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Hydraulic Performance Evaluation of Plastic Impact Sprinkler under Field Conditions

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ABSTRACT

An outdoor experiment was carried out at EL-Gemmeiza Agricultural Research Station, Gharbia Province, during August and September, 2018. The hydraulic performance of four types of rotating plastic impact sprinklers (S1, S2, S3 and S4) under four operating pressures (P1=100 kPa, P2=125 kPa, P3=150 kPa and P4=175 kPa) and two overlapping patterns (50 % D=50 % throw diameter and 65 % D=65 % throw diameter) were evaluated. The results referred to that: increasing operating pressure increased discharge rate and radius of throw for different sprinklers; the sprinklers arranged according to discharge rate as S2> S3> S1> S4. Maximum discharge rate of 1965 l/h was recorded for sprinkler S2 at 175 kPa operating pressure. The greatest radius of throw was 12 m obtained by sprinkler S2 at 175 kPa operating pressure. The sprinklers arranged according to application rate as S2> S3> S1> S4. The highest gross and net precipitation rates were 5.81 and 4.53 mm h^{-1} obtained by sprinkler S1 at 125 and 175 kPa operating pressure respectively. The highest application efficiency of 91.82 % was achieved by sprinkler S2 at 100 kPa operating pressure. The highest Christensen uniformity coefficient (CU) of 92.2 % was obtained by sprinkler S2 at 100 kPa operating pressure and 50 % D. The highest distribution uniformity (DU) of 88.3 % was obtained by sprinkler S3 at 175 kPa operating pressure and 50 % D.

Keywords: *sprinkler, discharge, application efficiency, application uniformity*

INTRODUCTION

Sprinkler irrigation system is widely used in agriculture across the world to rationalize irrigation water; it is classified a high efficient and proper irrigation system for many crops, soils and topographic Dilshad *et al.* (2017). In Egypt, sprinkler irrigation system is one of the necessary irrigation systems to overcome the problem of irrigation water scarcity. Choosing an appropriate sprinkler aids to get optimum water application rate and wetting patterns is crucially important. Currently, impact sprinklers (sometimes called an impulse sprinklers) are popular and highly utilized in Egypt. A sprinkler is mainly made of plastic, brass, bronze or stainless steel with single or double nozzles. To achieve the rotation for impact sprinkler, the rocker arm collides with the sprinkler body, so the life expectancy of the sprinkler is affected by spring stability. The plastic impact sprinkler is widely used in Egypt compared with other sprinkler types because it is cheaper and less exposed to theft. Sprinklers distribution in the field (spacing and layout) has a direct effect on sprinkler irrigation performance especially in wind conditions. Ortize *et al.* (2010) classified sprinkler irrigation system as excellent and acceptable with 85% distribution uniformity. Sanchez *et al.* (2011) reported that high distribution uniformity save water, time and thus money; so the factors affecting distribution uniformity must be well understood. Sprinkler discharge rate mainly depends on operating pressure and nozzle diameter. Amer *et al.* (2012) and Attafy *et al.* (2017) stated that the highest irrigation uniformity and lowest coefficient of variation realized at 100% overlapping. Hashad (2012) concluded that square layout achieved higher application efficiency and distribution uniformity than rectangular and triangle layouts. Mehawed *et al.* (2013) recommended that when using impact sprinklers with large nozzle the distance between sprinklers should not be less than 50-55% throw diameter while for small nozzle it must be ranged at a distance 67-70% throw diameter. Liu *et al.* (2013), Zhang *et al.* (2013), Zhu *et al.* (2015), Nörenberg *et al.* (2017) and Faria *et al.* (2019) listed some important factors that affect sprinkling water uniformity among which are sprinkler type, nozzle characteristics, flow rate, operating pressure, riser characteristics, lateral arrangement and environmental factors. Dehkordi *et al.* (2016) revealed that sprinkler layout and wind speed had important effects on sprinkler irrigation uniformity; Christiansen uniformity coefficient decreased by increasing wind speed. Rectangular layout is affected more by wind speed than square layout. Jiao *et al.* (2017) stated that a high degree of application uniformity can be accomplished if proper design is performed. Selection of sprinklers usually depends on the price. Al-Ghobari *et al.* (2018) determined three main factors which sprinkler irrigation losses are based on: 1) design factors include sprinkler (type, spacing and height), nozzle (diameter, size and shape), lateral length and operating pressure, 2) Management factors include irrigation scheduling and 3) climatic factors including humidity and more importantly wind (direction and speed). Zhang *et al.* (2019) referred to discharge rate as an important index for evaluating the hydraulic performance of sprinklers. Zhang *et al.* (2018) found that throw diameter is an important index for assessing sprinkler performance; in the design of a sprinkler system, lateral and sprinkler spacing are determined on the basis of throw diameter. Sarwar *et al.* (2020) pointed out that wind drift and evaporation losses accurately can help improve application efficiency and distribution uniformity for sprinkler irrigation system. Zapata *et al.* (2021) considered solid-set sprinkler irrigation the most popular sprinkler irrigation systems worldwide. Spatial distribution of

