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DESIGN OF A POP-UP SPRAY IRRIGATION SYSTEM FOR TURF LANDSCAPES USING AN EXPERT SYSTEM

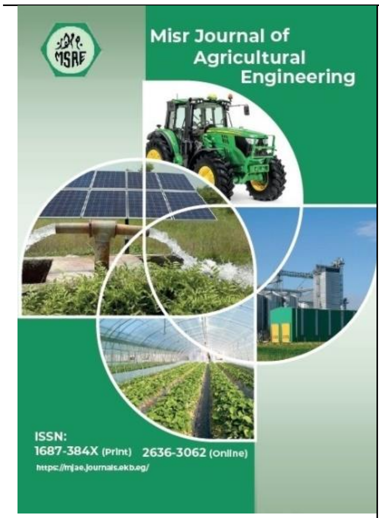
A. M. Abokora[1], K. F. El Bagoury[2], O. M. Bedeer[2], Z. M. Hendy[3]

[1]PhD Cand in Ag. Eng. Dept., Fac. of Ag., Ain shams U. Qalyubia, Egypt.

[2]Prof. of Ag. Eng. Dept., Fac. of Ag., Ain shams U. Qalyubia, Egypt.

[3]Assist. Prof. of Ag. Eng. Dept., Fac. of Ag., Ain shams U. Qalyubia, Egypt.

* E-mail: zainabhendy@agr.asu.edu.eg



Keywords:
Pop-up sprinkler; Expert program; Runtimes; Actual water requirements

ABSTRACT

Designing an irrigation landscape turf network using pop-up sprays and expert system programs involves integrating hydraulic principles, nozzle selection, spacing strategies, and software tools to optimize water efficiency and coverage. This study evaluates the performance of a sprinkler irrigation system at Al Azbakeya historical garden using two layout patterns, square and triangular, under varying operating pressures (150, 170, and 200 kPa). Performance indicators such as Distribution Uniformity (DU) and Christiansen's Uniformity (CU) were analyzed. Results showed significant improvements in DU and CU with increasing pressure, particularly for the square layout, which achieved 90% DU and 93.74% CU at 200 kPa classified as excellent. In contrast, the triangular pattern reached only 86.35% DU and 75.10% CU, maintaining an acceptable range. To support irrigation design and management, the DOSEX program was used and validated against CROPWAT estimates. DOSEX produced irrigation run-times and component configurations closely matching those of CROPWAT, confirming its reliability. Furthermore, monthly water requirement analysis revealed that site-specific data produced by DOSEX better aligns with local climatic variations than generic calculations. Water saving analysis demonstrated that both DOSEX and CROPWAT showed increasing savings with higher pressures; however, DOSEX consistently reported slightly higher savings due to its use of localized, real-time weather data and optimization capabilities. At 210 kPa, water savings reached 11.2% with DOSEX versus 10.11% with CROPWAT.

INTRODUCTION

Lawn areas of at least 60% in most gardens are the main element representing the aesthetic and attractive destination of the garden. It also means the minimum in the gradual elements from trees to shrubs to flowering herbs to the green area that represents the basis of the artistic painting of the garden. Usually, no garden is devoid of a green surface, as it is one of the aesthetic elements in the garden. **Fontanier, and Steinke, (2017).**

The emergence of some problems in the green areas that follow the design of sprinkler irrigation systems due to the lack of technically qualified technicians created the need for an expert system to address this. Choosing the best technical specifications for the design of the sprinkler irrigation system is one of the basic processes that lead to an increase in the efficiency of the irrigation system and thus an increase in productivity (**Fontanier, and Steinke, 2017).** On the other hand, irrigation scheduling expert systems combine environmental information, agricultural expertise, and computational methods to produce tailored, efficient irrigation plans. These tools, which range from research-focused platforms like CAIS to commercial IoT-based solutions and decision support systems (DSS) like Irri net, encourage effective and sustainable water usage in contemporary agriculture. **(Mannini et al., 2013).**

In addition, (**Beder, 2010)** stated that using real-time microclimate data from automated irrigation systems significantly improves water use efficiency in turf irrigation, saving around 43.74% more water compared to traditional methods based on design assumptions or average climate data from the Central Lab for Agricultural Climate (CLAC). The engineering design and operational efficiency of sprinkler irrigation systems depend on careful selection and management of operating pressure, nozzle diameter, and sprinkler spacing, with adjustments for wind speed and soil conditions. Modeling and simulation tools further enhance system performance by allowing dynamic prediction and optimization of water distribution patterns (**Amer et al, 2012).**

The Demand for high–quality grass has resulted in the search for new methods. So, more effort should be made to develop qualified design methods to increase distribution uniformity. The sprinkler efficiency had been affected by some engineering design factors such as nozzle characteristics, operating pressure and overlapping ratio. So, this study focused on some engineering factors to increase the sprinkler irrigation system uniformity, which affects efficiency. The main objectives in this study are: (1) Obtaining the most appropriate design for the irrigation network with pop-up sprinklers, (2) Studying the factors affecting design for the irrigation, and (3) Establishing an expert system to help determine the success rates of the design about the available operational conditions

MATERIALS AND METHODS

1.1.Location and weather conditions:

This Study focused on investigating the engineering factors that effect of spray sprinkler irrigation system performance which had different characteristics at different operating pressure, Also the good design by using the accurate Sprinkler with Specific according to P.R and Lawn area nozzle can help in saving water consumption and cost by reducing operating run times according to ETo, soil type, water source and shape of area. The experiments of this study were conducted in Egypt, Downtown Cairo at Al Azbakia Historical Garden with coordination (N: 30°00'23.6"; E: 31°14'54.2) during the 2023 and 2024 seasons. The main weather variables were presented in Figure 1, which includes the maximum (T_{max}) and minimum air temperature (T_{min}), and average relative humidity (RH).

The average air temperature was 15.1°C, emphasizing the need for efficient water management. The average relative humidity was 68.3%, contributing to moderate ambient moisture. The average wind speed of 2.2 m/s provided moderate cooling and ventilation as presented in Figure (2). were collected from the Central Laboratory for Agricultural Climate (CLAC) for three years (2022,2023, and 2024)

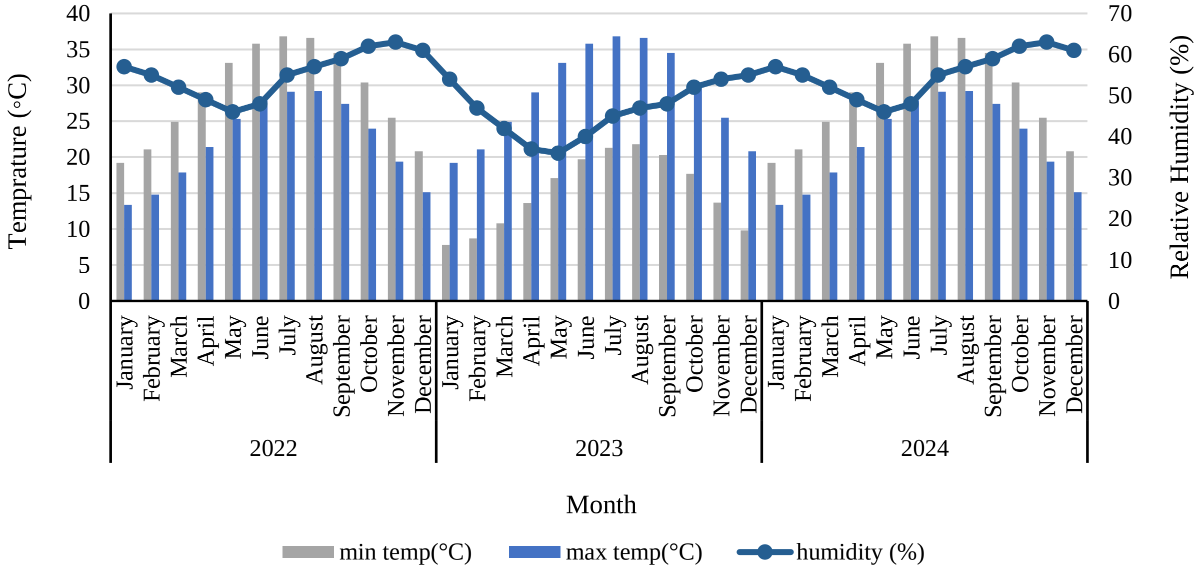


Fig. (1): Maximum, Minimum air temperature, and average relative humidity data for 2022, 2023, and 2024.

