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Performance Characteristics of Various Impact Sprinkler Types Locally Used

Hussein M. Abo-Ghobar and Ahmed I. Al-Amoud
Agricultural Engineering Department, College of Agriculture, King Saud University, Riyadh, Saudi Arabia

Abstract. Performance characteristics of twelve commonly used impact sprinkler types were determined. Tests were conducted on three sprinklers from each type under three pressure levels: 200, 250, 300 KPa (2, 2.5, 3 bars). The performance of each sprinkler type was evaluated and compared with the data supplied by manufacturers. The results showed some variation between the measured and the supplied data, possibly due to the local field conditions.

This study may assist the agricultural and sprinkler system designers to select the proper irrigation types locally available for efficient water use, and some recommendations were suggested.

Introduction

The agricultural production under hot and arid conditions is based exclusively on irrigation. The agricultural development in the Kingdom of Saudi Arabia in recent years resulted in the expansion of irrigated areas, thus the increase of using sprinkler irrigation systems. The use of sprinkler irrigation method is very popular in the Kingdom of Saudi Arabia, where most of the large scale agricultural projects are irrigated by sprinkler systems. Their popularity is attributed to many advantages as compared to the surface irrigation methods, especially their ability to cope with uneven topography, sandy soils, or variable soil infiltration rates.

Sprinklers spread water as 'rain like' over the land surface uniformly without runoff or excessive deep percolation loss. Uniform water distribution by sprinkler system is essential to optimize crop yield and quality; allow minimum sprinkler system capacity; conserve pumping power, and make more efficient use of the available irrigation water supplies. considerable research has been conducted on many aspects of sprinkler irrigation systems.

Water application uniformity is an important measure of performance used in the design and evaluation of sprinkler irrigation systems. The water application uniformity of a single sprinkler system depends less on the dynamics of the individual sprinklers and more on the spacing and operating pressure [7]. The design of sprinkler irrigation systems requires a minimum knowledge of the water distribution pattern from a single sprinkler under normal wind conditions. The effects of climatic parameters, nozzle pressure, and design of the individual head on single sprinkler water distribution pattern have been the subject of numerous field, laboratory, and analytical studies [1,2, 3-7]. Procedures to determine the distribution of water from sprinklers are given in ASAE Standards [8]. Christiansen [2], developed a formula used as the basis for describing the uniformity of water distribution in sprinkler irrigation.

Many investigators have studied the effect of nozzle geometry and the operating pressure on sprinkler performance such as Bilanski and Kidder [9] who studied the effects of various sprinkler components including operating pressure and nozzle diameter on the distribution pattern and radius, but made no general conclusion. Kincaid [3] proposed a mathematical relationship describing the combined effect of nozzle size, nozzle discharge, and operating pressure on sprinkler pattern radius. Edling [10] found that distance of throw of water was affected by nozzle diameter and droplet size. Chen and Wallender [11] studied application characteristics from low pressure sprinklers. They concluded that the droplet size was a function of nozzle diameter. Hills *et al.* [12] showed that the application uniformity was affected by nozzle geometry and wind speed.

The agricultural sector in the Kingdom of Saudi Arabia import various types and makes of sprinklers. Most sprinkler manufacturers publish informaiton that describe their products performance under ideal conditions. These sprinklers are being used by the farmers without the knowledge of the sprinkler performance under the local conditions. Sprinklers should be selected on the basis of costs, operating pressure requirments, and ability to provide the design daily irrigation requirements with acceptable uniformity. In addition, sprinklers must have the proper nozzle angle, droplet size, distance of throw and application pattern characteristics for the crop, soil and wind conditions in which they are to operate. Therefore, there is a need for these sprinkler types to be evaluated in local field conditions, to determine their performance. This evaluation will assist the farmers and irrigation system designers to select the proper sprinkler type for improved irrigation efficiency, water conservation and increase in crop yield. Therefore, the objectives of this study are:

1. To evaluate the performance of some sprinkler types commonly used under local field conditions, and
2. To compare the measured sprinkler characteristics with information supplied by manufacturers.

