/5/2023	10.29	8.23	6.17	4
15/5/2023–24/5/2023	12.67	10.14	7 . 6	3
25/5/2023–3/6/2023	12.95	10.36	7.77	3
TOTAL	63.46	50.76	38.06	

When cultivating a cucumber crop, Table 1 shows the irrigation timetable that the system generates. By lowering irrigation levels, the system can maximize water use efficiency; the three irrigation levels are sixty percent, eighty percent, and fully of standard evapotranspiration (ET0). For instance, table 1 shows that there are six intervals from March 15, 2023, to March 24, 2023. For each irrigation operation, the required amounts are 2.66 Liter/m^2/week at 100%, 2.13 Liter/m^2/week at 80%, or 1.59 Liter/m^2/week at 60%.

The proposed system provides the irrigation timetable based on the place where the farm, if the same two varieties of a cucumber crop cultivate at two different farms with different weather and same soils type, the system will provide the two different irrigation timetables. Also if the same two varieties of a cucumber crop cultivate at two different farms with same weather and different soils type, the system will provide the two different irrigation timetables. As well if the different two varieties of a cucumber crop cultivate at two different farms with same weather and same soils type, the system will provide the two different irrigation timetables. So the proposed system can reason and give solutions intelligently as experts.
The following section will discuss effect of the reductions in the quantity of the used irrigation water on production, quality, and storability of cucumber fruits by using expert system technology.

2.3 Experiment Setup

The experiment was carried out on a cucumber crop under a greenhouse of white nets (30 m length and 8.5 m width) at the experimental farm of Dokki site for Protected Agriculture, Ministry of Agriculture and Land Reclamation, Giza, Egypt, during the season of 2023. Seeds of cucumber (Viva Sun F1) were sown on the 15th of March.

Table 2 contains a tabulation of the soil's physical and chemical characteristics. Ninety-centimeter wide ridges were created within the experiment area. On the ridge, the seeds were planted in double rows spaced 50 cm apart. All input required data (farm data, crop data and soil data) is entered by a grower into the proposed system. The location of the farm is entered into NASA. The predicted weather data is obtained from NASA and entered into the system every ten days. Consequently, the system provides an output irrigation timetable every ten days. The three irrigation levels used in the experiments: 60, 80, and 100% of output timetable irrigation were set up in a split-plot design with three repetitions. The area of Plot is 4.5 m^2 with dimensions were 5 m long by 0.9 m wide. According to [12], the required rate of NPK mineral fertilizer was 9 kg P_2O_5 ,22 kg N, and 25 kg K_2O/1000 m^2.

Table 2: Analyses of the experimental soil

Clay	Silt	Sand	Texture	pH	EC	Cations meq/l				Anions meq/l		
						Ca++	Mg++	Na+	K+	HCO3-	Cl-	SO4=
%	%	%			dS/m							
48.2	42.3	8.5	Clay silt	8.25	1.26	2.80	1.55	6.34	1.18	2.44	5.46	3.58

These fertilizers were provided using a multi-fertilizer (20:9:20) at a rate of 125 g/m^2. Twice a week, the drip irrigation method received fertilizer injections. On the advice of the Agricultural Ministry, additional agricultural techniques were carried out.

After 50 days of sowing, five plants were randomly chosen from each plot to determine the following: number of leaves, height, stem diameter, and fresh weight at the shoot. In addition, the fourth higher leaf's 18 chlorophyll measurement was measured using a Minolta Chlorophyll Meter Spad 501. By using the method outlined by FAO (2008), the fourth upper leaf of cucumber plants was used to calculate the nutrient content (NPK). Total nitrogen was estimated using the Kjeldahl method, phosphorus was measured using a spectrophotometer, and potassium was measured photometrically using a flame photometer. The cucumber fruits were picked twice a week after 55 days of seeding. Following each harvest, the total yield was noted for each plot cumulatively until the end of the harvesting season; the total yield/m^2 was computed from the plot yield. To determine how many fruits each, plant produced, five plants were randomly selected from each replication.

Fruit weight, length, diameter, hardness, total soluble solids, and ascorbic acid concentration were assessed on a randomly selected sample of thirty fruits from each replication at harvest.

3. RESULTS AND DISCUSSION

The following parameters have been collected during the experiment:

- **Vegetative properties**

The impact of levels of irrigation on the vegetative development qualities of plants of cucumber was demonstrated by the data in table 3. All the vegetative growth properties revealed their highest values with the highest irrigation level (100%), while the lowest values of the represented vegetative growth properties were displayed by the lowest irrigation level (60%). The applied highest irrigation level is the calculated recommended dose, where the positive impact of higher irrigation level could be returned to its impact on supporting the elongation and division of cells in need of additional water sources Remarkably, the highest irrigation level employed in this study aligns closely with the recommended dosage. This implies that optimal growth conditions are achieved when cucumber plants receive ample water. Higher irrigation levels are positively correlated with increased vegetative development; this is because they provide enough water resources, which support important cellular activities like elongation and division. Therefore, it's clear that proper irrigation plays a pivotal role in facilitating the robust development of cucumber plants by ensuring that they have access to essential water levels needed for cellular activities. [13, 14].