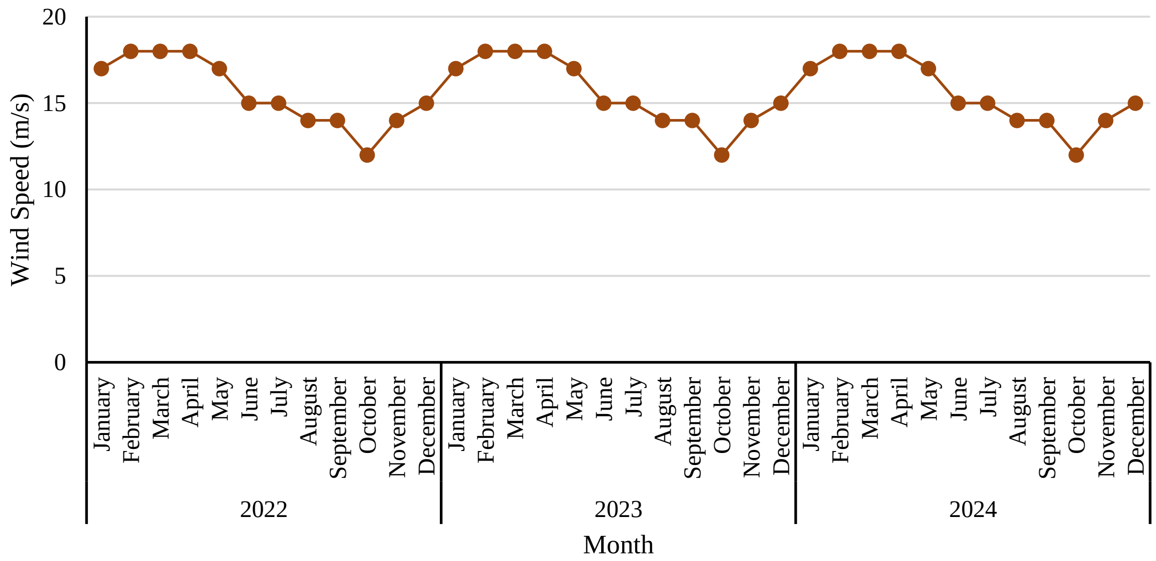


Fig. (2): Wind Speed data for 2022, 2023, and 2024

Soil samples were collected according **to (Jones, 2018),** physical and chemical analyses were done at SWERI (Soil-Water-Environment Research Institute) for the three selected sites. Some physical and mechanical properties for the Al Azbakia garden site are shown in Tables (1) and (2).

Table (1): Some Mechanical analysis, soil texture and soil-water relationship parameters of the soil sample for Al Azbakia garden site:

Sample depth	**Particle size distribution [%]**			**Soil texture**	**FC**	**WP**	**Bulk density**
Cm	Clay	Silt	Sand		(%)	(%)	(g/cm^3)
0-15	2.11	2	95.8	Sand	15.2	5.8	1.6

Table (2): Some chemical analysis of soil sample for Al Azbakia garden site:

Sample depth	pH	EC [dS/m]	Soluble Cautions [meq/l]				Soluble Anions [meq/l]		
Cm			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{--}	Cl^{-}	SO_4^{--}
0-15	7.43	3.1	9.5	6.5	14.4	0.85	1.5	19.5	10.25

1.2. Description of Irrigation System:

The experimental irrigation system at the selected site as shown in Figure (3) have the following structure: UPVC pipes in diameters 32 mm, 50 mm, 63 mm and 75 mm, designed to withstand a working pressure of 400 kpa, the pipeline has a flow range of 0.05 to 9 m³/hr and operates within a pressure range of 150 to 1000 kpa, solenoid valve (size 2"), a 120-mesh disk filter with a working pressure of 200 kpa, and spray sprinklers, the water source was a tap water.

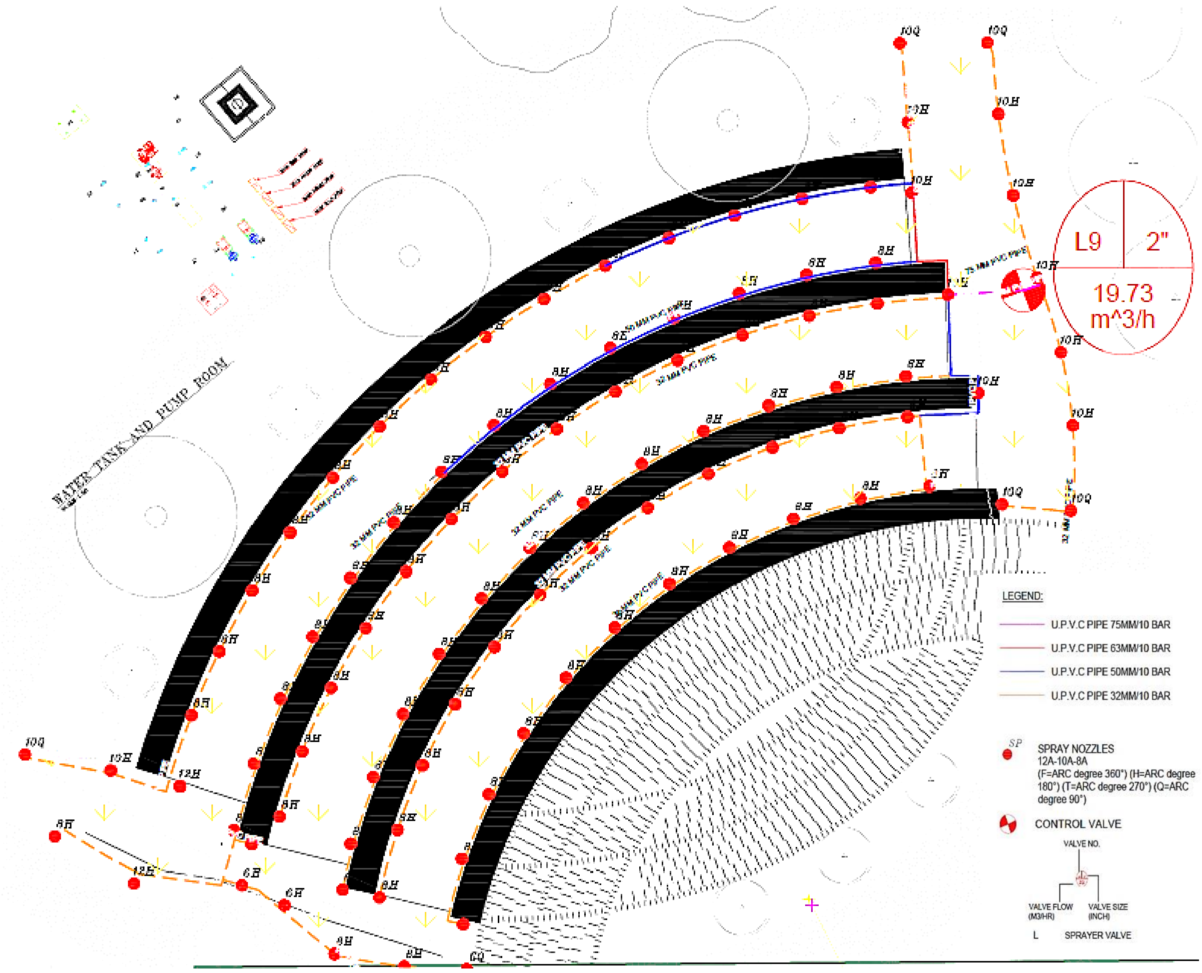


Figure (3) Experimental design of spray network for Site Al Azbakeya.

