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Performance Characteristics of Micro-sprinklers Irrigating Greenhouses in Saudi Arabia

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Abstract. Six types of micro-sprinklers were tested under controlled conditions inside a greenhouse at three operating pressure levels; 100, 150, 200 kPa (1, 1.5, 2 bars). The performance characteristics including uniformity, water application rate and water distribution patterns were studied. A comparison between the actual measured data and the data reported by the manufacturer showed that there were some variations possibly due to inaccuracy in nozzle designs. The results of this study may assist the agricultural and system designers to select proper irrigation nozzles locally available for efficient water use and some recommendations were suggested.

Introduction

Agricultural production is based mainly on irrigation, especially in arid and semi-arid zones. The agricultural sector is expanding rapidly in the Kingdom of Saudi Arabia. This expansion was achieved by using modern irrigation methods to irrigate crops in the field and in the greenhouses.

In recent years, the number of greenhouses in the Kingdom has increased rapidly either by small growers or by large agricultural establishments. The reasons for the increasing popularity of the greenhouse agriculture are their ability to control atmospheric parameters, saving water, increasing the crop yield, growing the crop any time during the year, labor saving advantages and their extreme versatility.

Trickle irrigation encompasses a number of methods or concepts, such as drip, subsurface, bubbler, and spray irrigation. The primary difference between these methods is the type of emitter or device used to apply water to the plants and the range of application rates.

In spray method, small sprinklers like devices (often called micro-sprinklers) spray water as a mist over the irrigated area (Figs. 1 and 2). They are used to overcome some limitations of the other trickle methods. These devices have larger

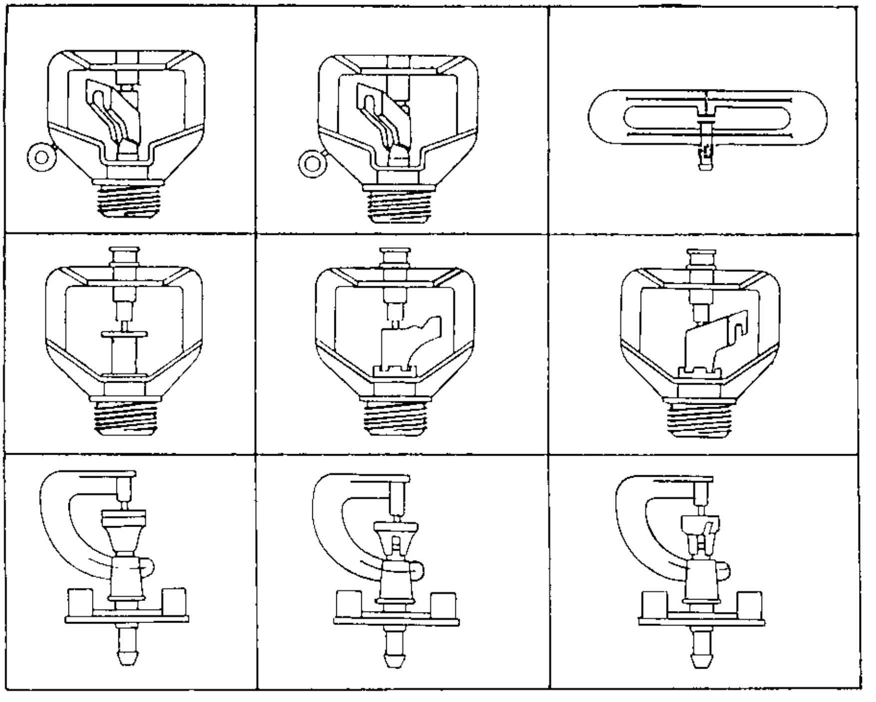

Fig. 1. Typical micro-sprinkler devices.