Materials and Methods

Data for this study were collected from experimental field runs conducted at the Educational Farm of the College of Agriculture, King Saud University, using a single stationary sprinkler system. The layout of the system is shown in Fig. 1. It consisted of the following components: water supply tank, pump, flow control valve, flow meter, pressure regulator, two pressure gauges, 10 m lateral pipe of 25 mm diameter with riser sprinkler and catch containers. The flow meter and pressure gauges were examined and calibrated. Graduated cylinders were used to collect and measure the distribution of water sprayed by the sprinklers.

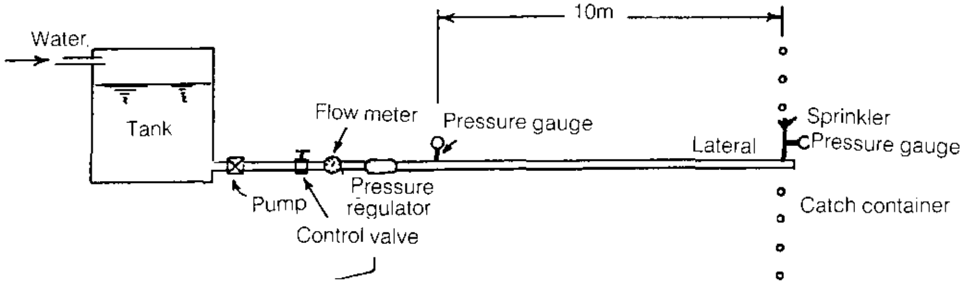

Fig. 1. Layout of the apparatus used to evaluate sprinklers

Twelve commercial sprinkler types that are commonly used for field irrigation were tested as listed in Table 1. Some of these Tests, however, were conducted using three sprinklers from each type. Some of these types are locally available in the market but the manufacturers are unknown, and there was no design information relating to these sprinkler types. However, they were selected for being used by farmers. All tests were performed according to ASAE Standard (S330.1) [8]. Catch cans were made of cylindrical metal containers, 100 mm diameter and 115 mm height with pressed edges to minimize deflectin of water droplets. Containers were placed on both sides of the lateral at spacing of 1.0 meter on level ground surface. Each sprinkler was mounted on the riser at height of one meter above the ground surface. Wind direction, speed, air temperature and relative humidity were continuously recorded during each test. The system was operated for a duration of one hour for each run, so that a sufficient amount of water could be caught by the containers.

Field tests were conducted to evaluate the performance of the twelve sprinkler types. The evaluation included the sprinkler discharge, the water application rate, the uniformity coefficient, the diameter of throw, and the water distribution pattern

Table 1. Names and sizes of the sprinklers used in the study

Model No.	Model code	Nozzle dia (mm)	Manufacturer
1	B 50	8.5×5.5	Regen – Greece
2	B 40	5.5×3.2	Regen – Greece
3	B 38	5.5×4.2	Regen – Greece
4	President-5048	6.1 No. 3	Pope-Australia
5	WA U260-ST	4.76	Western Brassworks-USA
6	470-1″	5.0	A. Soultatis - Greece
7	WA-SU62-ST	3.97	Western Brassworks-USA
8	25 AFP-TNT 20°	3.57	Rain Bird-Mexico
9	P3-PJ	2.77	Rain Bird-Mexico
10	(Z)	2.5	Unknown
11	(X)	4	Unknown
12	(Y)	4	Unknown

on three operating pressure levels for each sprinkler type (200, 250 and 300 KPa). The relative humidity and wind speed were also recorded during each test. Discharge of each sprinkler was measured during the test. The water application rate was calculated at each operating pressure by dividing the depth of water caught by the time of water application. The average value of application rates are presented in Table 3. Sprinkler tests were analyzed for uniformity of distribution by using the concept introduced by Christiansen [2]. This concept is a numerical expression that serves as an index of uniformity for a sprinkler system's distribution of the form:

$$Cu = 100 \left[1 - \frac{\sum_{i=1}^{n} \left| Xi - \bar{X} \right|}{n \bar{X}} \right]$$

where:

- Cu = Christiansen Coefficient of Uniformity.
- Xi = A single observation of collected water.
- $\bar{X}$ = Mean of individual observtions.
- n = the total number of observations.