The design is implemented across the Al Azbakia garden site, covering an area of 348.6 m² with variable arc nozzles which are : nozzle 8H (Pro Fixed Nozzle, 2.4 m radius, 180°, fixed arc, female thread), nozzle 10H (Pro Fixed Nozzle, 3 m radius, 180°, fixed arc, female thread) and nozzle 12H (Pro Fixed Nozzle, 3.7 m radius, 180°, fixed arc, female thread) as presented in Figure (4) for sprinklers with100% overlapping between spray heads as presented in Table (3).

Fig. (4): (a) nozzle 8H, (b) nozzle 10H and (c) nozzle 12H

Table (3): Pop-UP Spray Sprinkler Nozzles Specifications

Operating pressure(kPa)	P.R (mm/hr)	Radius (m)	Pattern	Spray Van number	Flow (m^3/h)
150	72	2.2	SQUARE	8H	0.17
170	70	2.3	SQUARE	8H	0.18
200	67	2.4	SQUARE	8 H	0.2
150	83	2.2	TRIANGLE	8 H	0.17
170	80	2.3	TRIANGLE	8 H	0.18
200	77	2.4	TRIANGLE	8 H	0.2
150	49	2.8	SQUARE	10 H	0.19
170	49	2.9	SQUARE	10 H	0.2
200	49	3	SQUARE	10 H	0.23
150	57	2.8	TRIANGLE	10 H	0.19
170	57	2.9	TRIANGLE	10 H	0.2
200	56	3	TRIANGLE	10 H	0.23
150	39	3.4	SQUARE	12 H	0.23
170	40	3.6	SQUARE	12 H	0.26
200	40	3.7	SQUARE	12 H	0.3
150	46	3.4	TRIANGLE	12 H	0.23
170	49	3.6	TRIANGLE	12 H	0.26
200	51	3.7	TRIANGLE	12 H	0.3

2.3. Measurements and Calculations:

2.3.1. Distribution uniformity:

To validate the results of the proposed expert system program, distribution uniformity was used as a key performance indicator. This ensured the reliability of the system under varying conditions, including different sprinkler patterns (rectangle and triangle), numbers of sprinklers, and operating pressures (150, 170, and 200 kPa). The evaluation focused on how effectively water was distributed, ensuring that areas receiving the highest amounts of water met their irrigation needs while minimizing under-irrigation in other zones.

The irrigation system was evaluated by calculating the distribution uniformity (DU) for two types of sprinkler distribution patterns square as presented in Figure (5) and triangular as presented in Figure (6) using nozzle radius of 2.4, 3.0, and 3.7 meters (corresponding to nozzle number of 8H, 10H, and 12H) at an operating pressure of 200 kPa.

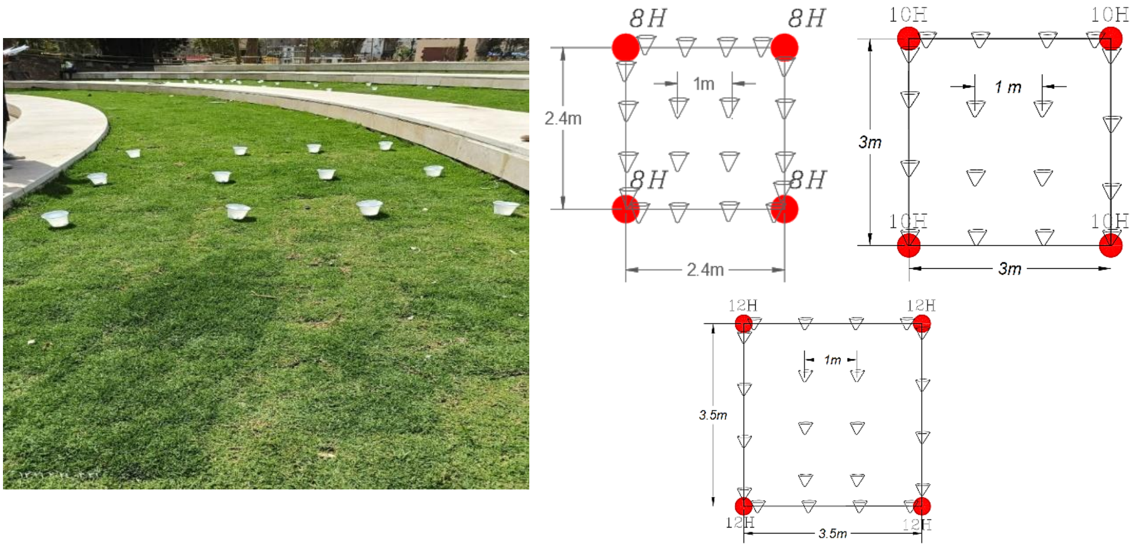


Figure (5) Catch cans distribution for square pattern distribution for 8H, 10H, and 12H nozzles

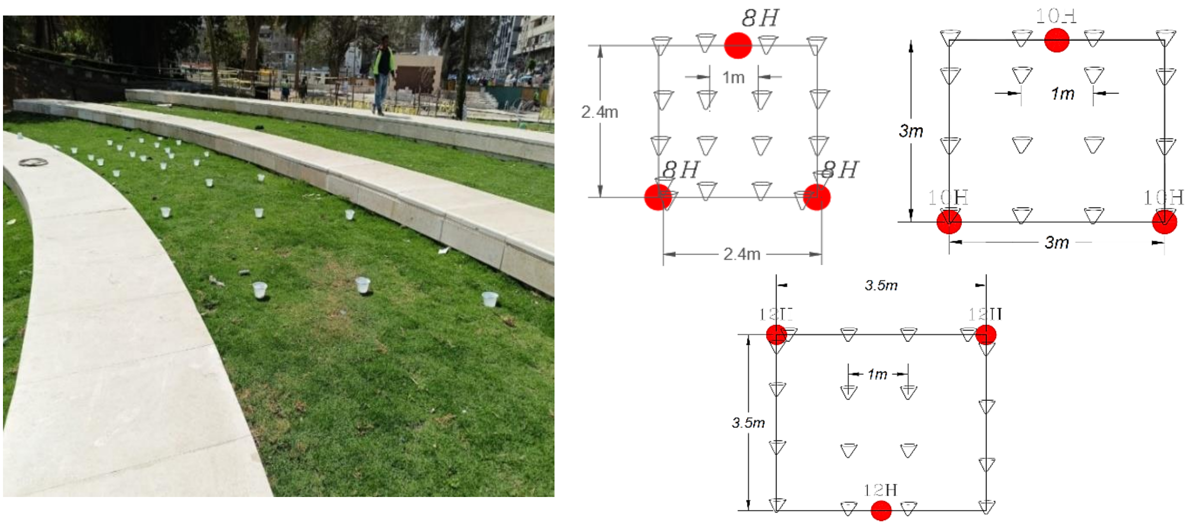


Figure (6) Catch cans distribution for triangular pattern distribution for 8H, 10H, and 12H nozzles

The evaluation was conducted using the catch-can method as described by **(Redding et al. 2024),** following the installation of the sprinkler system. The distribution uniformity of the low quarter (DUlq) was determined during the field experiment using the following equation:

$$DUlq = (dlq / davg) \times 100$$

where: DUlq is the distribution uniformity of the low quarter (%), dlq is the lowest quarter discharge (the lowest 25% of the observed discharge) (lph), davg is the average discharge of the total elements, which consists of 12 cup catch cans (lph).

Irrigation uniformity can be used as an indicator to describe the performance of the on-farm sprinkler irrigation network. Irrigation uniformity is usually characterized by:

According to **(Sinha, 2022),** DU is classified into four performance categories. A DU greater than 87% is considered excellent, indicating highly efficient water application. Values ranging from 75% to 87% are classified as good, while DU between 62% and 75% is deemed acceptable, suggesting moderate efficiency. However, a DU below 62% is regarded as unacceptable.

2.3.2. The Christiansen Uniformity Coefficient:

The Christiansen Uniformity Coefficient is commonly used in agricultural sprinkler uniformity assessment, **(Christiansen, 1942)** and **ASAE (2001)** and is expressed as,

$$CU\% = 100 \times (1 - (\Sigma(V - V')nV'))$$

where (CU) is Christiansen Uniformity Coefficient (%), (V) is individual catch can measurement (ml), and (V′) is average volume of application over all catch can measurements (ml).