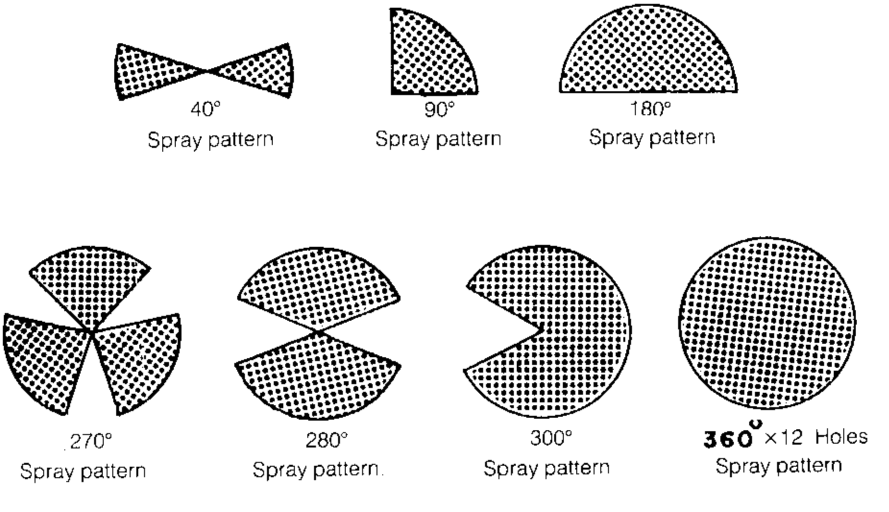

Fig. 2. Areal distribution patterns of different micro-sprinkler (after James 1988).

orifices than those of drip emitters which reduce the need for filteration to control clogging and to allow the crop to be irrigated in shorter time.

The function of sprinklers and micro-sprinklers is to distribute water uniformly over the irrigated area without runoff. Micro-sprinklers spray water with very small droplets to avoid damaging the irrigated crops or plants. Operating pressure and nozzle geometry (i.e. nozzle opening size, shape and angle) are the primary factors that control the operation of micro-sprinklers. The performance of a micro-sprinkler is described by its discharge, distance of throw, distribution pattern, application rate, and droplet size. These factors can affect the irrigation efficiency, the amount of water used, and the crop production. The application characteristics of these micro-sprinklers reflect the interaction among the hydraulic characteristics, the soil-crop-system and the management practices of the irrigator.Seginer and Kostrinsky [1], Soloman [2], and Kincaid [3] have studied the effect of operating pressure and nozzle sizes on the sprinkler pattern radius.

One of the most important conditions for achieving a good irrigation efficiency and saving water is certainly the uniformity of application over the irrigated area [4]. Christiansen [5] developed a formula used as a basis for describing the uniformity of water distribution in sprinkler irrigation. The uniformity of water application to plants by micro-irrigation system is an important concept affecting the design and operation of these systems [6,7]. The hydraulic characteristics of micro-sprinkler nozzles (pressure-discharge relationship) significantly affect the performance of the device. It is important therefore for the designer to check this fundamental relationship between pressure and discharge of these devices.

A number of investigators studied the effect of various sprinkler variable parameters including pressure, nozzle height, and nozzle size, such as Bilanski and Kidder [8], Kohl and DeBoer [9], Karmeli *et al.* Kohl, *et al.* [11], and Bernuth [12].

Due to the increase in need for irrigation and miro-irrigation devices in recent years in the Kingdom of Saudi Arabia, many irrigation devices made by different manufacturers are locally available. There are various types and sizes of micro-sprinklers products that differ in their qualities used by the farmers.

Therefore, there is a need to evaluate the most common micro-sprinklers with local distributors to help the farmers and irrigation system engineers in the selection of the proper device, operating pressure, discharge, and the throw diameter, which will lead to improve the irrigation efficiency and to increase the yield, and also to conserve water. So, the objectives of this study are the following:

1. To evaluate some of the common micro-sprinkler types available in the market at different operating pressures.

2. To compare the actual measured results with the reported manufacturer's specifications.

Materials and Methods

Data for this study were collected from a single stationary micro-sprinkler system. The layout of the system is shown in Fig. 3. It consisted of the following components; water supply tank, pump, flow control valve, pressure regulator, polyethylene pipe, micro-sprinklers and pressure measuring device. Catch containers and graduated cylinders were used to collect and measure the distribution of water sprayed by the micro-sprinklers.

Six commercial micro-sprinkler types that are common for irrigating crops in greenhouses were tested, these devices are listed in Table 1. Micro-sprinklers were mounted on 0.3 meter risers for the purpose of experiment and each test was conducted at three pressure levels, namely; 100, 150 and 200 kPa (1, 1.5 and 2 bars), and repeated three times.