With the numerical value, a comparison of sprinkler patterns and determination of how different operating pressures affect the resulting distribution of water could be obtained.

Results and Discussion

A comparison was made between the actual measured data and the data supplied by the manufacturers for the discharge and the diameter of throw at the three operating pressures, as shown in Table 2.

In general, the results showed an increasing trend in the sprinkler discharge and the wetted diameter of each sprinkler type with an increase in operating pressure as expected, but the increase in the wetted diameter of each individual sprinkler was affected by the wind speed and relative humidity during the test period. However, there was some variation between the measured and the manufacturer's data as indicated in Table 2.

The water distribution patterns for the tested sprinklers were obtained by catching water from a single sprinkler for each type at three operating pressure levels. These patterns are shown in Figs. (2,3 and 4). In general, impact sprinkler types when operated within the recommended operating pressure range have nearly triangular shaped distribution patterns (i.e., patterns in which the depth of application increases linearly from the outer edge of the pattern towards the sprinkler). However, the distribution patterns beneath the various tested sprinklers showed a variation in water distribution at the three operating pressures, and did not follow the general trend. It seems that, some of these sprinklers sprayed their water in a ring like shape near the outer edge of the patterns. Some other sprinklers have applied more water at one side of the sprinkler than the other, as shown in Figs. 2, 3 and 4. This might create the problem of over-irrigation in some areas and under irrigation in others. But in general the water was distributed on both sides of sprinkler more uniformly as the nozzle size increased. This may indicate that nozzles with small sizes are susceptible to climatic parameter effects such as wind and air temperature.

The application rates varied for each sprinkler type, and that no consistent trend was observed with the increase in the operating pressure. This is because the average application for an individual sprinkler varies widely depending upon nozzle geometry [13] which would affect the produced droplet size, and this in turn could be influenced by the atmospheric conditions.

The uniformity of water application for single sprinkler was determined using Christiansen's coefficient of uniformity (Cu). The average Cu values are listed in Table 3.

Table 2. Comparison between experimental (Exp) and Manufacturer (Man.) discharge and diameter of throw of tested sprinklers.

Operating pressure KPa	200				250				300			
Sprinkler	**Discharge** m^3/hr		**Dia** (m)		**Discharge** m^3/hr		**Dia** (m)		**Discharge** m^3/hr		**Dia** (m)	
Model No.	Man.	Exp	Man.	Exp	Man.	Exp	Man.	Exp	Man.	Exp	Man.	Exp.
1	2.3	2.11	13	24	NA	2.63	NA	24	NA	2.48	NA	23
2	NA	1.31	NA	22	NA	1.46	NA	23	2.35	1.56	28	24
3	NA	1.40	NA	26	NA	1.54	NA	29	2.80	1.59	32	28
4	2.19	1.50	26.1	26	2.44	1.80	27.7	25	2.67	2.03	28.8	26
5	1.25	1.0	26	26	1.36	1.1	27	26	1.54	1.25	28	26
6	1.2	0.47	26	21	NA	0.54	NA	22	1.62	0.58	29	23
7	1.09	0.82	23	24	1.19	0.91	24	24	1.35	1.01	26	26
8	0.69	0.82	17	20	0.78	0.89	17.8	20	0.85	0.93	18.8	21
9	0.40	0.48	21.6	18	0.44	0.51	21.8	19	0.49	0.61	22	23
10	NA	0.34	NA	12	NA	0.39	NA	14	NA	0.43	NA	18
11	NA	0.81	NA	22	NA	0.89	NA	22	NA	0.95	NA	22
12	NA	0.83	NA	23	NA	0.89	NA	23	NA	0.97	NA	23

