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Impact of Overhead Floppy Sprinkler and Water Stress on Uniformity and Wheat Yield

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ABSTRACT

The effect of different overhead heights, pressures and water stress to determine high uniformity and water relations of wheat as well as yield and yield components under overhead floppy sprinkler was addressed in this study. The experiments and measurements were designed and implemented at the experimental farm of ElSalhia, ElSharkia Governorate, Egypt during the winter season of 2018-2019 to study. The uniformity coefficient (UC) and uniformity distribution (UD) were calculated under five levels of pressure (100, 150, 200, 250 and 300 kPa), four overhead heights (1, 2, 3 and 4 m) and water stress (20, 40, 60, 80 and 100% of evapotranspiration (ET_c)). The results indicated that the highest values of UC and UD 72.14 and 58.13%, respectively were succeeded with pressure of 200 kPa and 3 m height for overhead floppy. Also, the results showed that water stress from 20 to 100% ET_c with optimum operating conditions were carried out to get up high wheat production. The total yield and yield components were increased with decreased water stress. Also, the total yield was increased with increasing ET_c from 20 to 100%. The grain and straw yield values were increased by 68.98, 66.55, 55.66 and 35.35% & 69.70, 64.29, 50.00 and 44.44% compared with 20% for overhead floppy. The maximum yield production and components were achieved with 100% ET_c, while water use efficiency (WUE) with 20% ET_c was maximum value. Finally, under the current experimental conditions, it could be concluded that the application of irrigation water 100% ETc under pressure of 200 kPa and 3 m overhead height with high UC and UD for overhead floppy sprinkler was the best system for obtaining high wheat yield production. On the other hand, using the application of irrigation water 80% ET_c could be suggested to get high yield production and save water which will lead to deal with future water scarcity.

Keywords: Overhead floppy, Uniformity and Wheat.

INTRODUCTION

Water resources are one of the most important problems which affect agriculture worldwide. In Egypt, limited water resources with high population a great rivalry for water supply that makes saving and efficient use of water necessary. Agriculture consumes the maximum amount of the available water in Egypt, with its share more than 85% of the total demand for water. Moreover, several research showed that the Nile River is very sensitive to temperature mainly because of its low run off, Egypt is affected by climate change impacts (Topcu *et al.,* 2006 and MWRI, 2014). The actual water use by yield differs greatly due to the difference of seasons and locations, dependent on the evaporative conditions and the crop characteristics (Nabila *et al.,* 2014). So, the knowledge of the optimum amounts of water necessary for obtaining maximum yield and high quality is essential. It has been stated that soil moisture limits the growth of the plants before it reaches the wilting point (*WP*).

The using of modern irrigation techniques is becoming a necessity to save water for cultivating new areas and solve part of drainage problems of the already cultivated land (El-Gindy, 1988). Sprinkler system is a new modern irrigation technique in Egypt mainly in the newly reclaimed areas because its maximum control of uniformity distribution and suitability to best of soil and yield types. The primary necessity for the efficient operation of sprinkler irrigation system is uniform of application. Found that a greatly uniform of application does not ensure great efficiency then water can be uniformly under or over-applied. On the other hand, found that a great efficient system along with good grain yields needs uniform of applications (Pitts, 2001).

Field assessment of irrigation system performance is necessary to improve irrigation management. Griffiths and Lecler (2001) assessed of seven floppy sprinklers in terms of field distribution. They found that the uniformities coefficients of floppy sprinkler were ranged from 66 to 84%. Meanwhile, the uniformities distribution of floppy sprinkler was ranged from 59 to 78%. Schwankl *et al.* (2003) mentioned that the uniformity were excellent, good and poor values of 75-85%, 65-75% and 50-65%, respectively. Aboamera and Sourell (2003) found that the good distribution of water for floppy sprinkler at an acceptable irrigation intensity. They mention that, the averaged uniformity coefficient (*UC*) and uniformity distribution (*UD*) was 88.01% and 80.94%, respectively for the 8 m of sprinkler and lateral distance at 1.5 m height and 200 kPa pressure. Ascough and Kiker (2002) found that the uniformity distribution values of irrigation systems center pivot, dragline, microirrigation, floppy and semi-permanent sprinkler were 81.4, 60.9, 72.7, 67.4 and 56.9%, respectively in the sugar industry in five sugar-growing regions in Africa.