Table 3: Impact of irrigation amounts on cucumber plants vegetative growth characteristics

Season 2023			
Irrigation level	**100%**	**80%**	**60%**
Plant height (cm)	**266**	**254**	**229**
Leaf number/plant	**35.9**	**34**	**27**
Stem diameter (cm)	**1.50**	**1.3**	**1.3**
Chlorophyll (SPAD)	**37.9**	**36.2**	**34.2**
Shoot fresh weight (kg)	**1.42**	**1.26**	**0.96**

- **Nutritional status**

The NPK content that explained the nutritional status of the plant is presented in Table 4.

Table 4: Impact of irrigation amounts on cucumber plants' nutritional status

Season 2023			
Irrigation level	**100%**	**80%**	**60%**
N%	4.8	3.7	3.1
P%	0.5	0.47	0.4
K%	4.3	3.9	3.6

The impact of the applied irrigation levels on NPK contents revealed a similar attitude as growth properties for cucumber plants. Plants with 100% irrigation had the highest NPK content, followed by 80% irrigation and 60% irrigation, which resulted in the lowest NPK content. The increasing uptake of NPK by 100% irrigation level may be due to the influence of good soil water content, which raises the NPK content of plants This pattern implies a significant relationship between the irrigation regime and the uptake of essential NPK nutrients by cucumber plants. The significant rise in NPK content seen in plants that were supplied with 100% irrigation highlights the critical role that ideal soil moisture conditions play in promoting improved nutrient absorption. Such conditions likely promote efficient root uptake and translocation of NPK elements within the plants, thereby leading to higher nutrient accumulation [15, 16]. Furthermore, the influence of irrigation levels on NPK content underscores the importance of soil water content management in agricultural practices aimed at maximizing crop productivity. By ensuring adequate irrigation levels, farmers can create an environment conducive to optimal nutrient uptake, thereby potentially improving crop yield and quality. Overall, the results show how intricately soil moisture content, nutrient uptake dynamics, and irrigation management interact, providing insight into ways to optimize agricultural practices for efficient and sustainable crop production—especially when it comes to growing cucumbers

- **Fruits number**

The results of an examination of how irrigation level treatments affected yield more particularly, yield/m^2 and fruit number/plant are shown in table 5. The fruits yield at irrigation level 100% was the highest, although it differed negligibly from the lower values of the fruit yield at irrigation level 80%. Ultimately, at 60% irrigation level, the lowest results were recorded.

The enhanced vegetative development resulting from increased NPK uptake by plants, as seen in table 4, can be attributed to the beneficial impact of 100% irrigation on fruit yield. Plants benefit from this stimulation of photosynthesis, which increases yield. [17] and [18] reported the same outcomes.

Table 5: Impact of irrigation levels on cucumber yield and fruits count

Cucumber Yield			
Irrigation level	**100%**	**80%**	**60%**
Yield/plot (kg/4.5 m^2)	33.9	32.8	27.5
Yield (kg/m^2)	7.5	7.3	6.12
Fruit number /plant	32	31	28

- **Chemical and Physical properties**

Fruit quality was determined by the chemical and physical characteristics of cucumbers, including fruit weight, diameter, and length. Table 6 displays chemical and physical characteristics of cucumber fruits impacted by varying irrigation levels. When the irrigation level was 100%, the best grade of cucumber fruits, Cucumber fruits have a greater weight, diameter, and length due to increased photosynthetic stimulation and improved carbohydrate accumulation [19–21]. Although the irrigation level 80% revealed lower values but it

Table 6: Impact of water levels on the chemical and physical characteristics of cucumber fruits

Season 2023			
Irrigation level	**100%**	**80%**	**60%**
Fruit weight (g)	99.1	98.1	78.6
Fruit length (cm)	14.8	14.7	12.6
Fruit diameter (cm)	2.96	2.93	2.66
Firmness (kg/cm^2)	5.43	5.3	3.9
T.S.S (%)	3.8	3.6	3.2
Ascorbic acid (mg/100 g FW)	2.99	2.98	2.88

is insignificant difference than 100%. The 60% watering level produced the lowest grade results. Consequently, the close results of 100% and 80% for the yield parameters explained that 80% didn't have significant negative impact on yield.

4. CONCLUSION

The experiment results have addressed two issues which are the reduction in the used quantity of irrigation water and the suitability of using expert systems as an application for calculating the needed irrigation water. The reduction of irrigation water was 20% which also achieved a reduction in power and cost for the irrigation process. The amount of reduction of water was 57.15 per 4.5 m^2.

For future work, the experiment illustrates that the following point can be considered, and it will improve the irrigation process which is the integration between the expert system and the weather station which will reduce the time and accuracy for the obtained results, and the use of prediction model for the weather information that will increase the accuracy of the obtained results.

5. ACKNOWLEDGMENTS

Many thanks to the following individuals for their expertise and assistance throughout all aspects of this study and for their help in writing the manuscript.