NA = Not available

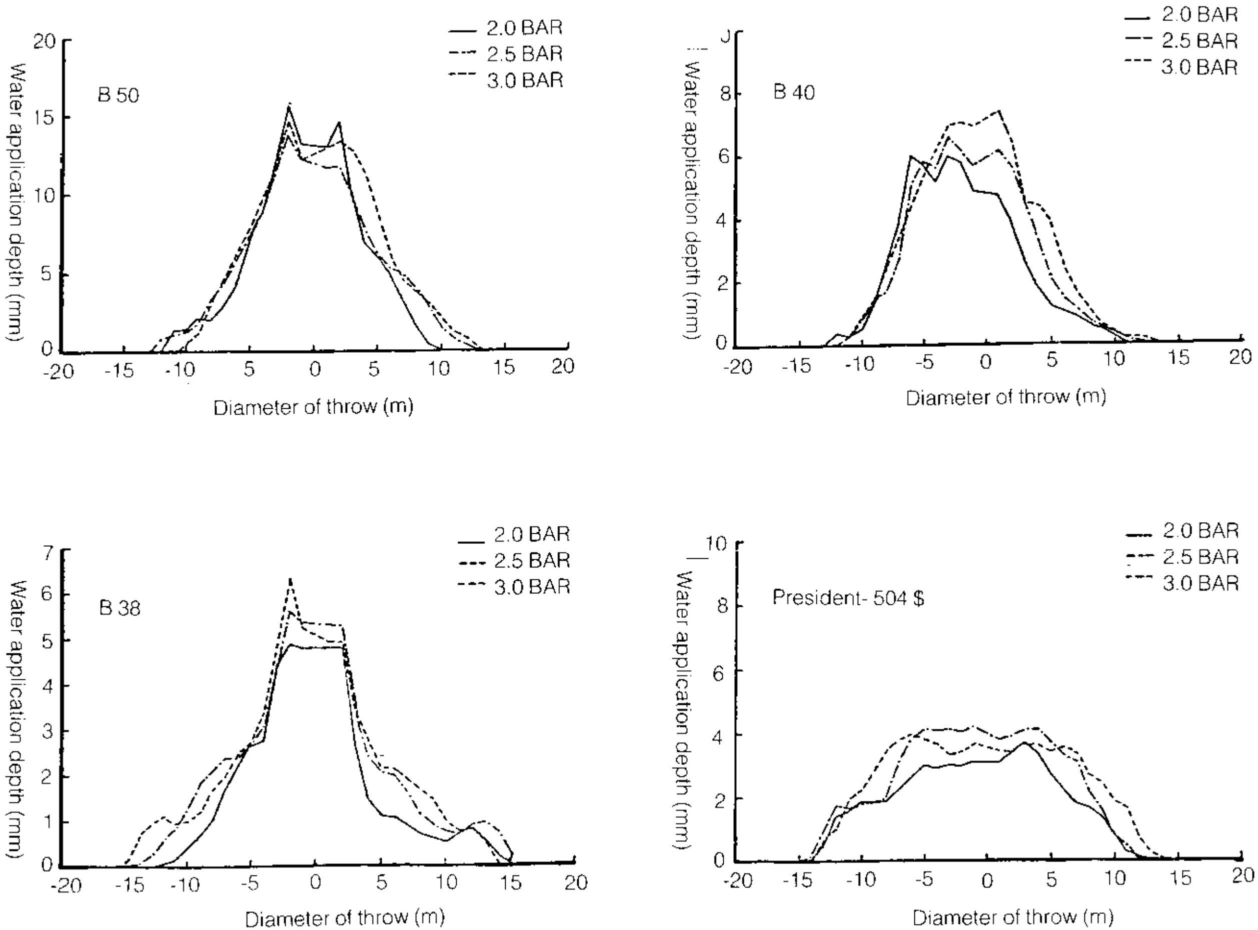

Fig. 2. Water distribution patterns for different sprinkler types

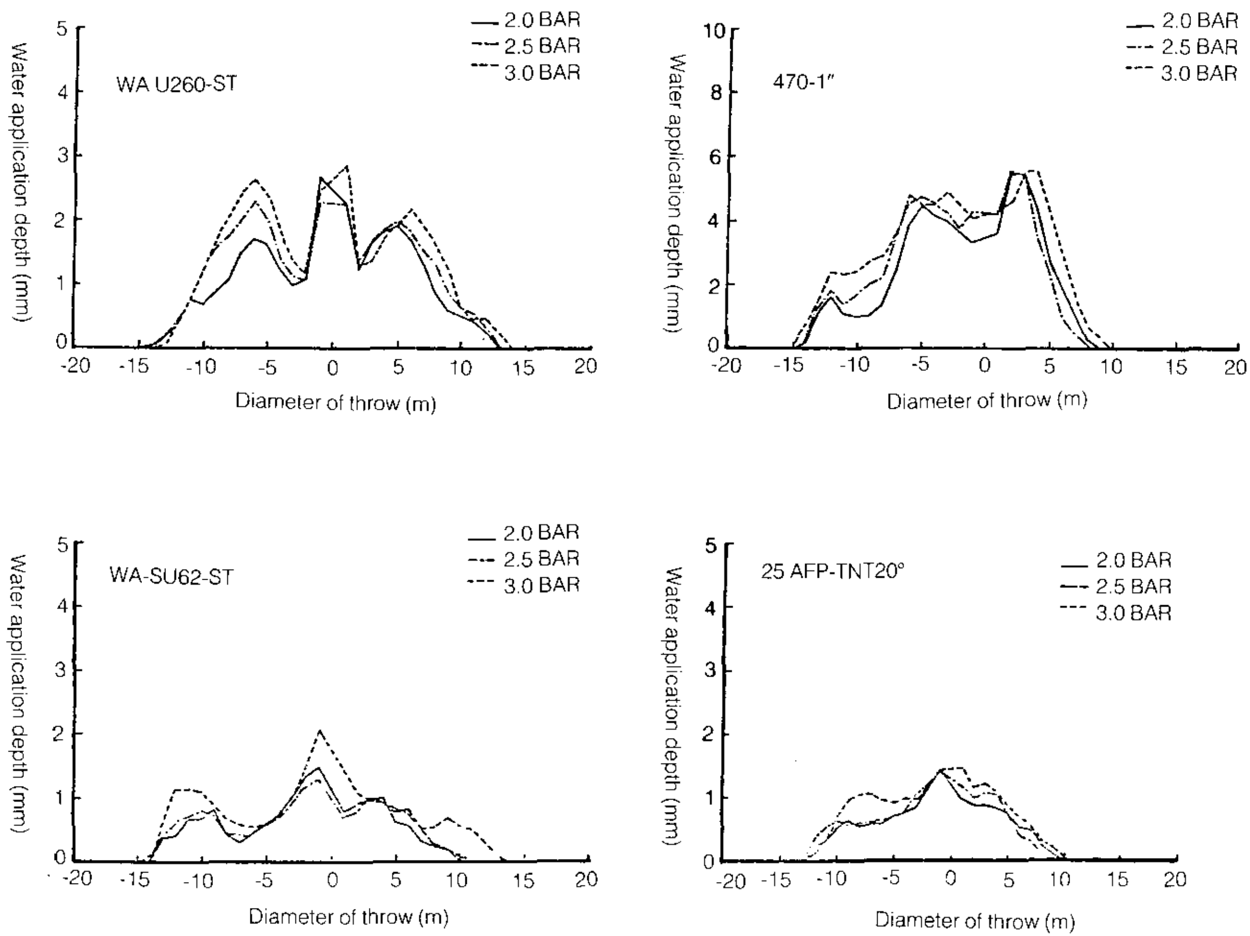

Fig. 3. Water distribution patterns for different types

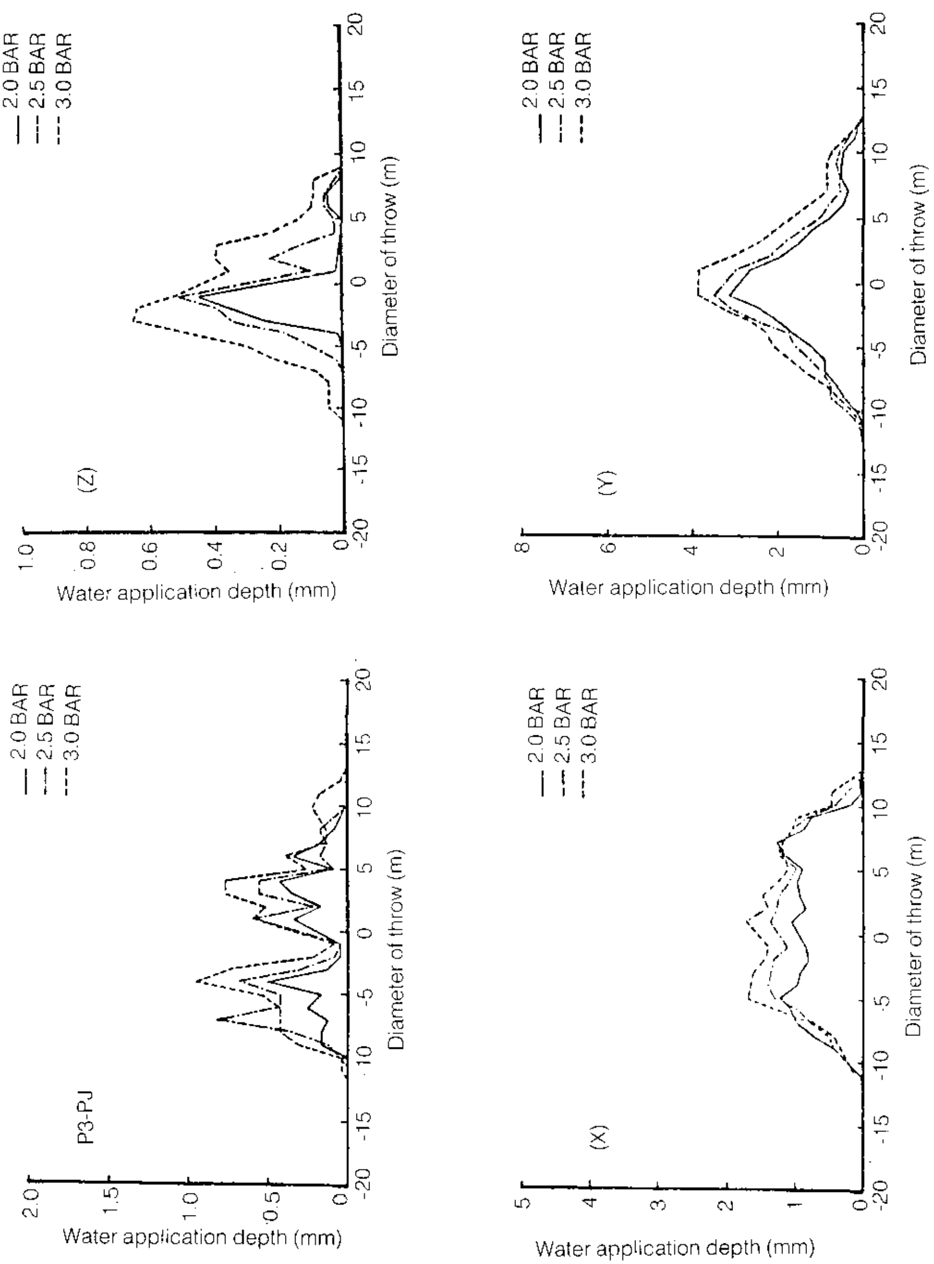

Fig. 4. Water distribution patterns for different sprinkler types