A number of catch containers were placed on both sides of the lateral at spacing of 0.5 meter (Fig. 3). The system was operated for a duration of 1.5 hr for each test so that a sufficient amount of water could be caught by the containers.

$$Cu = 100\,(1 - \Sigma X / M \, . \, N) \qquad \dots (1)$$

where:

Cu = coefficient of uniformity

X = the absolute deviation from the mean of individual measurements

M = the mean value of measurements

N = the number of measurements.

Procedure to determine the distribution of water from sprinklers, illustrated by the American Society of Agricultural Engineers Standard, ASAE [13, pp. 487-89], was followed.

The relationship used for identifying the hydraulic characteristics of nozzles is in the form:

$$q_e = K \, . \, P_e^c \qquad \dots (2)$$

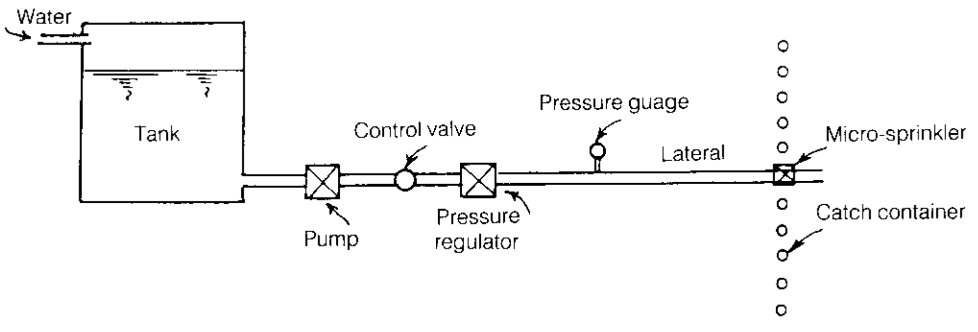

Fig. 3. Layout of the apparatus used to evaluate micro-sprinklers.

Table 1. Micro-sprinklers used in the study

Code	Name	Manufacturer
SMB 16 green nozzle	Challenger micro-sprinkler	Wingfield
SMB 20 blue nozzle	Challenger micro-sprinkler	Wingfield
SMB 24 yellow nozzle	Challenger micro-sprinkler	Wingfield
SMB 27 red nozzle	Challenger micro-sprinkler	Wingfield
Orange SWM 414	Micro-sprinkler II	Hardie
SPDO2	Mazak spray nozzle	Hardie

where:

q_c = the nozzle discharge

p_c = the nozzle operating pressure

c = the nozzie discharge exponent that expreses the emitter flow regime

K = the coefficient of proportionality that characterizes each nozzle and depends on its size and shape.

Results and Discussion

In this study an effort was made to evaluate the performance of six micro-sprinkler types, the evaluation included the uniformity coefficient, water distribution patterns of applied water, water application rate, and the discharge pressure relationship.

A comparison was made between the actual measured data and the data sheets for these nozzles supplied by the manufacturers. Table 2 shows the comparison of discharge and diameter of throw for the test nozzles at three operating pressures.

The results showed that the discharge of each micro-sprinkler was increased by increasing the operating pressure. The increase in the throw diameter was generally small, except in the SPD02 nozzle where the diameter of throw decreased at pressure of 200 kPa (2 bar) and may be due to small droplets that tend to evaporate. However, the measured and manufacturer's data were different at all operating pressures as shown in Table 2.

Table 2. Comparison between experimental (Exp.) data and manufacturer's (Man.) data at three operating pressures

Operating pressure kPa (bar)	100 (1)				150 (1.5)				200 (2)			
Micro-sprinkler code	Measurements											
	Discharge l/hr		Dia (m)		Discharge l/hr		Dia (m)		Discharge l/hr		Dia (m)	
	Man.	Exp.	Man.	Exp.	Man.	Exp.	Man.	Exp.	Man.	Exp.	Man.	Exp.
SMB 16 green nozzle	72	75	6.2	7	90	96	8.2	8	101	114	9.2	8
SMB 20 blue nozzle	98	108	8.1	8.5	120	128.4	9.6	9	138	146.4	11	10
SMB 24 yellow nozzle	155	114.6	9.5	9	185	162	10.6	10	218	224.4	11.5	11
SMB 27 red nozzle	195	180	8	9	240	199.2	11	10	272	240	12	11
Orange SWM414	78	130.2	6.1	8	89	159	7	9.5	114	180	7.7	9.75
SPDO2	90	150	2	3	–	162	–	4	–	168	–	3.4

The water distribution patterns for the test nozzles were obtained by catching water from a single micro-sprinkler for each type at three operating pressures. These patterns are shown in Fig. 4. Each type shows a variation in water distribution at the three operating pressures, and there was no general trend between these nozzles, and even for one nozzle. However, the water depth near the nozzle was larger than the depth caught in the far cans. Also, some of the nozzles have applied more water at one side of the nozzle than that on the other side, especially with SPDO2 nozzle.