According to **(Sinha, 2022)**, CU can be classified into five categories based on performance. A CU value above 90% is considered excellent, while values between 80% and 90% are rated as good. A CU between 70% and 80% is deemed fair, and values ranging from 60% to 70% are classified as poor. Any CU below 60% is considered unacceptable.

2.3.3. Crop Evapotranspiration:

Awady et al. (2003), Irrigation Association (IA, 2005), and Radwan et. al.2010 proposed using a Landscape Coefficient (KL) instead of the traditional Crop Coefficient (Kc) for more accurate estimation of plant water requirements in landscape settings. The KL accounts for plant type, microclimate, and planting density, and is calculated as:

$$KL = Ks \times Kmc \times Kd$$

where: (KL) is Landscape coefficient (dimensionless), (Ks) is Adjustment factor representing characteristics for a particular plant species (dimensionless), (Kmc) is Adjustment factor for microclimate influences upon the planting (dimensionless) and (Kd) is Adjustment factor for plant density (dimensionless).

CROPWAT was used to calculate reference evapotranspiration (Eto), then calculate the actual crop evapotranspiration (ETc), which reflects the water requirement of a specific crop, as follows (Katerji et al., 2011):

$$ETc = ETo \times Kc$$

where: Kc is the crop coefficient for paspalum 10 turf grass

Table 4: Microclimate Factor (Kmc), Density Factor (Kd), and Species Factor (Ks) for turfgrass:

Vegetation	**High**	**Average**	**Low**
Turfgrass	1.2	1.0	0.8
Density Factor (Kd) for different plant types of Vegetation	High	Average	Low
Turfgrass	1.0	1.0	0.6
Species Factor (Ks) for different plant types of Vegetation	High	Average	Low
Cool Season Turfgrass	--	0.8	--
Warm Season Turfgrass	--	0.6	--

Source: (Awady et al., 2003) and (IA, 2009).

2.3.4. Irrigation time:

The irrigation time calculation approach described integrates essential agronomic and climatic parameters to ensure efficient water management tailored to crops and environmental conditions. Three core parameters are considered: the Perception Rate (PR), which represents the rate at which water is applied to the soil (mm/hr); the Irrigation Interval (II), which is the number of days between irrigation events; and the Irrigation System Efficiency (Ea), which accounts for water losses due to system inefficiencies such as evaporation, wind drift, or deep percolation.

These values are presented in Table (4), turfgrass under average canopy and climate conditions may have Kc values calculated based on standard factors. By combining these inputs, the optimal irrigation time can be calculated by the following equation (**Shaw and Pittenger, 2009).**

$$\text{Irrigation time (T)} = \frac{Eto \times Kc \times II}{PR \times Ea}$$

where (PR) is the perception rate (mm/hr), (II) is the irrigation interval (day), and (Ea) is the irrigation system efficiency.

2.3.5. Water Saving Percentage:

The total seasonal irrigation requirement was calculated at each of the three pressure levels. The water saving percentage was then determined by comparing the water requirements at each pressure level (150, 170 and 200kPa) for CROPWAT and DOSEX program.

2.4. Design and operating Sprinkler Expert Program (DOSEX):

DOSEX is designed to develop the most appropriate design and operation methods for irrigation network spray sprinklers. The flowchart illustrates the operational procedure for the DOSEX program as presented in Figure (7), which is designed to develop optimal design and operation methods for spray sprinkler irrigation networks. The process begins with the user initiating the program and inputting two key categories of data: sprinkler data and location data. For the sprinkler configuration, the user manually selects parameters such as sprinkler pattern, pressure, spray nozzle, and valve size. The program verifies that all required sprinkler inputs are complete before proceeding. Simultaneously, the user inputs location data, either by selecting predefined locations, Cairo Al Azbakeya, or other locations by manually entering location details and reference evapotranspiration (ETo) if the location is not listed. If a known location is chosen, the user must provide the year and month for ETo and input the irrigation area. Once all data is confirmed to be fully inputted, the program executes calculations to determine the number of sprinklers (quarter, half, and full circle types), total water flow, initial pipe size, number of zones and valves, and the required run time. This structured approach ensures accurate and efficient irrigation system design tailored to specific environmental and operational parameters. Dosex is based on the Visual Basic programming language and needs to small space storage (1109 KB).

2.4.1. The manual of DOSEX contains the steps of the Program:

The user can add location data by clicking the location menu strip once the input panel has opened. The Area Per Square Meter can then be written by the user. Following each step, the user can clear any entered data or return home for any changes. Initially, the user can choose from three preset destinations or enter a different option when the location screen opens. For instance, a new page with fields for the compound name, North latitude, East longitude, water type, and all physical and chemical information about the soil and pump will appear if the user chooses downtown (Al-Azbakeya)

