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EFFECT OF OVERHEAD FLOPPY SPRINKLER ON WATER DISTRIBUTION UNIFORMITY

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ABSTRACT: This study looked into how changing operating pressures affected the uniformity of water distribution under overhead floppy sprinklers. Coefficient of uniformity (CU%), distribution uniformity (DU%), and application efficiency of the low quarter (AELQ%) were calculated under five levels of operating pressure (1.0, 1.5, 2.0, 2.5, and 3.0 bar) under overhead height (3 m) for tow devices of floppy sprinkler, original type (FS1), and local type (FS2) at the experimental farm of ElSalhia, ElSharkia Governorate, Egypt during the 2023 season. The findings showed that the overhead floppy sprinkler with the highest CU, DU, and AELQ values (82.37%, 72.91%, and 65.81% for FS1) and 80.75%, 72.88%, and 65.59% for FS2), respectively, required an operating pressure of 2.0 bar and a height of 3 meters. Additionally, the results demonstrated that, under the identical operating pressure conditions, the FS1 sprinkler's CU, DU, and AELQ values are higher than those of the FS2.Finally, it is recommended to use the original floppy sprinkler.

Key words: Floppy sprinkler, Uniformity and Operating Pressure.

INTRODUCTION

The blessing of nature and an essential component of life's existence are freshwater resources. Since water is essential to the economy as a whole, its demand is unavoidable in all facets of existence. Based on the disparity between rainfall and evapotranspiration rate, the area is divided into semiarid and arid zones. A serious issue now is the rising demand for water in cities, industries, and agriculture **(AlEmadi, 2021)**. More than 70% of water withdrawals worldwide are for irrigation, which uses more water than any other application. Water, which makes up 20% of all cultivated land, is essential to feeding the world's population and accounts for 40% of global food production **(Hamidov and Helming, 2020)**.When used properly, modern irrigation techniques can save a significant amount of water, particularly in dry and semiarid regions.The flooded land magnitude represents the water supply as opposed to irrigation with surface water, and the high irrigation efficiency of FSS, sprinkler, and drip irrigation systems allows for higher crop production and more revenue with better supervision **(Samimi *et al*., 2020).** These are just a few of the main benefits of these systems.Uneven water circulation is the outcome of a poorly built and maintained PIS.Irrigation water homogeneity is the evaluation method's highest valued outcome in these irrigation practices.Following the conveying technologies, the UC is a crucial indicator of how uneven or equal the application rates (AR) are **(Sadeghi *et al*., 2021)**.Surface irrigation, subsurface irrigation, sprinklers, micro irrigation, and hybrid irrigation are the most effective irrigation methods. For each of the aforementioned systems, the standard irrigation and water application efficiency results are 82% for the center pivot system, 74% for the floppy system, 95% for subsurface drip, and 68% for the solid set **(Shabbir *et al*.,**

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2020).The performance of the sprinklers aids in differentiating the cropping system choosing process. Evaporation losses, distribution uniformity, and wind drift are the main metrics used to assess the performance of sprinkler systems in highly efficient irrigation systems **(Roberts *et al*., 2021).** The distribution pattern, droplet size, application rate, wetted radius, and water discharge were used to analyze the sprinkler's performance.Sprinkler irrigation systems are heterogeneous due to variations in weather conditions, sprinkler spacing, layout, design, and hydrant locations **(Zema *et al*., 2019).**The sprinkler system's maximum water flow capacity may be impacted by the sprinkler design's disregard for wind direction or speed.According to **Darko *et al*., (2017),** high wind speeds are not recommended for sprinkler system design management or dependability.The effects of pulsing pressure on the uniformity of sprinkler distribution on sloping terrain were recently discovered by a study **(Zhang *et al*., 2019).**It came to the conclusion that pulsing pressure had 10% more homogeneity than continuous pressure. The Kakara Tea Irrigation System (KTIS) sprinkler system's performance was assessed in the study. The results showed that the delivery performance ratio was 79% and the coefficient of uniformity was 90.9% **(Ngasoh *et al*., 2018).**To enhance irrigation management, field evaluation of irrigation system performance is required.

