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Investigation of riser height and operating pressure on sprinkler irrigation performance under different wind condition

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Abstract: Due to limitation of water resources in Egypt and booming population more efficient techniques of irrigation are required. These techniques should be able to control the amount of water applied and its timing more precisely to save on water amount and maximize the productivity. The current research investigates sprinkler irrigation system performance. The main objective of this study was to evaluate: the effect of riser height and operating pressure on sprinkler irrigation performance and water application under different wind speed conditions and different irrigation time. The study was applied on sandy soil cultivated with intensive crops, barley (*Hordeumvulgare* L.) Giza 129 variety.

To achieve this goal the field experiments were carried out during two successive winter seasons of 2013/14 and 2014/15 at the Research and Production Station, National Research Center, El-Nubaria Province, El-Behira Governorate, Egypt. The statistic experimental design was spilt spilt plot design. Eighteen cultivated areas were irrigated by movable sprinkling system, in different parts of the day. Nine areas were irrigated with riser height 1m and the rest with 1.5m. For each riser height areas three areas were irrigated at morning, three at midday and three at evening. The morning three areas as well as those of midday and evening (of each riser height) were irrigated at different pressure levels, 2.5, 3.0 and 3.5 bars. The results show that, the wetted diameter area increased by increasing the pressure level, especially from 2.5 to 3 bar. The wind speed at the evening achieved significantly the highest value of wetted diameter. Irrigation at evening gives the highest wetted diameter area especially with 3 bar pressure. The riser height 1m have better wetted diameter than 1.5 m riser at 2.5 bar and 3 bar, with insignificant difference at 3.5 bar. This study highly recommends sprinkler irrigation with 3 bar pressure and riser height at 1 m at evening. This will give the highest irrigation wetted diameter.

Keywords: Movable sprinkler irrigation system, Riser height, Operating pressure, Wind speed, Irrigation performance, Water productivity.

Introduction

Pressure modern irrigation technologies, such as sprinkler and trickle irrigation, can result in less water wastage because water is conveyed in pipes. Furthermore the irrigators can control the amount of water applied and its timing more easily which can increase the productivity / unit of water[1]. [2]) said that, because water is the most important factor for limiting horizontal and vertical expansion in the production of different crops such as Zuchine. The crop yield and quality are affected by available water. It is highly desirable to obtain higher yield using the least possible quantity of water. Due to the limitation of water amount in Egypt, river Nile which floods about 55.5 billion m3 water / year is main water resource for agricultural, industrial, and urban activities. Rainfall which is about 130 mm a year and occurs only in winter season is not sufficient even for an irrigation interval [3,4]. [5] stated that, Throw out pressured irrigation systems can achieved uniformity of different fertigation rates, increasing of water use efficiency and improving the quality and quantity of yield. [6] indicated that, Egypt is of dry areas that suffer from lack of water needed for agriculture, so it was necessary to use alternative modern irrigation systems to save and control the irrigation water in arid and semiarid regions. The pressurized irrigation system such as sprinkler irrigation system has high potential properties to improve water productivity (water use efficiency) of crops [7].

The sprinkler irrigation systems are designed to achieve uniformly to irrigation water as possible to the crop root zone. The water distribution throw sprinkler is depend on: (i) the system design parameters (such as: the sprinkler spacing, operating pressure, nozzle diameters) which are all controllable in field trials; (ii) environmental variables (such as: wind speed and direction); and (iii) the management[8,9]. By sprinkler irrigation, the distribution of water is strongly affected by wind speed. Consequently, some areas of the field may not receive an adequate amount of irrigation water [10]. Several authors[10,11] have reported that, the wind speed considered the main environmental variable affecting the sprinkler performance. It is the most important uncontrollable factor [12,9]. Wind causes broken and distribution processes to change status in two ways: (1) It affects the breakup of the water due to air resistance; and (2) it blows all the resulting drops around [13].