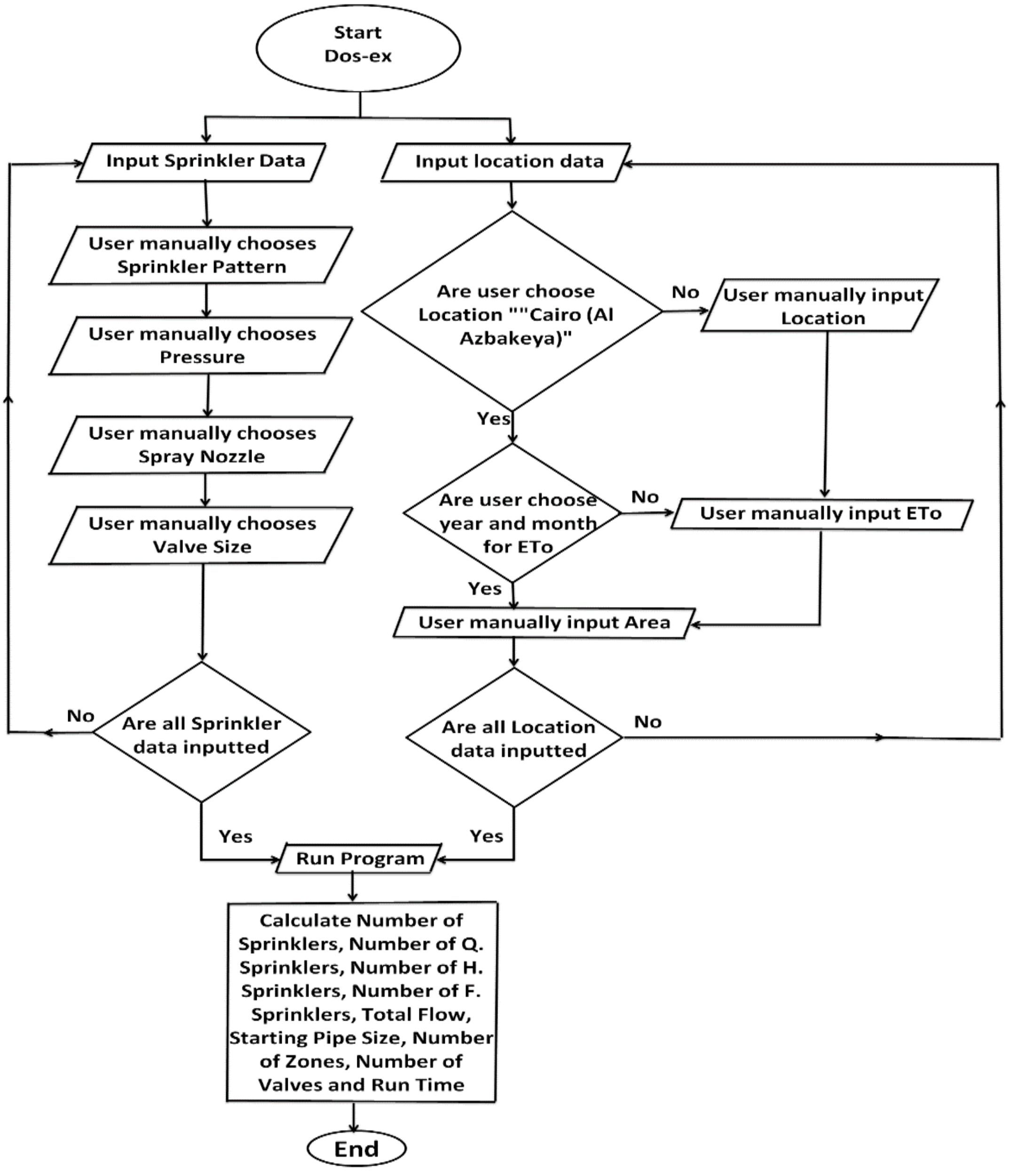


Fig. (7). Flow chart for operating the DOSEX-Program

The user can choose the month and year in the second step, after which the ET_O value will be displayed from the database. If the user wants to clear the entered data, they can click the clear data button to re-enter the data. If the user needs to continue, they can click the save Data button. Next, the user wants to open a new Screen and select a sprinkler Pattern (Square -Triangular), The user can click the sprinkler menu strip to open the sprinkler screen. Then you can press the pattern to open a new screen and select a sprinkler pattern. The user can click the pressure button to open a new screen and select the company and spray nozzle. The user can click the valve size button to open a new screen and select the sprinkler pressure. The user can click the spray nozzle button to open a new screen and select the company and spray nozzle. The user can click the valve size button to open a new screen and select the valve size. If they wish to continue, they can click the data button. The user must click the Run Program button to open the output screen as presented in Figure (8).

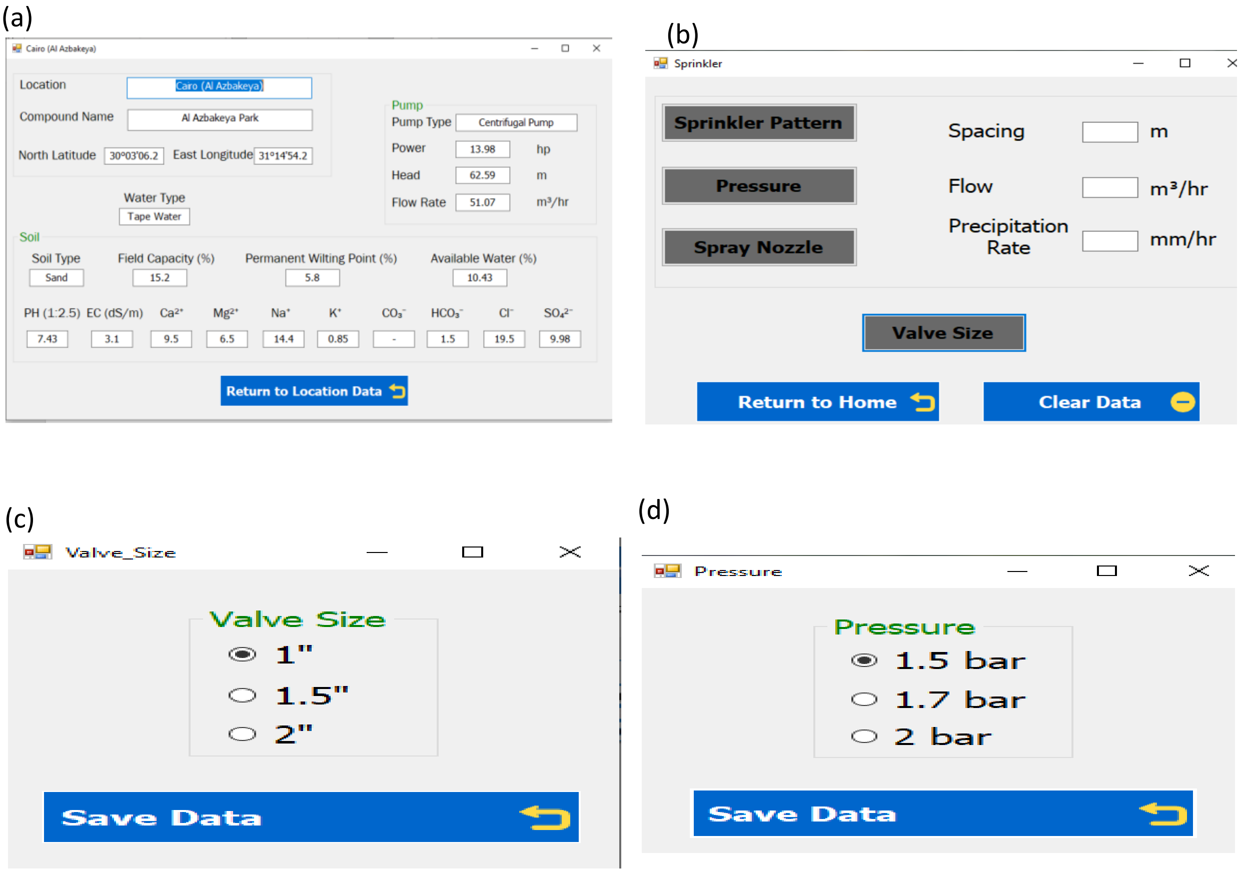


Fig. (8): Steps of Dosex program inputs sequence: (a) Site location Data According to Actual Data, (b) Sprinkler Data According to Specific Catalogs of material, (c) Valve size Estimated by user and (d) Actual Working Pressure at the site.

2.5. Verification & Validation Methods:

The verification step was carried out to ensure the system logic is consistent and complete, detect technical errors in rule implementation, and confirm that the system conforms to predefined specifications.

The verification step was carried out in two stages. Firstly, to verify the calculations that were entered into the Dosex program with the Excel program to ensure that the calculation is true and to determine the correlation percentage. Secondly, comparing the results of the case study evaluates whether the expert system has been developed correctly according to its design specifications and technical requirements. It ensures that the knowledge base, reference engine, and user interface are implemented properly, with the result of the calculation based on cropwat data to verify the logistics of applying the DOSEX program. The items of verification are summarized in calculating the percentage of water saved and the operating run times.

Validation is the process of evaluating whether the expert system fulfills its intended purpose and provides useful, accurate, and acceptable outputs to the end user.

The validation step was carried out to ensure that the results of the DOSEX program achieve the purpose of calculating the accurate number of sprinklers, calculating their operating conditions accurately from water requirements, run times, and the pattern of distributing the sprinklers.

RESULTS AND DISCUSSIONS

3.1. Irrigation System Performance Indicators:

The DU of the sprinkler irrigation system was evaluated under different operating pressures for both square and triangular sprinkler layout patterns. The results show a clear improvement in DU with increasing pressure for both configurations. For the square pattern, DU increased from 68.8% at 150 kPa, to 79.61% at 170 kPa, and reached 90% at 200 kPa, indicating a transition from acceptable to excellent performance as pressure increased. Similarly, in the triangular pattern, DU improved from 65.4% at 150 kPa, to 78.7% at 170 kPa, and further to 86.35% at 200 kPa, moving from unacceptable to good classification as presented in Figure (9).

The square pattern consistently showed slightly better uniformity than the triangular pattern across all pressure levels, especially at 200 kPa where it achieved the highest DU of 90%, classified as excellent. This indicates that the square pattern may be more effective under higher pressure conditions in delivering uniform water distribution.