Griffiths and Lecler, (2001) evaluated the field distribution of seven floppy sprinklers.They discovered that the floppy sprinkler's uniformity coefficients varied between 66 and 84%.The distribution of floppy sprinklers, on the other hand, varied between 59 and 78%. The proper water distribution for a floppy sprinkler at a suitable irrigation intensity was discovered by **Aboamera and Sourell, (2003).**They state that for the 8 m sprinkler and lateral distance at 1.5 m height and 200 kPa pressure, the averaged uniformity coefficient (UC) and uniformity distribution (UD) were 88.01% and 80.94%, respectively.

The primary goal of the current study was to compare the irrigation performance of the original floppy sprinkler (FS1) and the local floppy sprinkler (FS2) in order to assess performance and identify the ideal operating conditions that result in high application efficiency. Additionally, the study examined the effects of varying operating pressure on the application uniformity under overhead floppy sprinklers.

MATERIALS AND METHODS

During the 2023 season, field tests were conducted in sandy soil at the El Salhia experimental farm, which is situated at 30◦ 36′ N and 31◦ 47′ E, El Sharkia Governorate, Egypt.A pumping unit, head control unit, pipe lines, and sprinkler mechanism that up the experimental overhead floppy sprinkler system. Pipelines were designed with a 75 mm PVC main, a 63 mm PVC submain, and an overhead lateral line with 50 mm PE. A fixed overhead floppy system was connected. One original type (FS1) and another local type (FS2) of floppy sprinkler tow devices were placed as a permanent system. A variety of crops were used with the Overhead floppy design.A plastic pipe with a flexible silicon tube installed within the sprinkler body made up a floppy sprinkler.Water snakes through the tube as it rotates slowly in a 360degree circle, creating droplet. To collect water, plastic catch cans measuring 175 mm in diameter and 135 mm in height were placed beneath the floppy sprinkler in the whole sprinkler circle. The catch cans were spaced 1.5 meters apart for the throw sprinkler's radius across laterals and along them.The test lasted for sixty minutes.A measurement of the collected water's area in millimeters per hour was made.To ascertain high uniformity under Egyptian conditions, the floppy sprinkler was tested at five operating pressure levels (1.0, 1.5, 2.0, 2.5, and 3.0 bar) and at an overhead height of 3 meters .

The distribution of the catch cans followed the 2001 ASAE Standard, and table 1 shows the distance between collectors (catching cans) for determining the radius of throw.

By attaching a flexible tube to the sprinkler nozzle and gathering a known volume of water in a container for a predetermined amount of time (15 minutes), the discharge of a floppy sprinkler was measured.The following formula was used to determine the flow rate **(Melvyn, 1983)**

Table 1. Spacing of collectors according to **ASAE Standard, 2001**

Sprinkler Radius of Throw, m(ft)	Maximum Collector Spacing Center to Center, m(ft)
0.3 - 3 (1 - 10)	0.30 (1.0)
3 - 6 (10 - 20)	0.60 (2.0)
6 - 12 (20 - 39)	0.75 (2.5)
> 12 (> 39)	1.50 (5.0)

By attaching a flexible tube to the sprinkler nozzle and gathering a known volume of water in a container for a predetermined amount of time (15 minutes), the discharge of a floppy sprinkler was measured.The following formula was used to determine the flow rate **(Melvyn, 1983).**

$$Q = \frac{V}{t}$$

Where, Q is the flow rate of sprinkler in m^3 h^{-1}, V is the collecting water volume in m^3 and t is time of collecting water in h.

Catch cans placed across the sprinkler's entire circle under various treatments were used to collect the water applied by each sprinkler. The following formula was used to determine the sprinkler application rate **(James, 1988).**

$$A = k\frac{Q}{a}$$

Where, A is the application rate in mm h^{-1}, Q is the flow rate of sprinkler in l min^{-1}, a is the wetted area of sprinkler in m^2 and k: unit constant (k = 60.0 for A in mm h^{-1}, Q in l min^{-1} and a in m^2).

Wetting diameter (WD): By progressively raising the pressure, the wetting diameter of the throw for a floppy sprinkler was measured at various pressures between 1.0 and 3.0 bars, with an increment of 0.5 bar.The measuring tape was used to take a direct measurement from the sprinkler head's center to the water throw's end.The experimental setup's boundary sprinklers were used to compute the wetting diameter.

Many indicators were cited in many international studies and reports to assess a system's performance in the field.In this study, the effectiveness of the floppy sprinkler irrigation system was assessed using three parameters: DU, CU, and AELQ.