Table 3. Average results of application rate (Ra) and coefficient of uniformity (Cu)

Pressure (KPa)	200		250		300		Average	
Sprinkler Model No.	Ra (mm/hr)	Cu %	Ra (mm/hr)	Cu %	Ra (mm/hr)	Cu %	Wind speed km/hr	Relative humidity (%)
1	6.09	32.07	5.22	22.18	5.97	32.26	8.55	43.39
2	3.45	24.37	3.51	29.79	3.45	35.79	12.07	39.39
3	2.64	21.66	2.33	31.52	2.59	36.34	9.02	40.61
4	2.97	56.46	3.78	66.17	3.81	68.69	12.22	38.50
5	1.91	51.13	2.14	58.37	2.35	62.71	7.28	38.17
6	4.84	54.09	5.08	45.68	5.06	51.02	13.76	46.55
7	1.81	49.69	2.00	57.76	1.97	60.55	7.76	47.22
8	2.59	62.91	2.84	65.98	2.69	68.59	8.98	51.72
9	1.88	44.31	1.81	62.00	1.47	63.62	10.33	45.50
10	3.02	20.00	2.51	22.22	1.69	57.02	10.94	45.61
11	2.13	58.74	2.35	65.07	2.50	69.56	9.41	46.39
12	1.99	28.17	2.14	34.33	2.32	35.99	10.46	44.33