Wheat is considered one of the most main cereal crops in all over the world. In Egypt, it is used as a stable

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food crop for urban and rural societies. The wheat area above the last 10 years has been expanded from (0.18 - 0.25 million/ha) and the mean yield has been increased from (6.4 to 8.8 million tons/ha) through that period. But, consumption of total wheat has increased drastically because overall population growth of about 2.5% per year. So, Egypt imports about 60% of wheat requirements this reflects the size of the problem and the efforts necessary to increase wheat yield gap, as extremely limited. It has become essential to improve irrigation water productivity and decrease irrigation demand while keeping up the crop yield (Mansour *et al.*, 2015). Gad El-Rab *et al.* (1988) found that the maximum values of grain wheat and straw yields were found when six or five irrigations were applied water through different growth season. They also found that the best water use efficiency values of 1.72 and 1.59 kg/m^3 were obtained under 4 and 5 irrigations. El-Monoufi and Harb (1994) found that irrigation of wheat plants for six times increased number of spike/m^2 by 6.9, 9.3 and 11.5% as compared with five, four and three irrigation treatments.

Water stress affects nearly in the plant. The total of wheat yield reduction as a result of water stress is affected by the stage of crop development, where early grain development stage is more vulnerable to water stress than latter grain development stage (El-Kholy *et al.*, 2005). Water use efficiency is defined as the relation between grain yield and total evapotranspiration (ET_c) during the growing season.

The objective of the current study was to study the effects of different overhead heights, pressures and water stress on the application uniformity, growth, yield components, wheat productivity and water relations of wheat under overhead floppy sprinkler.

MATERIALS AND METHODS

Field experiments were carried out at the experimental farm of ElSalhia 30° 36′ *N*, 31° 47′ *E*, ElSharkia Governorate, Egypt during the winter season of 2018-2019 in sand soil. The experimental overhead floppy sprinkler system was consisted of a pumping, head control unit, pipe lines and sprinkler device. Pipe lines were conceited of main with diameter *PVC* 75 mm, submain 63 mm of *PVC*, overhead lateral line with *PE* 50 mm. Overhead floppy system was connected as a fixed system. The Overhead floppy design was applied for some different crops. Floppy sprinkler was consisted of a plastic pipe with a flexible silicon tube mounted inside sprinkler body. While water passes through the tube, it snakes during gently rotating 360º forming droplets.

Plastic catch cans 150 mm diameter, 100 mm height were sited under floppy sprinkler in the full circle of sprinkler to collect the water. The distance between catch cans was 1.0 m for radius of throw sprinkler at along and across laterals. The test duration was 20 minutes. The collected water was measured and related to its area in mm/h. The floppy sprinkler was tested at five levels of pressure (100, 150, 200, 250 and 300 kPa), overhead heights (1, 2, 3 and 4 m) to determine great uniformity.

In the winter season of 2018-2019, wheat grains (Misr-1 variety) was sown on 22th November 2018 in rows 0.15 m apart and harvested on 13th April 2019. Harvesting of wheat plants was 142 days after planting. The produced floppy sprinkler was used under pressure of 200 kPa, overhead height of 3.0 m and water stress was applied at 20, 40, 60, 80 and 100% of evapotranspiration (*ETc*) which was calculated using cropwat software 8 v.s. based on equation of Penman-Monteith (Allen *et al.*, 2011). All the agriculture practices were applied as normally used for growing wheat and fertilizer carried out according to the recommendations of Egyptian Agriculture Ministry.

The soil texture was sand. Some physical properties of the studied soil were measured of the experimental site before cultivation and were given in table 1. The tested depth layers have a homogeneous sandy soil in filed.

Table 1. Some physical properties of the studied soil of the experimental.

D (cm)	Particle size distribution %			Tex. Class	BD (g/cm^3)	FC (%)	WP (%)	AW (%)
	S	Si	Cl					
0-15	91.10	5.52	3.38	S	1.62	8.9	2.3	6.6
15-30	91.85	4.31	3.84	S	1.60	8.7	2.2	6.5
30-45	91.77	4.54	3.69	S	1.59	8.6	1.8	6.8

D: Soil depth, S: Sand, Si: Silt, Cl: Clay, Tex: Texture and S: Sand.

Discharge of floppy sprinkler was measured by collecting of water in a container with period 4 min. Rate application (*Ra, mmh⁻¹*) of floppy sprinkler was calculated by equation:

$$Ra = k\,\frac{Q}{A} \qquad (1)$$

Where: *Q* is discharge of floppy sprinkler (*ℓ min^{-1}*), *A* is wetted area of floppy sprinkler (*m^2*) and *k*: unit constant (*Q* in *ℓ min^{-1}*, *A* in *m^2* and *k* = 60 for *Ra* in *mm h^{-1}*).