[14] indicated that, both coefficient of uniformity and distribution uniformity of sprinkler irrigation system were increased with increasing both the operating pressure up to 300 kPa and riser height till 1.5 m of sprinkler from ground level. There is no irrigation system will apply water without losses because the cost of prevent all losses is expensive. Therefore, some water losses are expected and accepted in good irrigation system design, installation, and management. Thus, excessive losses may be caused by not effective irrigation system design, improper installation, poor management, and equipment failures. It is very difficult to apply the optimum amount of irrigation water required with perfect uniformity because of differences properties in soil types, variations in irrigation system components, pressure losses in systems due to friction and elevation changes and other causes[15].

Wind speed, evaporation and deep percolation are main causes of water losses [16]. The losses throw evaporation and wind drift are from 5 to 10 %, but can be higher with increasing air dry [17].

The uniformity coefficient of a sprinkler irrigation system has a obvious effect on the application efficiency and on the crop productivity [18]. The poor water uniformity causes decreased of irrigate efficient as parts of the field will be either over-irrigated or under-irrigated [19]. [20] also indicate that by increasing irrigate efficient in uniformity of water in the soil could result in 4% increase in yield and reduce cost of irrigation water by maintaining uniform water application and reducing application water losses[21].

The main objective of this study was to evaluate: the effect of riser height and operating pressure on sprinkler irrigation performance and water application under different wind conditions.

Materials and Methods

Field experiments were carried out during two successive winter seasons of 2013/14 and 2014/15 at the Research and Production Station, National Research Center, El-Nubaria Province, El-Behira Governorate, Egypt. It aims at studying the effect of riser height and operating pressure on wetted diameters under different wind conditions.

Sprinkler irrigation system is used to irrigate intensive field crops, such as barley, and other intensive crops. The field was cultivated with barley, (*Hordeum vulgare* L.) variety Giza 129. The used sprinkler irrigation system was movable system and content from Aluminum pipes. The length of main line was 75 m with PVC pipes 4" diameter and 4 bar pressure. The laterals pipes were from Aluminum, each one was 6 m length with 2" diameter. Each lateral installation is equipped with a pressure regulator and a control valve. Length of laterals is 40 m and formed of 5 sprinklers. The distance between each two sprinkler was 10 m with a planner wetted diameter of 20 m. The overlapping between every two sprinklers was 100 %. The first and last sprinkler turned with 90^0 and the all three in the middle turned with 180^0. Each valve is mounted over a riser fitted with a precautionary control valve. Risers are made of Aluminum with 1" diameter. One side of the research area was fitted with 1 m risers height and the other side with 1.5 m risers height. The laterals ware moved 9 times a day (3 Morning, 3 Midday, and 3 Evening) to irrigate 9 spaces each by every pressure (P_1, P_2, P_3) for 30 min. The type of sprinkler was Nan dan 0.5", with a discharge of 600 L/hr. Ten sprinklers were employed to irrigate each space, figure (1). The irrigation water rate totals to 27 m^3 / fed / day. With 2 time / week irrigation and 20 weeks per season, the irrigation water amounts to 1080 m^3 / fed / season. Irrigation time is based on the plant growing stage for barley and it was 180 irrigation hours / feddan / season.