These values ranged from 20.0% to 68.69%. Generally, the uniformity has improved with increasing pressure. Nevertheless, some sprinkler types produced a higher value of Cu than the others resulting in an even water distribution over the irrigated area, but most values of Cu were low. The coefficient Cu for sprinkler system is often evaluated using a grid of catch cans. But the coefficient of uniformity from single sprinkler was determined in this study in order to show how evenly each sprinkler type distributes water over the irrigated area, and this will reflect on Cu value. Therefore, the comparison between these sprinkler types could be made. The distribution pattern obtained from single sprinkler could be used to build up an overall field distribution pattern for each type using a simple overlapping procedure [14].

Conclusions and Recommendations

This study was conducted to investigate the performance characteristics of twelve impact sprinkler types used by local farmers irrigating crops. The generated data are expected to be helpfull to the farmers, irrigators, and system designers in selecting the proper irrigation sprinkler types, and therefore, design their system efficiently.

The conclusions from this study could be drawn as follows:

1. The water distribution patterns are useful as a basis for selecting the combination of sprinkler spacing to obtain high values of irrigation efficiency at specific operating condition.
2. There was a variation between the measured data and the manufacturer's ideal data under the local field conditions and the performance of these sprinkler types was not satisfactory.
3. The performance of these sprinklers did not follow a general trend in their water distribution patterns.
4. More attention should be given to nozzle geometry (i.e., nozzle opening, size, shape, and angle) by the manufacturer during the design in order to obtain an efficient irrigation taking into consideration the climatic parameter effects on the water distribution.
5. Based on the results of this study farmers and irrigation engineers, when they need to select sprinklers for their farm irrigation use are: (a) encouraged to seek advice from qualified advisors and designers, (b) or to make a simple evaluation in the field.
6. Farmers using an inefficient device in irrigation systems are delivering more water to compensate for the low efficiency of sprinklers, and hence abundant water is wasted.
7. Based on the results obtained local farmers are advised to use sprinklers with large nozzles to increase the uniformity of application.
8. Based on the important role of sprinkler uniformity of distribution in conserving water, especially in Saudi Arabia, which lacks the natural water resources, it is advisable that a government or private agency should make regular tests on new imported sprinklers to ensure meeting an acceptible level of performance.

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خصائص الأداء لأنواع متعددة من الرشاشات الدوارة المستخدمة محليًّا

حسين محمد أبو غبار و أحمد إبراهيم العمود

قسم الهندسة الزراعية، كلية الزراعة، جامعة الملك سعود

الرياض، المملكة العربية السعودية

ملخص البحث. أجريت دراسة على خصائص الأداء لإثنى عشرة نوعًا من الرشاشات الدوارة التي تستخدم محليًّا بكثرة. استخدم في هذه الدراسة ثلاثة رشاشات من كل نوع تحت ثلاثة ضغوط تشغيل هي ٢٠٠، ٢٥٠، ٣٠٠ كيلو باسكال (٢، ٢,٥، ٣ بار). وقد تم تقويم أداء كل نوع من الرشاشات ومقارنته مع بيانات الشركات المنتجة. وقد أوضحت نتائج الدراسة بعض الفروق بين نتائج التجارب وبيانات الشركات المنتجة والذي قد يعزى سببه للظروف الحقلية.

ويمكن لهذه الدراسة أن تساعد مصممي نظم الري بالرش في اختيار أنواع الرشاشات المناسبة والمتوافرة محليًّا والتي يمكن أن تحقق تطبيقًا أمثل في توفير مياه الري، كما تقترح هذه الدراسة بعض التوصيات.