Water used for irrigation is distributed to the field according to distribution uniformity (DU). About 1/8 of the region is equivalent to the uniformity represented by DUlq (as well as all phrases pertaining to the low quarter).Furthermore, it is less than the price of a numerator.

Heermann and Solomon (2007) state that the DU is "regular depth penetrated in the small ¼ of field alienated by an average distance of water penetrated incomplete field" **Bilalis *et al.*, (2009)** investigated the distribution uniformity and found that it was represented as follow:

$$DU = 100\frac{\overline{D}_{lq}}{\overline{D}}$$

Where: DU is distribution uniformity (%) $\overline{D}_{lq}$ is average can depth in the lowest quarter of the field *(*mm) and $\overline{D}$ is average can depth *(*mm)

Coefficient of Uniformity (CU): This term indicates the performance effectiveness of a sprinkler by measuring the water uniformity of sprinkler irrigation systems **(Christiansen, 1942)**.Other types of irrigation have occasionally used the CU.The most significant historical benchmark for sprinkler irrigation systems is used to gauge how well sprinkler systems are performing.When compared to the mean, the coefficient of uniformity handles overirrigation and underirrigation equally **(Pahlevani *et al*., 2021)**.This is measured using the Christiansen formula, which looks like this:

$$CU = 100\left[1 - \frac{\sum_{j=1}^{n}|V_i - {}^{-}V|}{\sum_{j=1}^{n}V_i}\right]$$

Where: CU showed the Christiansen's uniformity coefficient (%), Vi showed the water depth in individual collectors, ¯V showed the average water's depth in all cans. Other parameters, such as runoff, wind speed, AR, pump performance, water application amount, and overall system management, should be taken into account for the sprinkler performance evaluation in addition to the distribution uniformity and coefficient of uniformity **(Hartin *et al*., 2018).** Christiansen's uniformity coefficient is the highest value that is frequently utilized for calculating water uniformity distribution in highefficiency sprinkler irrigation systems, according to **Liu *et al*., (2019).**

Application efficiency of the low quarter (AELQ%): AELQ was calculated using the following formula **(Xiang, *et al*., 2018):**

$$AELQ = 100\frac{Z_{r.lq}}{D}$$

Where, Zr.lq shows the average low quarter depth of water measured (mm), and D demonstrates the required average water depth (mm).

RESULTS AND DISCUSSION

Effect of Operating Pressure on Discharge, Application Rate and Wetting Diameter

Table 2 showed how operating pressure affects the discharge, application rate, and wetting diameter of two different kinds of floppy sprinklers: the original type (FS1) and the local kind (FS2). It is clear that operating pressure had a significant impact on each sprinkler's discharge. The findings demonstrated a clear correlation between pressure and the discharge from the floppy sprinkler.

Therefore, the discharge for the floppy sprinkler increased by 71.6% for FS1 and 55% for FS2 when the pressure was raised from 1.0 to 3.0 bar. In the meantime, the application rate rose as operating pressure rose; for FS1 and FS2,the application rate rose by 36% and 26.3%, respectively.

It is evident from the results that high operating pressure might be used to generate a high application rate for the two types of floppy sprinklers, FS1 and FS2, respectively. Because of the higher discharge, the application rate rises as pressure rises.

Wetting diameter showed a similar pattern; generally speaking, operating pressure had an impact on wetting diameter for both FS1 and FS2 sprinkler types. The findings showed that the FS1 sprinkler type's wetting diameter was marginally greater than the FS2 sprinkler type's. For the FS1 and FS2 sprinklers, the wetting diameter rose by 11.40% and 14%, respectively, when the operating pressure was raised from 1.0 to 3.0 bar. Additionally, under study settings, comparable patterns were noted for all evaluated operating pressures.

Water Application Uniformity

For two varieties of floppy sprinklers, FS1 and FS2, the impact of operating pressure on the coefficient of uniformity, distribution uniformity, and low quarter application efficiency was examined in order to assess the uniformity of water application.