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the irrigation water related to design characteristics, climatic factors and canopy architecture. There are many types of plastic impact sprinkler in the Egyptian market, which differ in their manufacturing specifications (inlet diameter - nozzles diameter, shape and size), therefore, it is important to make a hydraulic evaluation to identify the optimal operating parameters. The overall aim of the present study was to evaluate influence of the two design factors operating pressure and spatial distribution on hydraulic performance for four types of plastic impact sprinklers.

MATERIALS AND METHODS

Field experimental layout

The outdoor experiments were carried out at EL-Gemmeiza Agriculture Research Station, Gharbia Province, during August and September, 2018. The experimental area situated at 31˚ 07´ longitude, and 30˚ 43´ latitude; 20 m above mean sea level. Experimental site classified an arid climate with hot dry summer and cool winter. The climatic data for the experimental site including wind speed, relative humidity "RH" and air temperature (maximum and minimum) "T" were obtained from "Central Laboratory for Agricultural Climate (CLAC), Agricultural Research center Figs. 1 and 2.

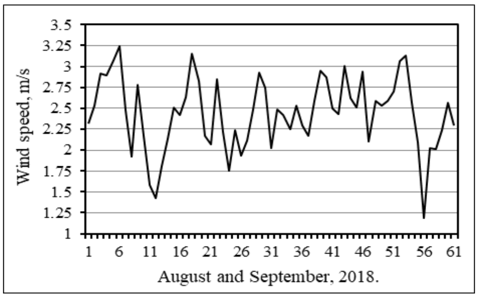


Fig. 1. Wind speed for experimental site during August and September, 2018

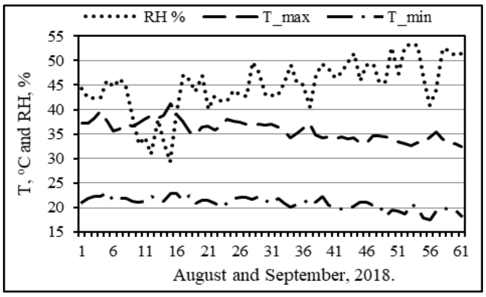


Fig. 2. Relative humidity (%) and air temperature (Maximum and minimum) for the experimental site during August and September, 2018

Components of sprinkler irrigation network

The sprinkler irrigation system consisted of: a) Centrifugal pump (3" inlet and outlet diameters and 30 m3 h-1 nominal discharge) powered by a 3.75kW gasoline internal combustion engine (single-cylinder, four stroke), pressure gauges and control valve; b) the Main lines were aluminum pipes of 75 and 70 mm outer and inside diameter respectively and 6 m in length; the pipes connected together by quick couple with rubber ring jointing; c) lateral lines supplied sprinklers with water from the main line, which made of (LDPE) with 25 mm diameter and 15 m length. The laterals connected to mainline with saddles of 75 x 32 mm, valve with 32 mm diameter, polyester screen filter (120 mesh with 32 mm inlet and outlet diameters) and starter 32 x 25 mm. Flexibility of lateral lines helped to re-distribute the sprinklers many times according to radius of throw for every test. The plastic impact sprinklers were used in this study (described in Table 1); this type is locally manufactured and used widely in Egyptian farms. Galvanized iron pipes of 0.75 inch diameter and 70 cm height were used as raisers to supply the water to sprinklers Fig. 3.