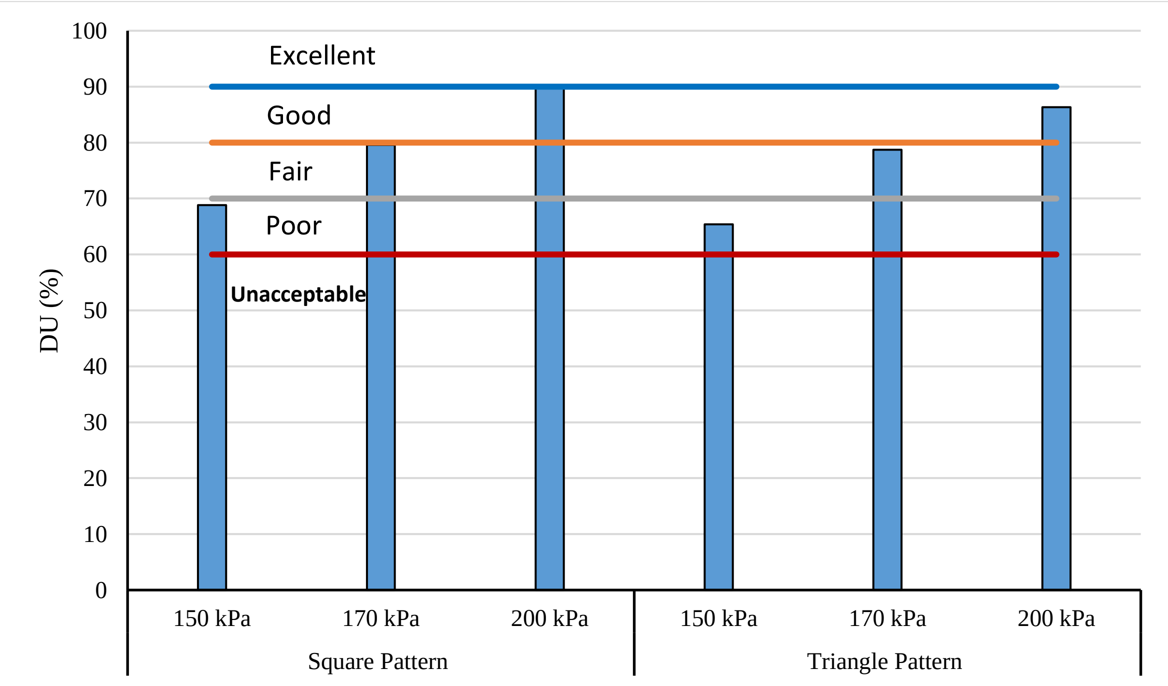


Fig. (9): Values of DU for Al Azbakeya historical garden under different operating pressures and sprinkler distribution patterns (square and triangular)

CU was evaluated for both square and triangular sprinkler distribution patterns under varying operating pressures of 150, 170, and 200 kPa. For the square pattern, CU increased significantly with pressure, rising from 70.3% at 150 kPa to 87.81% at 170 kPa, and reaching 93.74% at 200 kPa. This improvement indicates progression from fair to excellent uniformity, highlighting the positive impact of higher pressure on system performance. In contrast, the triangular pattern showed a more modest increase, with CU values of 70.12%, 72.98%, and 75.10% at 150, 170, and 200 kPa, respectively, maintaining a classification range between fair and acceptable as presented in Figure (10).

These results demonstrate that operating pressure is a key factor influencing water distribution uniformity, with higher pressures generally resulting in better performance. Additionally, the square layout pattern outperformed the triangular pattern at all pressure levels, particularly at 170 and 200 kPa, where the CU difference was more pronounced. This suggests that the square pattern, especially under higher pressures, is more effective in achieving uniform water application, making it a preferable option for efficient irrigation system design in similar conditions.

These results clearly illustrate that increasing the operating pressure enhances the performance of the sprinkler system, particularly in the square pattern.

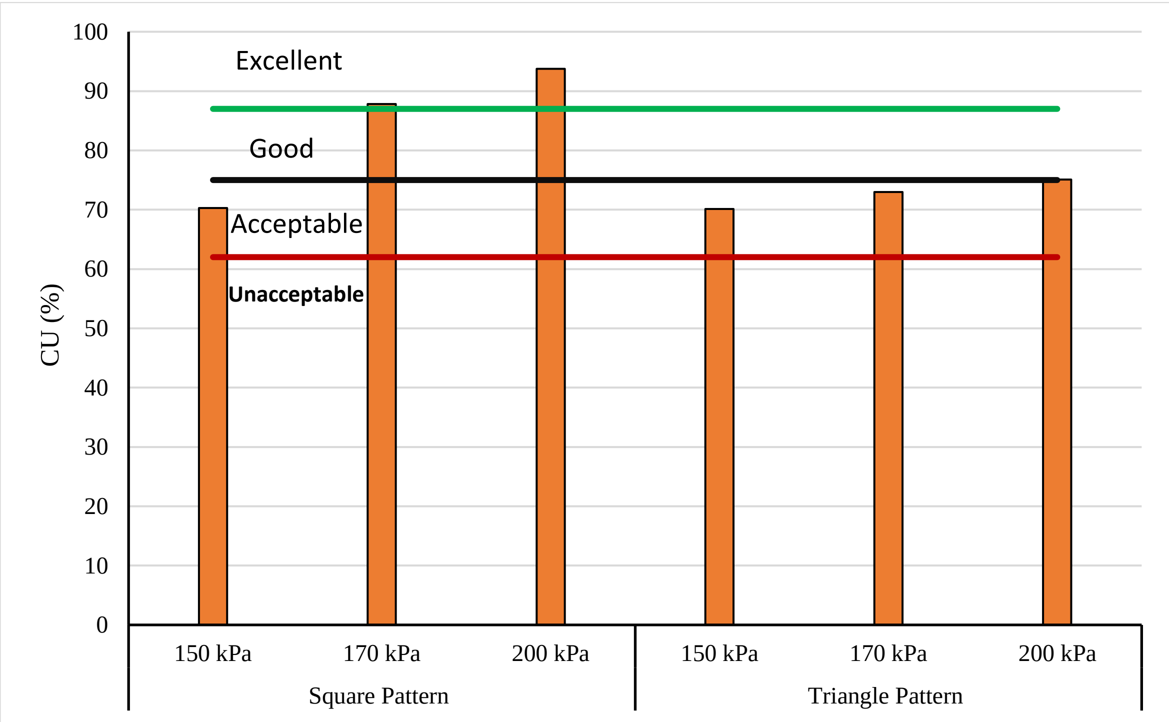


Fig. (10): Values of CU for Al Azbakeya historical garden under different operating pressure and sprinkler distribution patterns (square and triangular)

3.2. DOSEX Program:

3.2.1. Program Output data:

As presented in Figure (11), the output from the DOSEX program provides a comprehensive overview of the irrigation system's components and performance metrics. These include the number of sprinklers, types of sprinklers (quarter circle, half circle, full circle), total flow rate (m^3/h), starting pipe size (mm), number of zones, number of valves, and daily run time (min/day).

3.2.2. DOSEX Program Validation and Verification:

The monthly average water requirements for Al Azbakia, site show a consistent seasonal pattern, with the highest demand occurring in the summer months and the lowest in winter, as shown in Figure (12), water requirements gradually increase from January through June, peaking in June at 9.84 mm/day. July and August maintain high demand, though slightly lower than June, before the requirements begin to decline from September onwards.

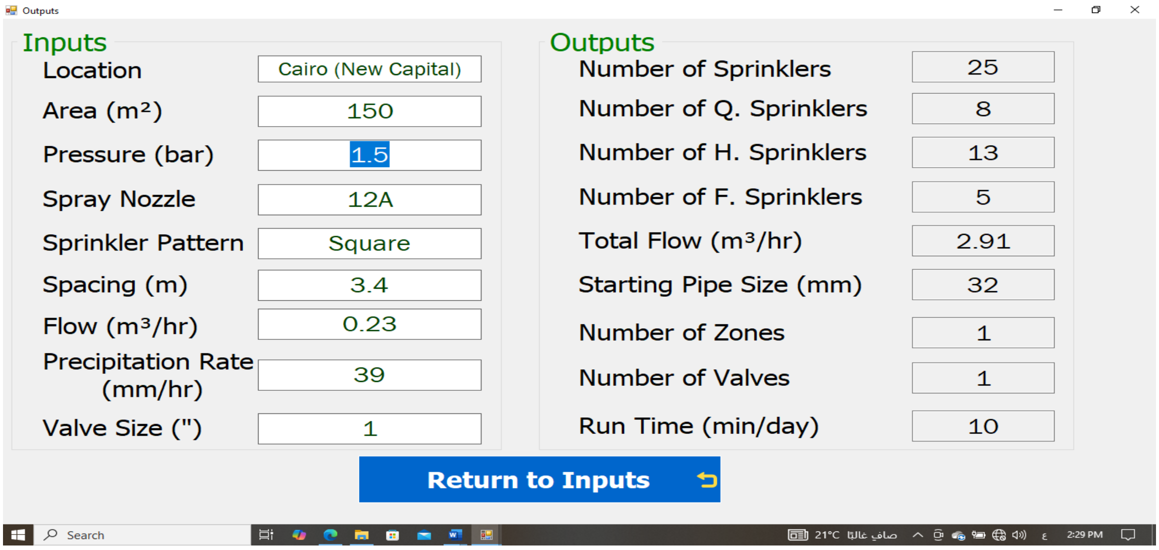


Fig. (11): Represents the output of DOSEX according to user choices.