Effect of Operating Pressure on The Coefficient of Uniformity

A numerical expression for the index of water distribution uniformity on the soil surface is the coefficient of uniformity (CU). At a floppy height of 3 meters and operating pressures of 1.0, 1.5, 2.0, 2.5, and 3.0 bar, the coefficient of homogeneity was calculated. The link between operating pressure and the coefficient of uniformity is depicted in Figure1. As can be observed, CU increased from 73.52% to 82.37% for FS1 and from 72.57% to 80.75% for FS2 when operating pressure increased from 1.0 to 2.0 bar. On the other hand, for floppy sprinklers FS1 and FS2, the CU dropped from 82.37% to 77% and from 80.75% to 76%, respectively, when the operating pressure increased from 2.0 to 3.0 bar.

Nonuniform water distribution may be the cause of the coefficient of uniformity's decline at both low and high operating pressures. As a result, the water jet did not disintegrate readily at low operating pressure levels, forming huge water droplets that fell near the sprinkler and decreasing sprinkler throw. Additionally, the jet broke up too much at high operating pressure levels, producing tiny water droplets that were easy to blow off and throw away from the sprinkler.

The findings showed that, across all evaluated operating pressure ranges, the maximum coefficient of homogeneity was achieved at 2.0 bar of operating pressure and 3.0 m of floppy height. This outcome is consistent with the pressure that the FS1 sprinkler manufacturer recommends, as stated by **Sarfraz Hashim *et al*., (2021) and Aboamera and Sourell (2003).**

The results showed that, under the same operating pressure settings, the CU values for FS1 sprinklers are higher than those for FS2.Thus, it can be said that 2.0 bar of operating pressure is advised in order to attain a high coefficient of uniformity for the sprinklers that were tested.

Effect of Operating Pressure on The Distribution Uniformity

One of the main concerned in the sprinkler irrigation design process is consistency of application. Figure 2 displays the trends of DU for sprinklers FS1 and FS2 at various operating pressures. For all tested operating pressures, the DU generally rose as operating pressure climbed until it reached its maximum at 2.0 bar. However, for operating pressures over 2.0 bar, the DU fell once more.

The DU values for FS1 and FS2 increased from 65.21 to 72.91% and 63.29 to 72.88%, respectively, when the operating pressure was raised from 1.0 to 2.0 bar. At the floppy height of 3.0 m, the DU values for FS1 and FS2 dropped from 72.91 to 66.20% and 72.88 to 64.5%, respectively, while the operating pressure rose from 2.0 to 3.0 bar.

According to the results, the highest DU values were obtained at an operating pressure of 2.0 bar; for FS1 and FS2, the corresponding values were 72.91 and 72.88%, respectively. It is evident from the results that CU and DU exhibit a parallel pattern across all tested operating pressure levels. The operating pressure of 2.0 bar produced the highest CU and DU values.

This indicates that with the operating pressure previously mentioned, a more uniform water application might be accomplished. Additionally, under all measured operating pressure levels, the FS1 sprinkler outperformed the FS2 in terms of water application uniformity. This could be because of the FS1 sprinkler's production dependability, as stated by **Sarfraz Hashim *et al*.,(2021) and Aboamera and Sourell ,(2003).**

Additionally, as Figure (2) illustrates, the FS1 sprinkler has a higher modulus of elasticity than the $FS_{2.}$

Effect of operating pressure on application efficiency of low quarter

The parameter known as application efficiency of low quarter (AELQ) measures how evenly water is distributed and how well irrigation is working. Figure (3) displays the AELQ values for FS1 and FS2 at various operating pressure levels. For the two floppy sprinkler types, FS1 and FS2, AELQ generally rose as operating pressure climbed from 1.0 to 2.0 bar and reduced as operating pressure increased from 2.0 to 3.0 bar throughout all test levels.

The AELQ values for FS1 and FS2 increased from 56.96 to 65.59% and from 58.69 to 65.81%, respectively, when the operating pressure was raised from 1.0 to 2.0 bar. In the meantime, the AELQ values for FS1 and FS2 dropped from 65.81 to 59.58% and from 65.59 to 58.05%, respectively, when the operating pressure was raised from 2.0 to 3.0 bar.

It is evident from the results that the maximum AELQ values were attained at 2.0 bar of operating pressure.Additionally, FS1 sprinklers had greater AELQ values than FS2 sprinklers. These AELQ related findings are consistent with CU and DU findings. This indicates that, in accordance with **Aboamera and Sourell, (2003) and Sarfraz Hashim *et al*., (2021**), FS1 and FS2 could both achieve high water application uniformity at an operating pressure of 2.0 bar.