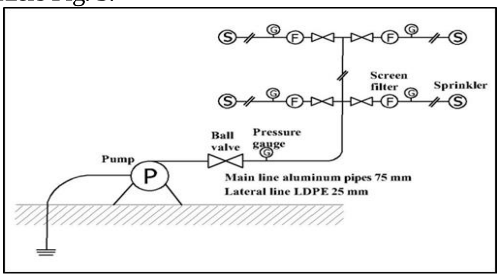
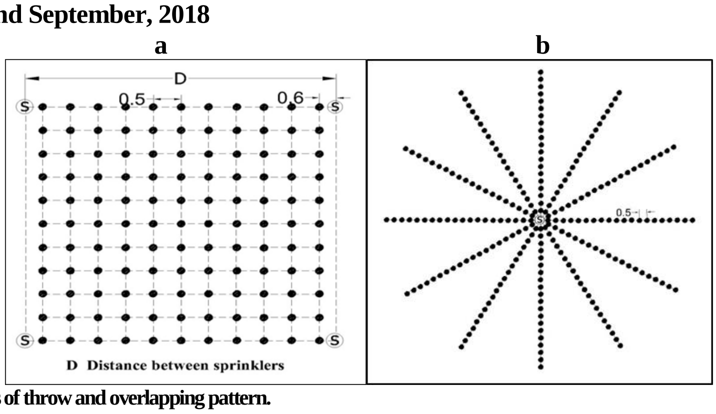


Fig. 3. Schematic diagram of the experimental irrigation network

Spacing of catch cans (collectors)

About a100 conical catch-cans were used in the study to collect fallen water from sprinklers. The cans were made of plastic with a total height of 120 mm and an upper diameter of 90 mm. The collectors had fixed 60 cm beyond the boundaries of the described spacing between sprinklers SWAT (2012). Collectors spacing center to center was 0.5 m to minimize the effect of wind on all sprinkler precipitation area as shown in Fig. 4. The water caught in each can was identified using a graduated cylinder, and the application rate was accounted attribution to test duration and upper diameter of the collectors



D: Based on sprinkler radius of throw and overlapping pattern.

Fig. 4. Catch cans distribution: a) Grid distribution for overlapping patterns, b) Radial distribution for single sprinkler distribution

Study parameters

The research work included three main parameters:

a) Sprinkler type: four types of plastic impact sprinkler were used (S1, S2, S3 and S4); specifications of sprinklers are listed in Table 1.

b) Operating pressure: four values of operating pressure were applied P1=100 kPa, P2=125 kPa, P3=150 kPa and P4=175 kPa.

c) Overlapping pattern: two distances between sprinklers as a percentage of wetted diameters were applied (50% D=50 % throw diameter and 65 % D=65 % throw diameter).

Different study variables were applied using square layout Patterns.

Table 1. Specifications of impact sprinkler types under study

Specifications		Sprinkler type			
		S1	**S2**	**S3**	**S4**
Sprinkler inlet		Female	Female	Mail	Mail
Inlet diameter		¾ inch	¾ inch	¾ inch	½ inch
Rotation		Full circle	Full circle	Full circle	Part circle
Trajectory angle		22º	20º	26º	27º
No. of nozzles		2	2	2	1
Main nozzle	color	Green	Blue	Yellow	Red
	diameter	3 mm	6 mm	6 mm	4 mm
auxiliary nozzle	color	Green	Blue with side slit	Red	---
	diameter	4 mm	3 mm	3 mm	---
Sprinkler shape					

Measurements

Response operating pressure with sprinkler discharge

The discharge rate for each sprinkler type was measured at different operating pressure ranging from 100 to 175 kPa with an increment of 25 kPa by gradually increasing the pressure. Sprinkler discharge rate was measured by the commonly used volumetric method (measuring the time required to fill a container of known volume) as described by James (1988). Discharge coefficient (C_D) expresses the effect of each combination of sprinkler type and operating pressure on discharge rate; it is calculated using the following equation:

$$Q = C_D . A . (2\,g\,P)^k$$

In which

Q is the sprinkler discharge rate (m^3/s), C_D is the discharge coefficient, A is the nozzles cross-sectional area (m^2), g is the gravitational acceleration ($m\ s^{-2}$), P is the operating pressure head (m) and k is a constant. Many findings explicated that for agricultural sprinklers, k equal 0.5 such as Stambouli *et al.* (2014), Zhu *et al.* (2015).

Response operating pressure with radius of throw

The radius of throw (m) was measured for each sprinkler at different pressures ranging from 100 to 175 kPa with an increment of 25 kPa. It was measured directly from the sprinkler head to the end of throw distance.

Precipitation rate

The precipitation rate is the speed at which the sprinkler applies the water. Gross precipitation rate for each sprinkler and net precipitation rate for four sprinklers at the two overlapping patterns 50 and 65 % D had calculated for every operating pressure according to SWAT (2012).

$$P.R._{gross} = \frac{Q\ .\ 1000}{A}$$

$$P.R._{net} = \frac{V}{T\ .\ a\ .\ 1000}$$

In which

$P.R._{gross}$ is the gross precipitation rate ($mm\ h^{-1}$), Q is the sprinkler discharge rate ($m^3\ h^{-1}$), A is the wetted area (m^2), $P.R._{net}$ is the net precipitation rate ($mm\ h^{-1}$), V is the average catchments volume (ml), T is the test run time (h) and a is the water collector upper area (m^2).