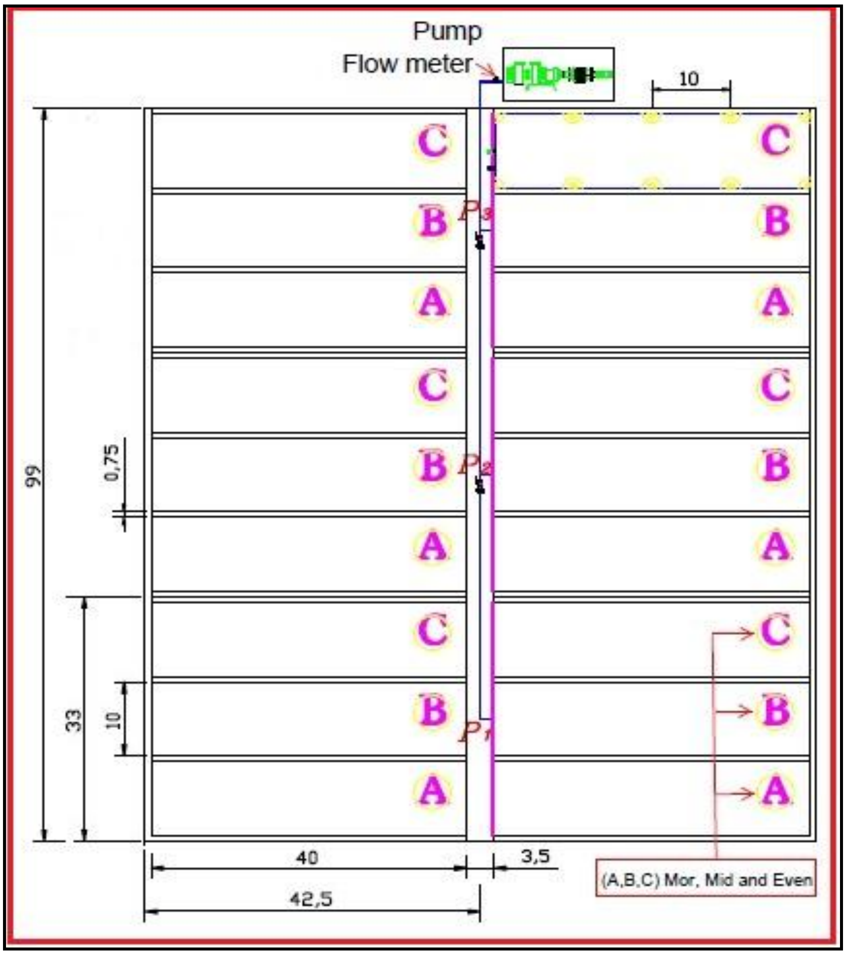

Fig. 1: Schematic diagram for the experiment design layout

Three operating pressure levels (P_1, P_2 and P_3 = 2.5, 3.0 and 3.5 bar) and two riser heights (R_1 and R_2) = 1m and 1.5 m was employed. Each feddan is divided to 9 partitions, (40 m x 10 m), and irrigated by 9 movements. The used pressure in the first part is 2.5 bar, second part is 3 bar, and third part is 3.5 bar. The first research area was irrigated by a riser height of 1 m and the other one was with 1.5 m riser height. Figure (1) shows in a schematic diagram for the experimental design layout.

To evaluate the effect of wind speed, the tests were carried out under different wind conditions during morning (from 6 to 8 A.M.), midday (from 12 to 2 P.M.) and evening (from 6 to 8 P.M.). The wetted footprint was determined by measurement which involves observing a sprinkler boundary between wetted area and non-wetted areas, marking the boundary, and measuring the area. The measured wetted footprint was compared with a specific nozzle pressure. The statistic experimental design was spilt spilt plot design.

Results and Discussion

Main effect of the treatments on wetted diameters:

According to the wetted diameters values obtained, the treatments under investigation could be written the following ascending orders: P_1፥ P_2 ፥ P_3, in Morning ፥ Midday and the Evening with two riser height R_1 (1 m) and R_2 (1.5 m).

Where:-

R_1 = Riser height = (1 m), R_2 = Riser height = (1.5 m).

P_1 = Operating pressure at the hydrant (2.5 bar), P_2 = Operating pressure at the hydrant (3.0 bar) and P_3 = Operating pressure at the hydrant (3.5 bar).

Table (1): Main effect of Riser height, Operating pressure, and Wind speed on Wetted diameters values m.

Treatments	wetted diameters m	Significant differences
Riser height (1 m)	26.50	b
Riser height (1.5 m)	28.15	a
Operating pressure (2.5) bar	24.10	b
Operating pressure (3) bar	27.05	a
Operating pressure (3.5) bar	27.30	a
Wind speed (Morning)	25.00	b
Wind speed (Midday)	23.65	c
Wind speed (Evening)	26.60	a

LSD at 5%

Table 1 shows that one feddan could be irrigated by 9 movements. The wetted diameter area increased by increasing the pressure level between 2.5 and 3 bar significantly, but between 3 and 3.5 bar there wasn't significant. There are significantly differences between the riser height of 1.5 m in comparison with the riser of 1 m on the wetted diameters values m. The wind speed at the evening achieved the highest significant value of wetted diameter area than morning and midday. Differences in wetted diameters values between any two treatments within the order were significant at the 5% level, except the differences between operating pressure P_2 and P_3.