Table 2. The average discharge, application rate, and wetting diameter for both original type (FS1) and local type (FS2) floppy sprinklers at various operating pressure levels.

Floppy sprinkler type	Operating pressure (bar)	Discharge (l/h)	Application rate (mm/h)	Wetting diameter (m)
	1.0	600	4.30	13.15
	1.5	771	4.73	13.80
Original type (FS_1)	2.0	939	5.25	14.20
	2.5	984	5.61	14.50
	3.0	1030	5.85	14.65
	1.0	600	4.30	12.50
	1.5	685	4.55	13.30
Local type (FS_2)	2.0	732	5.19	14.00
	2.5	881	5.23	14.15
	3.0	930	5.43	14.25

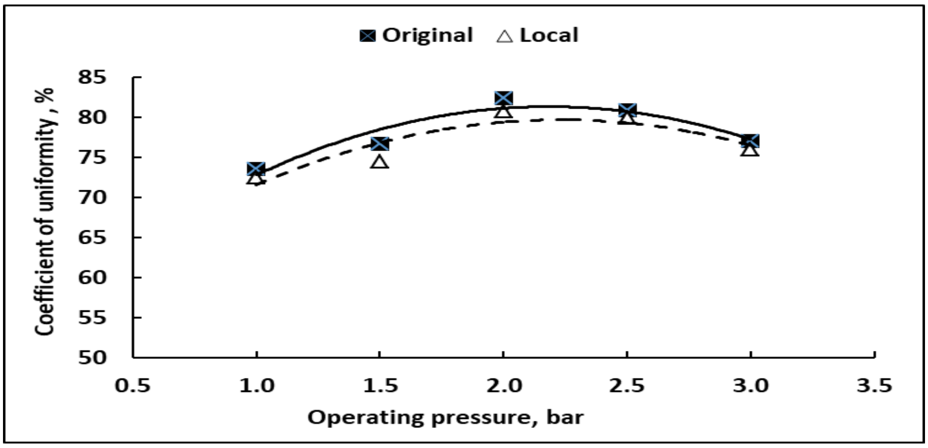

Figure 1. the relationship between the Christiansen coefficient of uniformity and operating pressure for two different kinds of floppy sprinklers

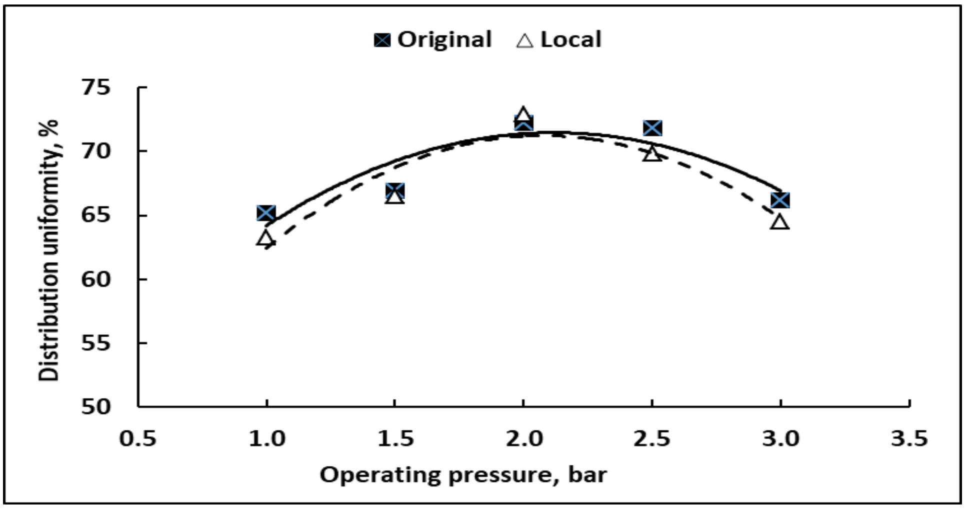

Figure 2. The Relationship between distribution uniformity and operational pressure for two varieties of floppy sprinklers