Distribution uniformity plays a main part in water uniformity, wheat production and water use efficiency. The sprinkler system unit was calculated under different pressure (100, 150, 200, 250 and 300 kPa) and overhead floppy (1, 2, 3 and 4 m) to define the distribution uniformity was tested by (Bilalis *et al.*, 2009):

$$UD = 100\,\frac{\overline{D}_{lq}}{\overline{D}} \qquad (2)$$

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

The quantity of water collected in each catch can was noted and measured by equation uniformity coefficient according to Christiansen (1942) as follows:

$$UC = 100\left(1 - \frac{\sum\left|D_i - \overline{D}\right|}{n\,\overline{D}}\right) \qquad (3)$$

Where: *UC is* uniformity coefficient (%) $\sum\left|D_i - \overline{D}\right|$ is the summation of absolute values of deviation from the average can depth, D_i is can measurement (*mm*), $\overline{D}$ is average of can measurements (*mm*) and *n* is the number of cans collector.

The amount of water consumed in each irrigation interval of yield through the plant season was measured based on the Penman-Monteith equation which calculated according to Allen *et al.* (2011):

$$IWR = ET_c\ A\,F \qquad (4)$$

Where: ET_c is actual wheat evapotranspiration (mm/day) *IWR* is irrigation water consumed (*ℓ/Irri.*), *A* is the wheat area (m^2) and *F* is the irrigation interval (day).

The applied water stress percentages were as follows 20, 40, 60, 80 and 100% ET_c. The time of water application (T_w, h) for each ET_c% was measured by equation:

$$T_w = \frac{IWR}{q} \qquad (5)$$

Where: ***q* is the sprinkler discharge ($\ell\ h^{-1}$).**

Water use efficiency could be affected by water stress, it would be necessary to define how these changes would impact plant season and water use of the plant. Also, the irrigation water use efficiency (*WUE*, kg/m^3) was expressed as the relation seeds yield (*kg/fed*) and water applied (m^3/fed) through the growing season, this was calculated from the following equation:

$$WUE = \frac{Grains\ wheat\ (kg/fed)}{Water\ applied\ (m^3/fed)} \qquad (6)$$

RESULTS AND DISCUSSION

Influence pressure and overhead on discharge and rate of application

Influence of different pressure and overhead height on discharge and rate of application (*Ra*) for overhead floppy sprinkler were presented in table 2. The results showed that the discharge from floppy sprinkler was increased with the increased pressure. So, increasing pressure from 100 to 300 kPa, the discharge for floppy sprinkler increased by 39.54%. Meanwhile, rate of application (*Ra*) increased by 17.81% once the pressure increased through research study from 100 to 300 kPa at 1 m overhead height for overhead floppy. Meanwhile, the *Ra* was increased by the same trend for overhead floppy of 2, 3 and 4 m then different values. On the other hand, the *Ra* increased by 36.11% when decreasing overhead from 4 to 1 m of pressure 100 kPa for overhead floppy sprinkler.

Found the results, the great *Ra* may be reached by mixture of high pressure with low height for overhead floppy sprinkler. Therefore, the *Ra* increase by increasing pressure because off increased of discharge. *Ra* decreased by increasing overhead floppy height because off increased of wetted diameter. Also, the discharge from floppy sprinkler was greatly affected by pressure.

Table 2. Discharge and rate of application under different pressure and overhead floppy height.

P	*Q*	Overhead floppy (m)							
		1		2		3		4	
		A	*Ra*	*A*	*Ra*	*A*	*Ra*	*A*	*Ra*
100	522.4	113.0	4.62	120.7	4.33	145.2	3.60	153.9	3.40
150	633.8	128.6	4.93	141.0	4.50	158.3	4.00	171.9	3.69
200	708.0	132.7	5.34	156.1	4.54	174.3	4.06	186.2	3.80
250	728.0	134.7	5.40	158.3	4.60	176.6	4.12	191.0	3.81
300	729.0	133.9	5.44	158.3	4.61	177.1	4.12	191.0	3.82

P: Pressure (kPa), Q: Flow rate (ℓh^{-1}), A: Wetted area (m^2) and Ra: Application rate (mmh^{-1}).