Application efficiency

Water application efficiency is defined as the ratio (%) of the average depth of water in catch cans and average of water applied by nozzles. It was calculated using fallowing formula as described by Merriam *et al.* (1983).

$$E_a = 100\left(\frac{X^-}{d}\right)$$

In which

Ea refers to the application efficiency (%), X^- refers to the average of all measurements in catch cans (mm) and d represents the average depth of applied water (mm).

Application uniformity

Christensen Uniformity Coefficient

Application Uniformity for every sprinkler was expressed by Christensen uniformity coefficient which calculated based on measuring the collected water in catch cans as developed by Christiansen (1942) and described by James (1988) as fallow.

$$CU = 100\left(1.0 - \frac{\sum_{i=1}^{n}|X_i - X^-|}{n\,X^-}\right)$$

In which

CU refers to Christensen uniformity coefficient (%), X_i refers to individual water depth collected by catch cans (mm) and n refers to the total number of collectors.

Distribution uniformity

Low quarter distribution uniformity is another indicator of application uniformity. It is defined by James (1988) as the ratio expressed in percent of the mean low-quarter amount caught to the average amount caught in catch cans.

$$DU = 100\left(\frac{X_{LQ}^-}{X^-}\right)$$

In which

DU is distribution uniformity (%) and X_{LQ}^- is average low quarter catchment (mm).

Statistical Analysis

Experimental design was set as a split and split-split plot design: main plot factor (sprinkler type), sub plot factor (operating pressure) and sub sub plot overlapping pattern. Analysis of variance and significant differences between means at 5% level was analyzed by CoStat statistical software program. (LSD) at 5% significance level was used to compare the means of different treatments.

RESULTS AND DISCUSSIONS

Sprinkler discharge rate

The average discharge rate of the four tested sprinkler types at varying operating pressures ranging from 100 to 175 kPa with an increment of 25 kPa is illustrated in Fig. 5. The results revealed that the discharge rate increased for all sprinklers as the operating pressure increased; similar results were obtained by many findings such as Zhu *et al.* (2012); Zhang *et al.* (2013); Zhu *et al.* (2015); Pachore and Deshpande (2019). The results revealed that minimum discharge rate of 648 l/h was recorded by sprinkler S4 at 100 kPa operating pressure, while the highest discharge of 1965 l/h was recorded by sprinkler S2 at 175 kPa operating pressure . S2 achieved the highest discharge rate followed by S3 followed by S1 and the least was recorded by S4. The discharge rate was directly based on nozzle characteristics (size, number and internal design), sprinkler inlet diameter and operating pressure Stambouli *et al*. (2014). Sprinkler S4 had the lowest discharge rate because it has a single nozzle with small diameter (4 mm) and lowest inlet diameter (½ inch) while sprinkler S2 had the highest discharge rate as a result of bigger nozzles size and the auxiliary nozzle has a side slit.

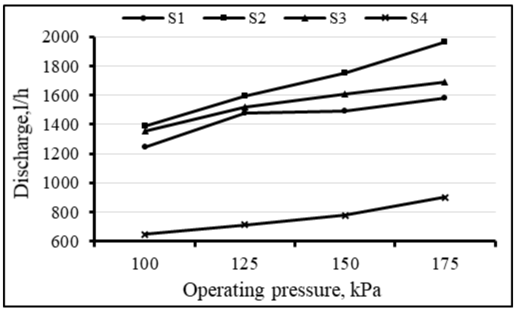


Fig. 5. Sprinkler discharge rate for different sprinkler types.

The discharge coefficient (C_D) and the standard deviation for different sprinkler types was calculated and listed in Table 2. C_D values for the sprinklers differed slightly with different operating pressures, this mean C_D is independent of operating pressure. Several studies have pointed to the same result Li *et al*. (1995); Zhu *et al*. (2012); Zhu *et al*. (2015). S4 recorded the largest discharge coefficient and standard deviation. S3 recorded the lowest discharge coefficient. S2 and S3 recorded convergent C_D; this may be due to the equal diameter of the nozzles. S2 recoeded the lowest standard deviation.