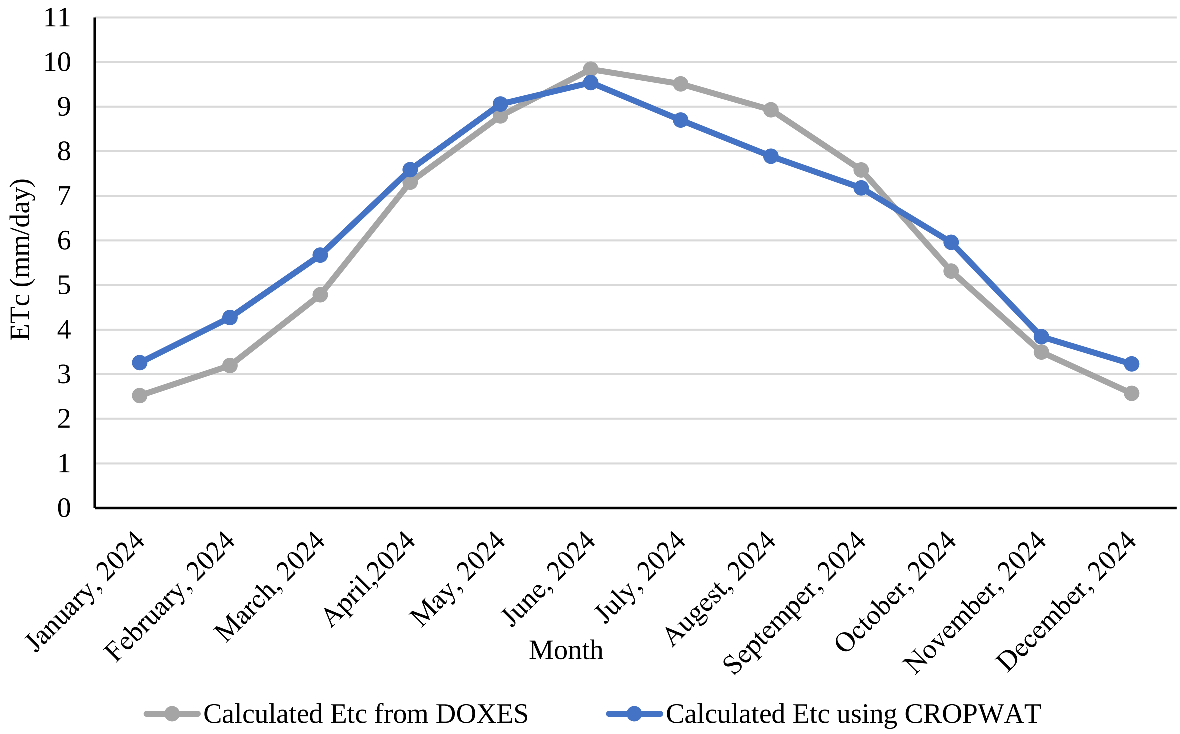


Fig. (12): Average of water requirements for the Al Azbakia site compared with calculated averages.

The lowest water demands are recorded in January and December, ranging between 2.27 mm/day and 2.57 mm/day. When compared to the calculated water requirement values, based on climatic and crop coefficients, it is evident that the calculated figures are consistently higher than the site-specific averages, particularly during the cooler months. For example, in January, the calculated requirement is 3.26 mm/day, while the site averages range between 2.31 mm/day and 2.52 mm/day. Similarly, in June, although the measured site demands peaked, the calculated value was 9.54 mm/day. This comparison indicates that the calculated water requirements provide a useful reference, but local weather statistics (Al Azbakia) show some deviations, especially in summer. This insight is important for optimizing irrigation scheduling based on site-specific conditions.

To assess the effectiveness of the DOSEX program in optimizing irrigation system design and water use, a comparative analysis was conducted between DOSEX outputs and manual design methods under an operating pressure of 210 kPa. The comparison included the number of sprinklers used and water savings achieved using different climatic data sources.

Figure (13) illustrates the variation in run times derived from three approaches: DOSEX with CROPWAT estimation for Sprinklers run time. The monthly sprinkler run-time values calculated from both the DOSEX program and the CROPWAT model demonstrate a high degree of similarity, indicating strong consistency between the two approaches in estimating irrigation requirements throughout the year. Across all months, the run-time differences between the two models are relatively minor, typically within a range of less than one hour. This close agreement suggests that both models are well-calibrated and capable of accurately reflecting crop water needs under the climatic conditions of the study area.

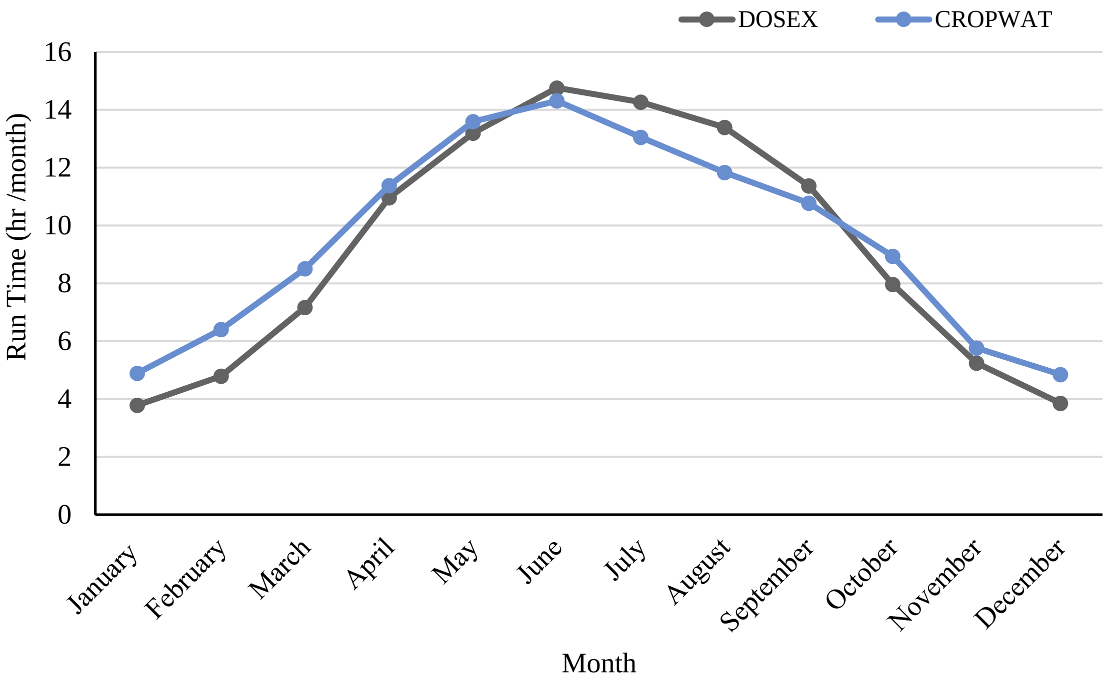


Fig. (13): Run time calculated according to the CROPWAT and DOSEX programs.

In May and June, both tools estimated almost identical irrigation times, 13.19, 13.59 hours in May and 14.76, 14.31 hours in June compared with DOSEX and CROPWAT respectively, such minimal differences underscore the reliability of DOSEX in replicating standard irrigation recommendations like those provided by CROPWAT, which is widely used for planning and managing agricultural water use. Even during months with relatively greater climatic variation, such as January, the discrepancies remain modest. In January, DOSEX estimated 3.78 hours while CROPWAT estimated 4.89 hours. These differences may be attributed to the models' sensitivity to climatic data inputs, with DOSEX potentially using more localized or real-time weather data, while CROPWAT is based on long-term climatic averages.