Effect of the interactions on wetted diameters:

Table (2) and Fig. (2) indicated the effect of the interaction between and/or among treatments used on wetted diameters.

Under riser height 1 m:

Table (2) and Fig. (2). Show that The effect of the operating pressure on wetted diameters values gives The following descending orders: $P_3\times$ Evening, $P_3\times$Morning, $P_2\times$ Evening, $P_2\times$Morning, $P_3\times$Midday, $P_1\times$ Evening, $P_2\times$ Midday, $P_1\times$Morning, and $P_1\times$Midday.

Table (2): Wetted diameters for different riser height combinations (m).

operating pressure	Wind condition	1m Riser height (R_1)		1.5 m Riser height (R_2)	
		wind speed (m/s)	Wetted diameter (m(	wind speed (m/s)	Wetted diameter (m(
(P_1) 2.5 bar	Morning	2.15	23.4	2.45	25.2
	Midday	1.85	21.5	2.00	22.8
	Evening	2.10	24.8	2.25	25.7
(P_2) 3.0 bar	Morning	2.15	25.9	2.45	27.1
	Midday	1.85	24.6	2.00	26.0
	Evening	2.10	26.9	2.25	28.1
(P_3) 3.5 bar	Morning	2.15	27.3	2.45	27.8
	Midday	1.85	25.8	2.00	26.5
	Evening	2.10	28.0	2.25	28.6

Differences in wetted diameters between any two interactions from those were significant at the 5% level.

Under riser height 1.5 m:

The effect of the operating pressure on wetted diameters is given in Table (2) and Fig. (2). The following descending orders: P_3× Evening, P_2× Evening, P_3×Morning, P_2×Morning, P_3×Midday, P_2×Midday, P_1× Evening, P_1×Morning, and P_1×Midday.

Differences in wetted diameters between any two interactions from those were significant at the 5% level.