Table 2. Discharge coefficient and Standard deviation for different sprinkler types at different operating pressures

Sprinkler types	Operating pressure, kPa				Average	Standard deviation
	100	125	150	175		
S1	0.640	0.681	0.627	0.616	0.641	0.025
S2	0.433	0.440	0.442	0.459	0.444	0.010
S3	0.422	0.424	0.405	0.399	0.413	0.011
S4	1.020	0.990	1.000	1.073	1.021	0.032

Operating pressure- radius of throw relationship

Radius of throw of four tested sprinklers was recorded at different operating pressures ranging from 100 to 175 kPa with an increment of 25 kPa. The average radius of throw in relation to operating pressure for four types of sprinkler under study is shown in Fig 6. It is obvious that increasing operating pressure from 100 to 175 kPa increased the radius of throw from 8.5 to 9.5 m, 10.0 to 12.0 m, 10.5 to 11.5 m and 8.0 to 11.0 m for S1, S2, S3 and S4 respectively. It is observed that nozzle characteristics and inlet diameter had direct effects on radius of throw. Many previous studies found the same relationships between operating pressure and wetted radius of throw such as Mandave and Jadhav (2014); Pachore and Deshpande (2019). The lowest radius of throw was 8.0 m which was obtained by sprinkler S4 at 100 kPa operating pressure, while the greatest radius of throw was 12.0 m which was obtained by sprinkler S2 at 175 kPa operating pressure. Increasing operating pressure from 125 to 175 kPa did not change radius of throw for S3 that was 11.5 m. Increasing operating pressure from 125 to 150 kPa did not affect radius of throw for S4 where it fixed at 10.0 m. Increasing operating pressure from 150 to 175 kPa did not affect radius of throw for S1where it fixed at 9.5 m.

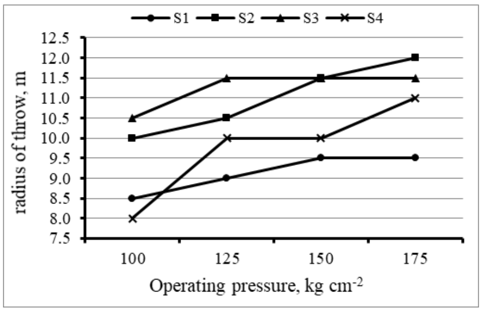


Fig. 6. Operating pressure – radius of throwrelationship for different sprinkler types

Water application patterns of single sprinkler

Fig. 7 shows the radial application rate patterns for various sprinklers at 100, 125, 150 and 175 kPa operating pressure.

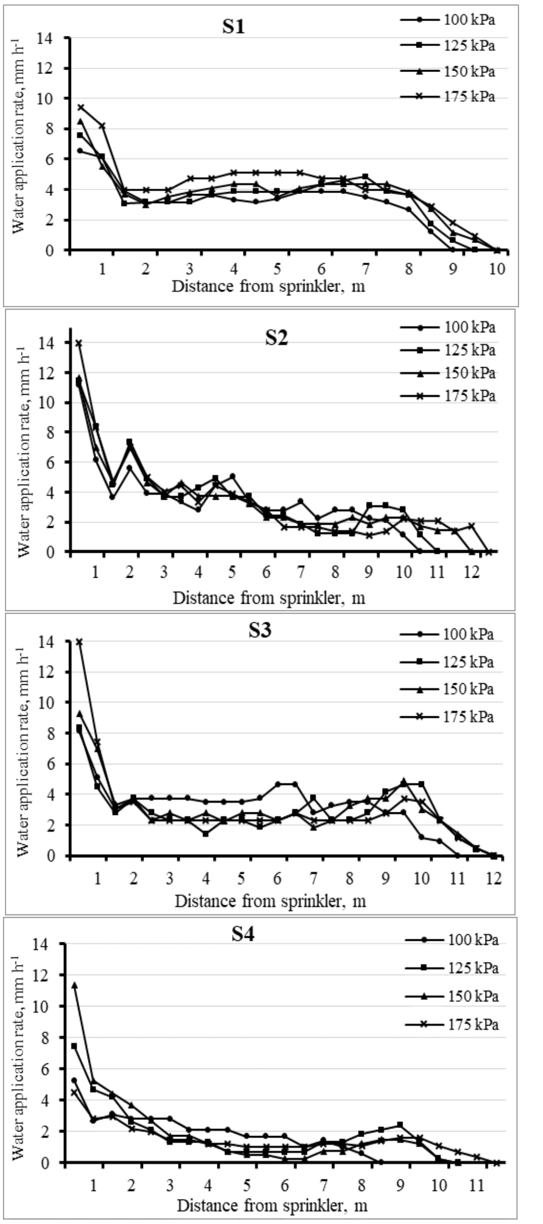


Fig. 7. Water application patterns of different sprinklers at different operating pressures