3.3.Water Saving using the DOSEX program:

Figure (14) compares the estimated water saving percentages obtained using the CROPWAT and DOSEX programs under three different operating pressures: 150 kPa, 170 kPa, and 210 kPa. The analysis reveals that both models follow a similar trend, with water savings increasing as the operating pressure rises. However, the DOSEX program consistently reports slightly higher water-saving percentages across all pressure levels compared to CROPWAT.

At 150 kPa, the water saving is 7.74% according to CROPWAT and 8.05% by DOSEX, indicating a marginal difference of 0.31%. As pressure increases to 170 kPa, the difference becomes more pronounced, with DOSEX estimating a saving of 9.43% versus 7.72% from CROPWAT—a difference of 1.71%. This trend continues at 210 kPa, where DOSEX predicts 11.2% saving, while CROPWAT estimates 10.11%, resulting in a 1.09% gap.

These differences can be attributed to the input sensitivity and computational structure of each program. While CROPWAT relies on generalized climatic data and standard crop coefficients, DOSEX integrates real-time weather station data and site-specific parameters, potentially leading to more precise estimations tailored to the actual field conditions. The higher water saving percentages in DOSEX may also reflect optimization in irrigation scheduling and system design, which are accounted for more dynamically in the program.

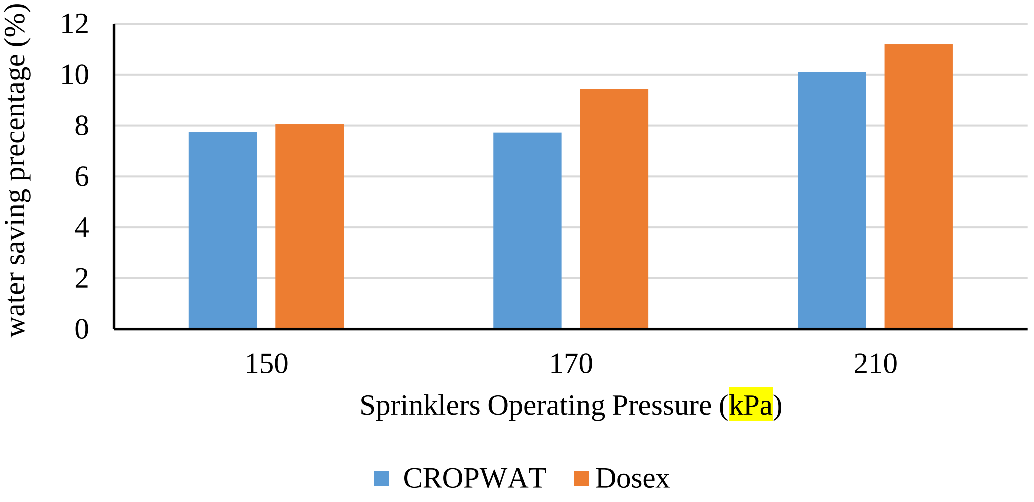


Fig. (14): Water saving comparison between Dosex design and CROPWAT

CONCLUSIONS

This study demonstrated the effectiveness of optimizing sprinkler irrigation system performance through the proper selection of layout patterns, operating pressures, and the use of decision-support tools. Among the tested configurations, the square sprinkler layout pattern at 200 kPa operating pressure provided the highest irrigation uniformity, with a Distribution Uniformity (DU) of 90% and a Christiansen's Uniformity (CU) of 93.74%, both classified as excellent. In comparison, the triangular layout showed lower efficiency, confirming that layout design significantly influences irrigation performance. The DOSEX program proved to be a reliable and accurate tool for scheduling and system design irrigation. Its results closely matched those of the widely used CROPWAT model but offered enhanced flexibility by integrating actual weather data, which enabled more precise water requirement estimations and improved water-saving calculations. Furthermore, water-saving analysis across different operating pressures indicated that higher pressures improved water distribution and efficiency, with DOSEX consistently achieving slightly greater savings than CROPWAT. This reinforces the value of using advanced, locally adaptive software tools in modern irrigation planning.

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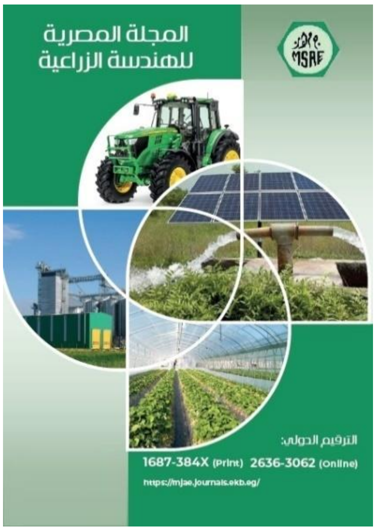
تصميم شبكه ري للرشاشات القافزة للمسطحات الخضراء باستخدام أحد النظم الخبيرة

ايه محمد علي أبو قوره[1] ، خالد فران طاهر الباجوري[2] ، أسامه محمد أحمد بدير[2] ، زينب محمود هندي[3]

[1]طالبة دكتوراه بقسم الهندسة الزراعية -كلية الزراعة - جامعة عين شمس- القليوبية - مصر.

[2]استاذ بقسم الهندسة الزراعية - كلية الزراعة - جامعة عين شمس - القليوبية - مصر.

[3]مدرس بقسم الهندسة الزراعية - كلية الزراعة -جامعة عين شمس- القليوبية - مصر.



الكلمات المفتاحية:
الرشاشات القافزة، البرامج الخبيرة، زمن التشغيل، الاحتياجات المائية الفعلية.

الملخص العربي

يُعد نظام الري للرشاشات القافزة من أكثر الطرق شيوعًا لري المسطحات الخضراء مثل "الإسبراي" ، ويختلف استخدام كلٍ منها بحسب ظروف التصميم. ومع التوسعات العمرانية الحديثة، التي تؤدي بدورها إلى زيادة مساحة المسطحات الخضراء. تقيم هذه الدراسة أداء نظام الري بالرش في حديقة الأزبكية التاريخية باستخدام نمطين للتخطيط مربع ومثلث تحت ضغوط تشغيل متفاوتة (١٥٠ و ١٧٠ و ٢٠٠ كيلو باسكال). تم تحليل مؤشرات الأداء مثل انتظام التوزيع (DU) وانتظام كريستيانسن (CU) . أظهرت النتائج تحسنًا كبيرًا في DU وCU مع زيادة الضغط، وخاصةً بالنسبة للتخطيط المربع، الذي حقق ٩٠٪ DU و ٩٣,٧٤٪ CU عند ٢٠٠ كيلو باسكال- وهو ما تم تصنيفه على أنه ممتاز. في المقابل، وصل النمط المثلث إلى ٨٦,٣٥٪ DU و ٧٥,١٠٪ CU فقط، محافظًا على نطاق مقبول. لدعم تصميم وإدارة الري، استُخدم برنامج DOSEX وتم التحقق من صحته مقارنةً بتقديرات CROPWAT. أنتج DOSEX أوقات تشغيل للري وتكوينات مكونات مطابقة تمامًا لـ CROPWAT، مما يؤكد موثوقيته. علاوة على ذلك، كشف تحليل الاحتياجات المائية الشهري أن البيانات الخاصة بالموقع التي ينتجها DOSEX تتوافق بشكل أفضل مع التغيرات المناخية المحلية مقارنةً بالحسابات العامة. أظهر تحليل توفير المياه أن كلاً من DOSEX وCROPWAT أظهرا وفورات متزايدة مع ارتفاع الضغوط؛ ومع ذلك، فقد أبلغ DOSEX باستمرار عن وفورات أعلى قليلاً بفضل استخدامه لبيانات الطقس المحلية والفورية وقدرات التحسين. عند ٢١٠ كيلو باسكال، بلغت وفورات المياه ١١,٢٪ مع DOSEX مقابل ١٠,١١٪ مع CROPWAT.