The rate of water application for each single nozzle type was calculated by dividing the depth of water caught by the time of water application. The average values of application rates are presented in Table 3. These values ranged from small value

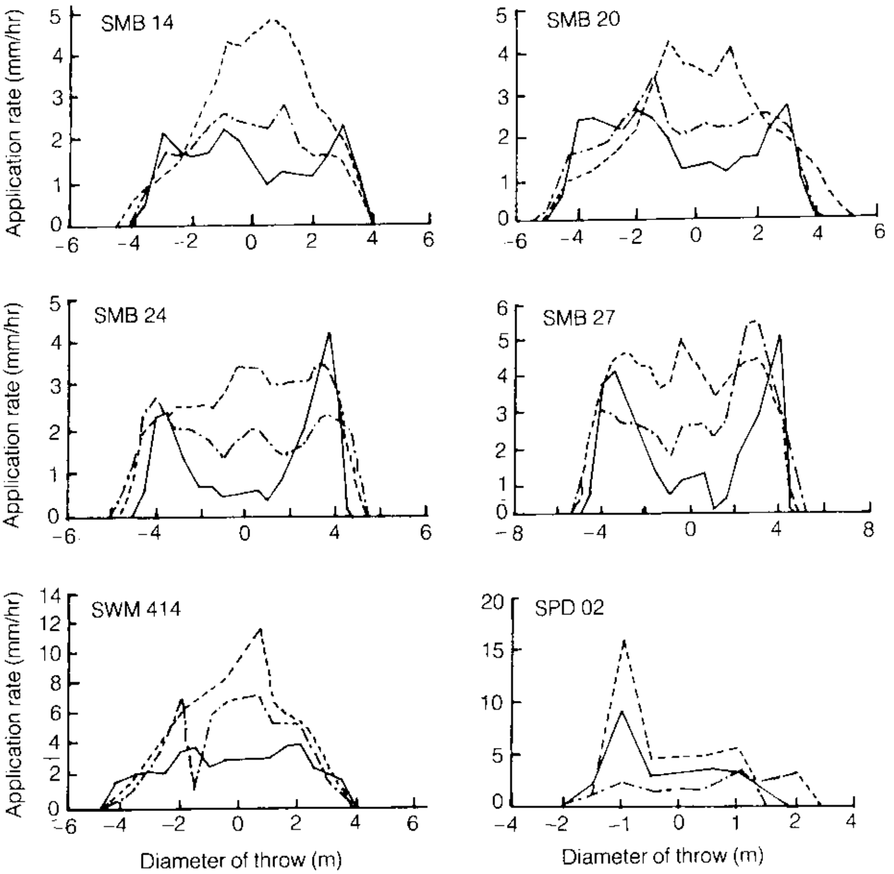

Fig. 4. Water application profiles for the various micro-sprinklers tested.

(—— : 1.0 , Bar , —·— : 1.5 , Bar , ---- : 2.0 , Bar).

of 1.86 mm/hr to higher values of 23.77 mm/hr. These high values were produced by the SPDO2 nozzle, and were high because the water was applied on a small area. The applicaiton rate for each nozzle was in general the same at all pressures with a slight decrease with some nozzle at higher pressures, as shown in Table 3.

The uniformity of water application was determined using the Christiansen's Coefficient of Uniformity (Cu) as defined in equation (1). The Cu values are listed in Table 3, these values ranged from 30.66% to 81.26%. Also, the results show variations between these nozzles, and the higher values were produced at operating pressure of 150 kPa (1.5 bar). In general the values of Cu were low and that could be improved by overlapping using more than one nozzle.