The profiles of radial water application rates for impact sprinklers are mainly based on design of sprinkler body and nozzle, trajectory angle and the change in operating pressure Tarjuelo *et al*. (1999); Zhu *et al*. (2015). Application rate for various sprinklers was high close to the sprinkler and decreased as the distance from the sprinkler increased. The instantaneous water application rate varied from maximum to minimum many times and then returned to zero. Application rate increased as operating pressure increased from 100 to 175 kPa except S4 at 175 kPa since it produced the lowest application rate; which may be caused by increasing wind and evaporation losses as result of sprinkler design and nozzle size (inlet diameter ½ inch and single nozzle with 4 mm diameter). The S2 achieved the highest application rate followed by S3 followed by S1 and S4 produced the least; this result can be attributed to sprinkler inlet and nozzle size. The highest values of application rate were produced at a distance of 0.6 m followed by 1.0 m from the sprinkler center and decreased sharply then. Increasing application rate for S2 at a distance of 2 m may be due to side slit in auxiliary nozzle. The highest values of application rate for the four tested sprinklers were (S1= 9.4 mm h^{-1} at 175 kPa; S2= 14 mm h^{-1} at 175 kPa; S3= 14 mm h^{-1} at 175 kPa and S4= 11.3 mm h^{-1} at 150 kPa).

Precipitation rate of single sprinkler

The average radial gross and net precipitation rate (mm h^{-1}) for the four tested sprinklers were estimated at different operating pressures ranging from 100 to 175 kPa and presented in Table 3. Precipitation rate (gross and net) for different sprinkler types was influenced by sprinkler type and operating pressure. The results revealed that precipitation rate (gross and net) depends mainly on nozzle design and pressure – discharge - radius of throw relationships; so it is not necessary that an increase in operating pressure corresponds to an increase in the precipitation rate. As a general average of operating pressures, S1 produced the highest gross and net precipitation rate with values of 5.53 and 3.98 mm h^{-1} followed by S2 (4.4 and 3.68 mm h^{-1}) followed by S3 (3.88 and 3.23 mm h^{-1}) while S4 produced lowest values (2.59 and 1.92 mm h^{-1}). The highest gross precipitation rate for four sprinklers was S1= 5.81 mm h^{-1} at 125 kPa, S2= 4.6 mm h^{-1} at 125 kPa, S3= 4.07 mm h^{-1} at 175 kPa and S4 =3.22 mm h^{-1} at 100 kPa. The lowest gross precipitation rate for four sprinklers was S1= 5.26 mm h^{-1} at 150 kPa, S2= 4.21 mm h^{-1} at 150 kPa, S3= 3.66 mm h^{-1} at 125 kPa and S4= 2.27 mm h^{-1} at 125 kPa.

Table 3. Radial gross and net precipitation rate, mm h^{-1} for sprinkler types at different operating pressures

Sprinkler	Gross precipitation rate, mm h^{-1}				Net precipitation rate, mm h^{-1}			
	operating pressures, kPa							
	100	125	150	175	100	125	150	175
S1	5.49^{c}	5.81^{a}	5.26^{d}	5.58^{b}	3.65^{e}	3.83^{cd}	3.92^{b}	4.53^{a}
S2	4.43^{f}	4.60^{e}	4.21^{h}	4.35^{g}	3.78^{d}	3.86^{bc}	3.54^{f}	3.55^{f}
S3	3.91^{j}	3.66^{k}	3.87^{j}	4.07^{i}	3.59^{ef}	2.97^{h}	3.20^{g}	3.16^{g}
S4	3.22^{l}	2.27^{o}	2.48^{m}	2.37^{n}	2.16^{i}	1.93^{k}	2.06^{j}	1.52^{i}
LSD	0.05				0.07			

Within a certain colums the different letters indicated significantly different at 0.05 level