6. REFERENCES

[1] Uthpala, T. G. G., et al. "Cucumber vegetable as a brine fermented pickle." TreNds & Prospects in Processing of Horticultural Crops. New Delhi: Today & tomorrow's Printers and Publishers (2019): 447-461.

[2] Salmani, Karim Arab, and Yousef Hakimi. "Evaluation of genetic diversity among some superior Cucumber (Cucumis sativus) by using Morphological and Pomological characteristics in the greenhouse under warm condition." (2023).

[3] Moursy, M. A. M., et al. "Productivity and profitability of modern irrigation methods through the application of on-farm drip irrigation on some crops in the Northern Nile Delta of Egypt." Alexandria Engineering Journal 62 (2023): 349-356.

[4] El-Gafy, Inas K., Akram M. El-Ganzori, and AlweI. Mohamed. "Decision support system to maximize economic value of irrigation water at the Egyptian governorates meanwhile reducing the national food gap." Water Science 27.54 (2013): 1-18.

[5] Abd Ellah, Radwan G. "Water resources in Egypt and their challenges, Lake Nasser case study." The Egyptian Journal of Aquatic Research 46.1 (2020): 1-12.

[6] Ayman Nada, Mona Nasr, and Maryam Hazman. "Irrigation expert system for trees." International Journal of Engineering and Innovative Technology (IJEIT) 3.8 (2014): 170-175.

[7] Gutierrez-Estrada, J. C., et al. "SEDPA, an expert system for disease diagnosis in eel rearing systems." Aquacultural engineering 33.2 (2005): 110-125.

[8] Yelapure, S. J., and R. V. Kulkarni. "Literature review on expert system in agriculture." International Journal of Computer Science and Information Technologies 3.5 (2012): 5086-5089.

[9] Maryam Hazman. "Crop irrigation schedule expert system." 2015 13th International Conference on ICT and Knowledge Engineering (ICT & Knowledge Engineering 2015). IEEE, 2015.Jilani, M.S., A. Bakar, K. Waseem and M. Kiran, 2009. Effect of different levels of NPK on the growth and yield of cucumber (Cucumis sativus) under the plastic tunnel. J. Agric. Soc. Sci., 5(3): 99-101.

[10] J.Breuker and W.Van de Velde, "CommonKADS library for expertise modeling reusable problem solving components," lOS Press, 1994.

[11] R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, "Crop evapotranspiration-Guidelines for computing crop water requirements," F AO Irrigation and drainage paper 56. F AO, Rome, 300,6541, 1998.

[12] Shehata, S.A., H.A. Hassan, A.A. Tawfik and M.F. Farag, 2016. Improving the productivity and quality of the cucumber crop grown under greenhouse conditions using some stimulants and spraying amino acids. J. Plant Production, Mansoura Univ., 7(4): 385-392.

[13] Naik, H.P., P.C. Mali, V.D. Kapse, K.P. Vaidya, R.V. Dhopavkar, N.A. Meshram and S.S. More, 2019. Response of F1 hybrids of cucumber (Cucumis sativus L.) to different levels of fertilizers under Konkan agro climatic condition. The Pharma Innovation Journal, 8(12): 429-430.

[14] El-Noemani, A.A., A.A.A., Aboellil and O.M. Dewedar, 2015. Influence of irrigation systems and water treatments on growth, yield, quality and water use efficiency of bean (Phaseolus vulgaris L.) plants. International Journal of ChemTech Research, 8(12): 248-258.

[15] Abdrabbo, M.A.A., A.A. Farag and M.K. Hassanein, 2009. Irrigation requirements for cucumber under different mulch colors. Egypt. J. Hort., 36: 333-346.

[16] Jilani, M.S., A. Bakar, K. Waseem and M. Kiran, 2009. Effect of different levels of NPK on the growth and yield of cucumber (Cucumis sativus) under the plastic tunnel. J. Agric. Soc. Sci., 5(3): 99-101.

[17] Shehata, S.A., H.A. Hassan, A.A. Tawfik and M.F. Farag, 2016. Improving the productivity and quality of the cucumber crop grown under greenhouse conditions using

some stimulants and spraying amino acids. J. Plant Production, Mansoura Univ., 7(4): 385-392.

[18] Feleafel, M.N., Z.M. Mirdad and A.S. Hassan, 2014. Effect of NPK fertigation rate and starter fertilizer on the growth and yield of cucumber grown in greenhouse. J. Agri. Sci., 6(9): 81-92.

[19] Metin, S.S., A. Yazar, M. Canbolat, S. Eker and G. Felike, 2005. Effect of drip irrigation management on yield and quality of field grown green beans. Agricultural Water Management, 71(3): 243-255.

[20] Abdel-Mawgoud, A.M.R., 2006. Growth, Yield and quality of green bean (Phaseolus Vulgaris) in response to irrigation and compost applications. Journal of Applied Sciences Research, 2(7): 443-450.

[21] El-Shawadfy, M., 2008. Influence of different irrigation systems and treatments on productivity and fruit quality of some bean varieties M. Sc. Thesis, Fac. of agric., Ain shams Univ.