Table 3. Application rates and Cu values for test nozzles

Operating pressure kPa(bar)	100 (1)		150 (1.5)		200 (2)	
	Measurements					
Micro-sprinkler code	Cu %	Ra mm/hr	Cu %	Ra mm/hr	Cu %	Ra mm/hr
SMB 16	73.34	1.95	63.11	1.91	48.90	2.27
SMB 20	67.92	2.15	68.72	2.02	48.10	1.86
SMB 24	30.66	2.23	81.26	2.06	66.78	2.36
SMB 27	40.12	2.83	67.00	2.54	67.00	2.53
SWM 414	67.70	2.59	35.32	2.50	34.80	2.83
SPD 02	51.13	21.22	48.80	21.9	34.74	23.77

The discharge-pressure relationship and equations for each nozzle type were determined. The equations and the relationships are shown in Fig. 5. The values of the micro-sprinkler discharge exponents (equation 2) ranged from 0.16 to 0.83, and the variations between these nozzles could be found from the difference in their values.

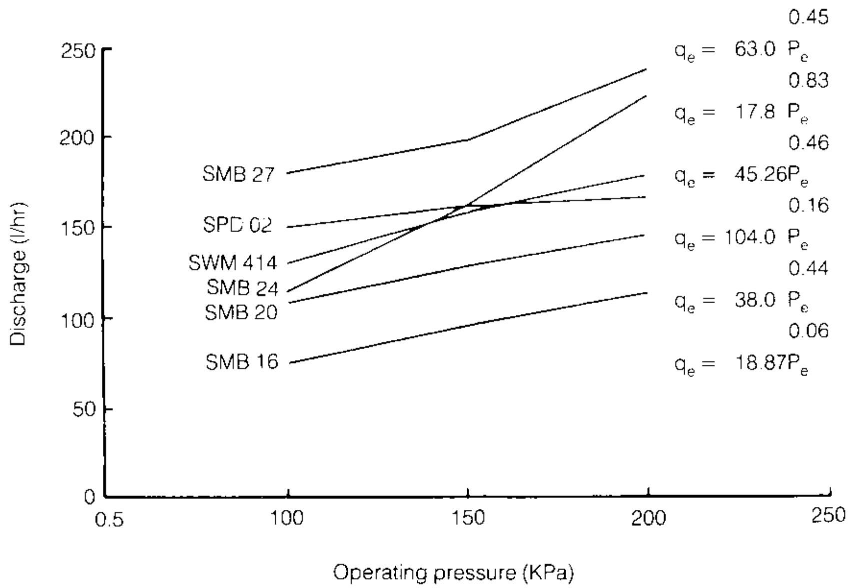

Fig. 5. Discharge-pressure relationships for the various micro-sprinklers tested .

The results obtained in the study and the variations between the measured and manufacturer's data may be attributed to inefficient design and/ or rough finishing of these nozzles.

Conclusions and Recommendations

This study was conducted to investigate the performance of the micro-sprinklers used by the farmer in greenhouses and nurseries. This data will help the farmers, irrigators, advisors, and system designers to select irrigation equipment and efficiently design their systems.

These nozzles have been tested under greenhouse conditions, and the conclusions from this study are as follows:

1. There was a variation between the measured data and the manufacturer's data with regard to water distribution.
2. The performance of these nozzles did not follow a general trend as expected from these devices at all operating pressures.
3. The performance of these nozzles were poor and that could be caused by inefficient design.
4. Farmers and irrigators are encouranged to seek advice from qualified advisors and designers when they need to use micro-sprinklers.

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خصائص الأداء لرشاشات تروي البيوت المحمية في المملكة العربية السعودية

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ملخص البحث. تم اختبار ستة أنواع من أنظمة الرش الصغيرة تحت ظروف البيوت المحمية عند ثلاثة ضغوط مختلفة وهي: ١٠٠، ١٥٠ و ٢٠٠ كيلو باسكال. وأجريت دراسة على خصائص الأداء لتلك الرشاشات والتي تشمل: انتظام الرش ومعدل التطبيق وأشكال توزيع المياه. وعند مقارنة المعلومات التي تم جمعها من التجارب مع المعلومات الواردة من الشركات المصنعة وجد اختلاف بين تلك المعلومات قد تكون نتيجة لعدم الدقة في تصنيع فوهات تلك الرشاشات نظرًا لحساسية تلك الفوهات. ويمكن لنتائج مثل هذه الدراسة أن تساعد مصممي نظم الري على اختيار رشاشات الري المناسبة نظرًا لتعدد أنواع مثل هذه الرشاشات في السوق المحلية حتى يمكن تحقيق أفضل كفاءة لاستخدام مياه الري، وقد تم استعراض بعض الاقتراحات.