Radial application efficiency

The average radial application efficiency (Ea, %) for various sprinklers was estimated at different operating pressures 100, 125, 150 and 175 kPa as listed in Table 4. Application efficiency illustrates the ability of the sprinkler to reduce water losses as a result of wind and evaporation Bishaw and Olumana (2016). Application efficiency was significantly affected by sprinkler type, operating pressure and their interaction. As a general average for four operating pressures S2 produced the highest Ea (83.74%) followed by S3 (83.33%) followed by S1 (72.01%) and the last was S4 (74.87%). Ea for S1 increased as operating pressure increased while Ea for S2 and S3 decreased as operating pressure increased. Ea for S4 increased as operating pressure increased from 100 to 125 kPa and decreased after that. The highest Ea value of 91.82 % was achieved by S2 at 100 kPa operating pressure, while the lowest Ea value of 64.34% was recorded with S4 at 175 kPa operating pressure. Sprinkler irrigation management was classified depending on the value of water application efficiency (Ea) by Tarjuelo *et al*. (2000): 60-69% (poor), 70-79% (good), 80-89% (very good) and ≥ 90% (excellent). S1 classified very good at 175 kPa; S2 classified very good at four operating pressure values; S3 classified excellent at 100 kPa and very good at 125 and 1.5 kPa; S4 classified very good at 125 and 150 kPa as shown in Table 4.

Table 4. Radial application efficiency and its classification for four sprinkler types at different operating pressures

Sprinkler	Radial application efficiency, %			
	operating pressures, kPa			
	100	125	150	175
S1	66.50^{hi} (poor)	65.86^{i} (poor)	74.46^{g} (good)	81.22^{e} (very good)
S2	85.34^{b} (very good)	83.90^{c} (very good)	83.94^{c} (very good)	81.78^{e} (very good)
S3	91.82^{a} (excellent)	81.31^{e} (very good)	82.71^{d} (very good)	77.47^{f} (good)
S4	66.94^{h} (poor)	84.99^{b} (very good)	83.21^{d} (very good)	64.34^{j} (poor)
LSD	0.68			

The same letters indicated not significantly different at 0.05 level

Application uniformity

The coefficient of uniformity (CU) and the low quarter distribution uniformity (DU) are considered the most important indicators to assess application uniformity for pressurized irrigation systems Zhang and Merkley (2012). CU and Du for the four tested sprinklers were estimated at four operating pressures (100, 125, 150 and 175 kPa) and two overlapping patterns (50% D and 65% D). The uniformity was statistically analyzed using split-split plot design (sprinkler type in main plot, operating pressure in sub plot and overlapping pattern in sub-sub plot). CU and DU were significantly affected by the three factors and even their interaction. Based on the CU value, the application uniformity was classified as very good (CU ≥ 90%), good (CU between 89% and 80%), poor (CU between 79 and 70%) and worse (CU ≤ 70%) Little *et al*. (1993) and classified based on DU as Excellent (DU ≥ 80%), very good (DU between 79% and 70%), good (DU between 70% and 65%), fair (DU between 65% and 60%) and poor (DU between 60% and 50%) Mecham (2004). Table 5 presents the uniformity values and classifications as affected by sprinkler type, operating pressure and overlapping patterns. The results generally demonstrated that the overlapping pattern 50% D achieved application uniformity more than 65% D for different treatments. This result is in line with the results obtained by Amer *et al.* (2012), Al-Ashram (2016), Attafy *et al*. (2017); they found that the application uniformity increased as the distance between sprinklers decreased. CU value is greater than the common DU value. Zhang and Merkley (2012) discussed the conditions under which CU > DU and vice versa. The highest CU value for four sprinklers obtained at 50 % D were; S1 = 90.7 % at 125 kPa, S2 = 92.2 % at 100 kPa, S3 = 89.7 % at 175 kPa and S4 = 91.1 % at 150 kPa. The highest DU value for the four tested sprinklers obtained at 50 % D were; S1 = 85.5 % at 175 kPa, S2 = 88.0 % at 125 kPa, S3 = 88.3 % at 175 kPa and S4 = 86.9 % at 125 kPa.

Table 5. Application uniformity of four sprinkler types at different operating pressures and overlapping patterns