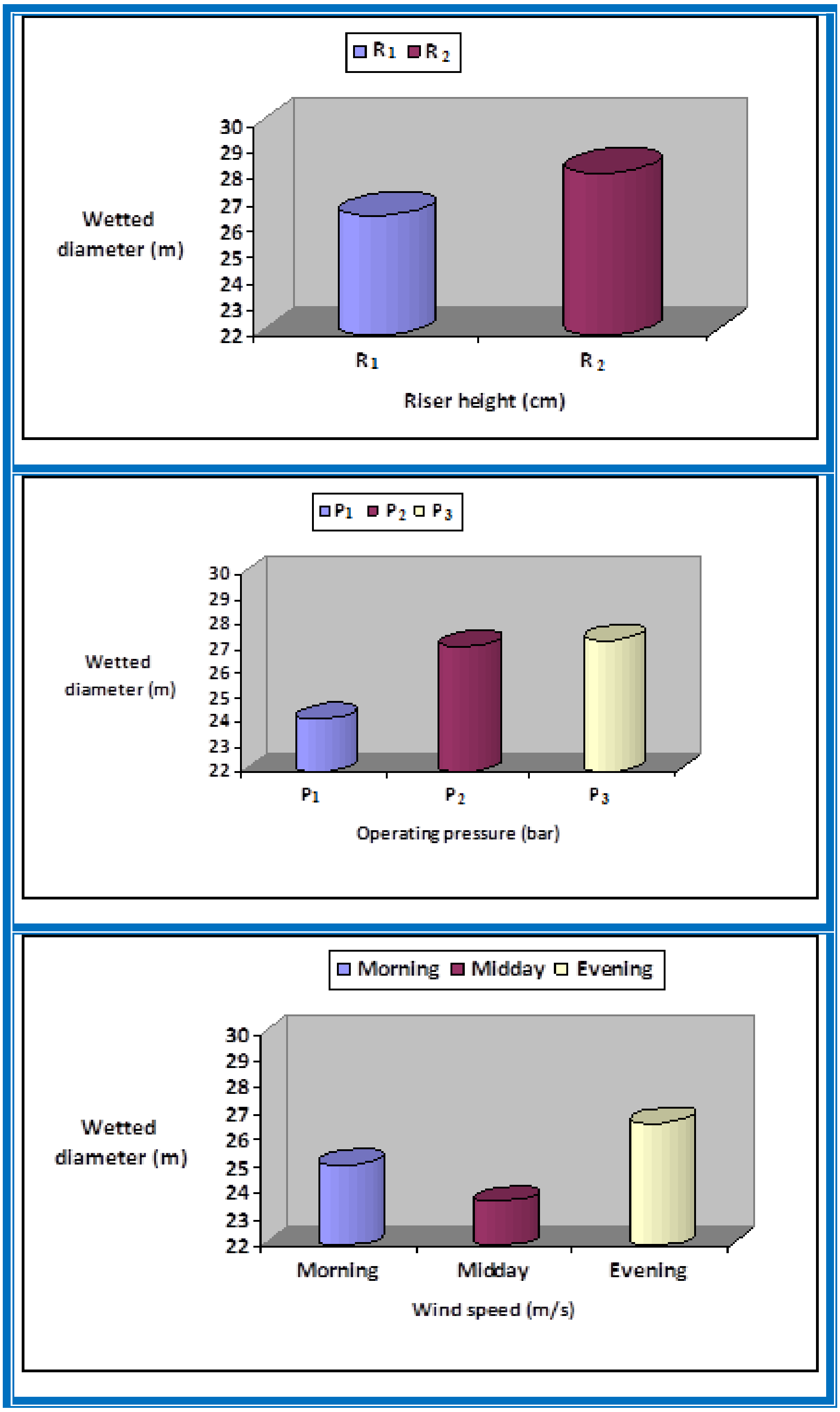

Fig. 2: The effect of riser height and operating pressure on irrigation water application under different wind conditions

From the above results, irrigation at evening gives the highest wetted diameter area in both P_2 & P_3. Though the P_2 has less pressure than P_3, but P_2 irrigation at evening gives high wetted irrigated diameter than P_3 at morning and midday especially by riser height 1.5 m.

The least value of wetted diameter was represented in treatment (P_1×Midday×R_1) and the maximum one was in treatment (P_3×evening×R_2) this were 21.5 and 28.6 m respectively. It found that, the wetted diameter increased as operating pressure increased and within high wind speed. The riser height 1.5 m has better wetted diameters values by P_1, P_2 and P_3 in comparison with the riser height 1 m but he has negative effect on the total yield. The results obtained could be due to the variations in wind speed and direction, whereas effect of other environmental factors on the wetted diameter was minor.

Effect of riser height and operating pressure on barely yield under different wind conditions

Regarding riser height and operating pressure will affect coefficient uniformity and distribution uniformity which will consequently effect on the green yield of barely which increased with increasing the above mentioned factors. This result occurred because some soil points received larger amount of water, whereas water distribution at other points was very scarce. By lowest pressure was found to cause a reduction in throw radius. These reductions may result in wetted diameter overlap changing and this will reduce the water distribution uniformity. The reduction in the water distribution uniformity indicated that the sprinkler irrigation system was not too good in delivery of water irrigation average, so the barley crop would not receive the same amount of water. The lowest operating pressure was dispersion, intensified and water drops hit the ground with the greater effect that will decrease the water distribution uniformity. When the operating pressure was increased from 2.5 to 3.5 bars, the CU and DU were increased respectively; these results reveal that the relation was not linear and full agreement with [22,23] and this trend was also shown by [24,25], recommended that the sprinkler irrigation system should operate between 2 and 3.5 bar. Therefore, to obtain the highest CU and DU, the sprinkler irrigation system must operate at pressure of P3 (3.5 bar). The highest yield will obtained from R2 * P3 * Evening time irrigation which was 1875 Kg/ Fed where the lowest R1 * P1 * Mid-day irrigation time which was 1425 Kg with significantly differences.

Conclusion

Based on the results obtained in this study, the following conclusions can be drawn:

This study highly recommends sprinkler irrigation with 3 bar pressure (P_2) and riser height at 1 m at evening. This will give the highest irrigation wetted diameter. Adjustment the optimum riser height to give better irrigation wetted diameter in different soil type (sandy, lame, and clay) by using sprinkler irrigation system is for further research.

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