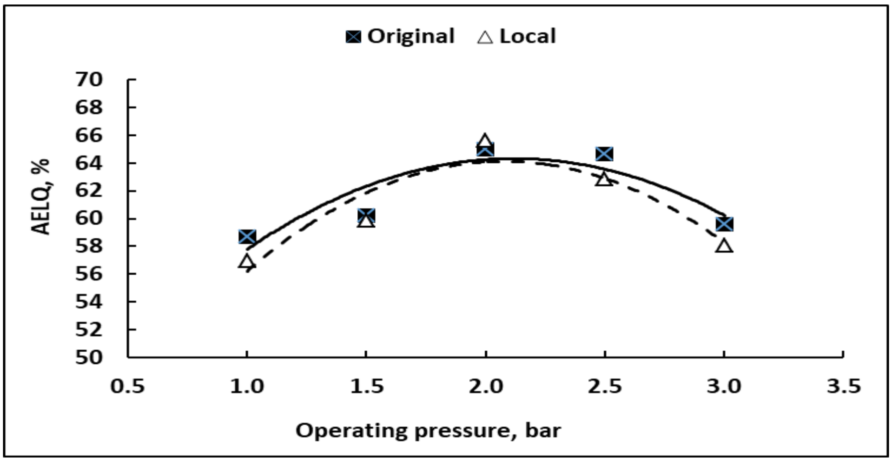

Figure 3. Relationship between two types of floppy sprinklers' operating prssure and low-quarter application efficiency

CONCLUSIONS

The findings indicated that it is advised to use an overhead floppy sprinkler. The findings might be summed up as follows: With an operating pressure of 2.0 bar and a height of 3 meters, the overhead floppy sprinkler achieved the highest values of CU, DU, and AELQ, which were 82.37, 72.91, and 65.81% for (FS1) and 80.75, 72.88, and 65.59% for (FS2), respectively.

Additionally, the results demonstrated that, under the same operating pressure settings, the FS1 sprinkler's CU, DU, and AELQ values are higher than those of the FS2, and that the overhead floppy sprinkler's maximum uniformity CU and UD were recorded at a pressure of 2.0 bar and a height of 3 meters.

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تأثيـــر الرشــــاش المـــرن المعلـــق عـــلى إنتظاميــــة توزيـــع الميــــاه

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يهدف هذا البحث لدراسه تأثير ضغط التشغيل لتحديد أعلى كفاءة إنتظامية توزيع المياه للرشاش لنظام الرى بالرشاش المرن المعلق تحت ظروف الأراضى الحديثة. تم حساب معامل إنتظامية توزيع المياه CU،كفاءة إنتظامية توزيع المياه DU، كفاءة الاضافة لاقل ربع AELQ تحت تأثير متوسط ضغوط تشغيل (1.0، 1.5، 2.0، 2.5، 3.0، كيلو باسكال)، إرتفاع للرشاش (3.0 متر) .

أظهرت النتائج أن أعلى قيم لمعامل إنتظامية التوزيع CU،كفاءة إنتظامية التوزيع DU وكفاءة الاضافة لاقل ربع AELQ كانت 82.37 ، 72.91، 65.81 ٪ للرشاش FS1 وكانت 80.75 و 72.88 و 65.59 ٪ للرشاش FS2 على التوالي عند ضغط تشغيل 2.0 كيلوباسكال و إرتفاع 3.0 متر لنظام الرى بالرشاش المرن المعلق.

أيضا أظهرت النتائج أن أعلى قيم لمعامل إنتظامية التوزيع CU،كفاءة إنتظامية التوزيع DU ،كفاءة الاضافة لاقل ربع AELQ كانت للرشاش المستورد FS1 اعلي من الرشاش المحلي FS2 تحت نفس ظروف ضغط التشغيل.

يوصى بتشغيل الرشاش المرن المعلق عند ضغط تشغيل 2.0 كيلوباسكال ،إرتفاع الرشاش 3 م للحصول على أعلى قيمة لكفاءة إنتظامية توزيع المياه ويسمح بحرية كامله لمعدات تجهيز التربة الزراعية والرش والحصاد الآلى للمحصول ويحقق عدم وجود معدات تخلق عوائق على التربة أثناء إجراء العمليات الزراعية.

الكلمات المفتاحية : الرشاش المرن – الانتظامية – ضغط التشغيل

المحكمـــــون:

1- أ.د. ســامح سعيد كشك استاذ الهندسة الزراعية ـ كلية الزراعة ـ جامعة قناة السويس.

2- أ.د. يــاسر صبحي عبدالله أستاذ الهندسة الزراعية المساعد ـ كلية الزراعة جامعة قناة الزقازيق.