Sprinkler	Operating pressure, kPa	CU		DU	
		overlapping pattern			
		50% D	65% D	50% D	65% D
S1	100	86.3^{lm} (good)	79.6^{p} (poor)	74.4^{m} (v. good)	65.1^{n} (good)
	125	90.7^{c-f} (v. good)	87.1^{lm} (good)	83.6^{ef} (excellent)	77.4^{i-l} (v. good)
	150	88.7^{h-k} (good)	88.6^{ijk} (good)	80.6^{gh} (excellent)	80.1^{ghi} (excellent)
	175	87.7^{jkl} (good)	77.0^{q} (poor)	85.5^{a-e} (excellent)	56.8^{pq} (poor)
S2	100	92.2^{ab} (v. good)	85.7^{mno} (good)	86.4^{a-e} (excellent)	83.6^{ef} (excellent)
	125	91.5^{abc} (v. good)	84.8^{no} (good)	88.0^{ab} (excellent)	74.9^{lm} (v. good)
	150	84.3^{o} (good)	89.4^{fghi} (good)	86.8^{a-d}(excellent)	76.8^{j-m} (v. good)
	175	90.8^{b-f} (v. good)	84.5^{no} (good)	85.6^{a-e} (excellent)	78.1^{h-k} (v. good)
S3	100	79.8^{p} (poor)	72.2^{r} (poor)	66.6^{n} (good)	59.7^{op} (poor)
	125	87.5^{kl} (good)	86.0^{mn} (good)	81.8^{fg} (excellent)	79.7^{g-j} (v. good)
	150	87.7^{jkl} (good)	86.5^{lm} (good)	83.9^{def} (excellent)	79.7^{g-j} (v. good)
	175	89.7^{d-h} (good)	69.1^{s} (worse)	88.3^{a} (excellent)	54.5^{q} (poor)
S4	100	92.3^{a} (v. good)	78.6^{p} (poor)	85.3^{b-e} (excellent)	60.5^{o} (fair)
	125	90.9^{a-e} (v. good)	89.6^{e-i} (good)	86.9^{abc} (excellent)	84.8^{cde}(excellent)
	150	91.1^{a-d} (v. good)	86.3^{lm} (good)	85.7^{a-e} (excellent)	78.4^{h-k} (v. good)
	175	86.9^{lm} (good)	89.2^{ghi} (good)	76.1^{klm} (v. good)	83.7^{ef} (excellent)
LSD		1.5		3	

The same letters indicated not significantly different at 0.05 level

CONCLUSION

This research study aimed to compare the hydraulic performance of four types of plastic impact sprinklers. The discharge rate and radius of throw increased as operating pressure increased. Water application rate varied instantaneously from maximum to minimum many times and then returned to zero. Precipitation rate depends mainly on nozzle design and pressure – discharge - radius of throw relationship. Application efficiency was classified excellent for S3 at 100 kPa operating pressure. Overlapping pattern 50 % D achieved application uniformity more than 65 % D. CU value is greater than the common DU value. This research demonstrated that idetentifing the optimum operating conditions for various sprinkler types would useful for enhancing different efficiency indicators of sprinklers. Thus the selection of proper operating parameters will lead to suitable management for water resources especially in water scarcity situations.

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تقييم الآداء الهيدروليكي للرشاش التصادمي البلاستيك تحت ظروف الحقل

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تم عمل تجربة حقلية بمحطة البحوث الزراعية بالجميزة – محافظة الغربية خلال شهري اغسطس وسبتمبر لعام 2018، وذلك لغرض التقييم الهيدروليكي لآداء بعض أنواع الرشاش التصادمي البلاستيك. وتم تقييم الآداء لأربعة أنواع وهي الأكثر إستخداما والتي تم الإشارة إليها بالأرقام من 1 إلى 4 وذلك تحت أربعة قيم لضغوط التشغيل هى 100، 125، 150 ، 175 كيلوباسكال و قيمتين للمسافة بين الرشاشات وهي 50٪ و 65٪ من قطر الرش. وقد أشارت النتائج المتحصل عليها إلى الآتى: بزيادة ضغط التشغيل زاد التصرف ونصف قطر الرش وكان ترتيب الرشاشات من حيث التصرف كالتالي رشاش 2> رشاش 3 >رشاش 1 >رشاش 4 وكان أعلى تصرف 1965 ل/س و أكبر نصف قطر رش 12 م للرشاش 2 عند ضغط تشغيل 175 كيلوباسكال. كان ترتيب الرشاشات من حيث معدل الاضافة (معدل التساقط) رشاش 2> رشاش 3 >رشاش 1 >رشاش 4، أعلى معدل تساقط (كلي وصافي) كان 5.81و 4.53 مم /س على التوالي والمتحصل عليه من الرشاش 1 عند ضغوط تشغيل 125 و 175 كيلوباسكال على التوالى. كانت أعلى كفاءة إضافة 91.82٪ للرشاش 2 عند ضغط تشغيل 100 كيلوباسكال. كانت أعلى قيمة لمعامل الإنتظامية (كريستيانسن) 92.2٪ للرشاش 2 عند ضغط تشغيل 100 كيلوباسكال ومسافة بين الرشاشات 50٪ من قطر الرش و كانت أعلى قيمة لإنتظامية التوزيع 88.3٪ للرشاش 3 عند ضغط تشغيل 175 كيلوباسكال ومسافة بين الرشاشات 50٪ من قطر الرش.