Influence of pressure and overhead floppy on water uniformity

Influence of different overhead heights and pressures on water uniformity of overhead floppy sprinkler in order to determine high uniformity. The uniformity coefficient (*UC*) and uniformity distribution (*UD*) were calculated under five levels of pressure (100, 150, 200, 250 and 300 kPa) and four overhead heights (1, 2, 3 and 4 m). The relation between uniformity and pressure at different overhead floppy was shown in figures 1 and 2. From the figures, the *UC and UD* were increased with increasing of pressure through research study from 100 to 200 kPa at overhead floppy height 3 m, *UC and UD* value increased by 19.28% and 40.09%, respectively. Meanwhile, when the increased pressure from 200 to 300 kPa reduced values by 10.60% and 18.92%, respectively of *UC and UD* for overhead floppy sprinkler. The obtained results of the *UC and UD* were increased with increased pressure at 200 kPa. When the pressure was over 200 kPa, the *UC and UD* decreased according to Aboamera and Sourell (2003).

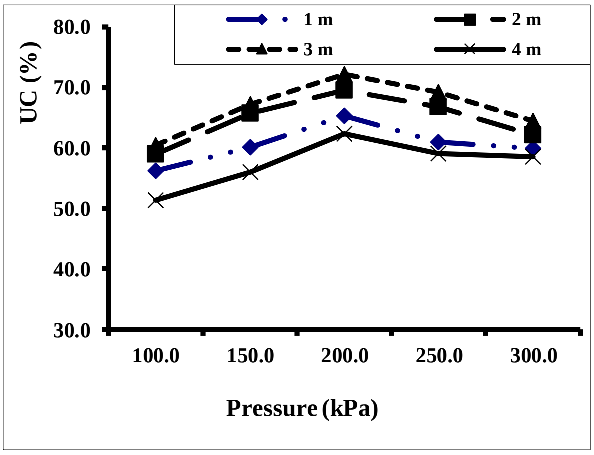

Figure 1. Effect of pressure and *UC* for overhead floppy sprinkler.

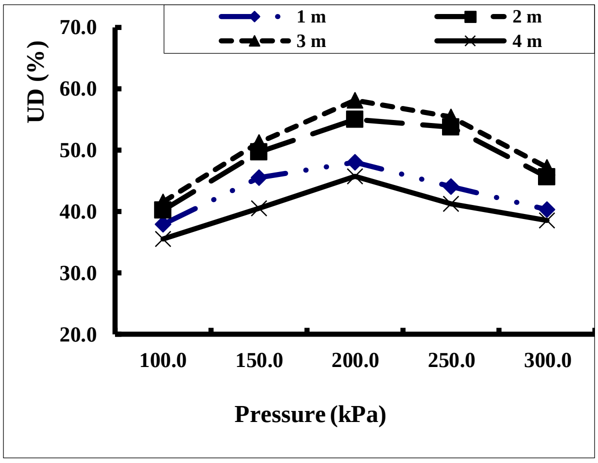

Figure 2. Effect of pressure and *UD* for overhead floppy sprinkler.

From the figures, the *UC and UD* decreased at high and low pressure because off non-uniformity distribution. Therefore, at minimum pressure, the water jet didn't break up simply and big water drop was formed. Similarly, at maximum pressure, the jet broke up also much and lesser water droplets were made. This was simply to be blown and threw gone from the floppy.

Finally, the obtained results of *UC* and *UD* were paralleled movement. The maximum values of *UC* and *UD* were succeeded at pressure of 200 kPa and 3 m overhead floppy height. This finding would help and improve using agriculture mechanization and spraying and automatic crop harvesting. However, the better uniformity might be reached under stated pressure and overhead floppy with wind speed ranged from 1.02 to 2.37 ms^{-1}.

Wheat yield and yield components

The effects of water stress from 20 to 100% *ETc* and optimum operating conditions with pressure of 200 kPa and 3 m height for overhead floppy sprinkler on growth characteristics were addressed. The following characteristics were measured: plant height, spike number per square meter, spike length, 1000 grain mass, grain number per spike and spike grain mass of wheat. Wheat yield and straw yield (ton/fed) at 142 days of sowing during the growth season was presented in table 3 and figures 3 and 4. The results showed that the yield production and yield components were increased with decreased water stress. The total wheat and straw yield were increased with increasing *ETc* from 20 to 100%.

Table 3. Yield, wheat characteristics and water use efficiency under treatments (ET_c) for overhead floppy sprinkler.

T (ET_c)	W (m^3/fed)	Yield and wheat characteristics						Grain yield (ton/fed)	*WUE* (kg/m^3)
		Plant height (cm)	Spike length (cm)	Spike n/m^2	Grain n/pike	1000 grain mass (g)	Spike grain mass (g)		
100	1850	96.46	9.95	356	46	37.83	1.74	2.60	1.41
80	1480	92.62	9.43	350	44	37.27	1.64	2.41	1.63
60	1110	90.51	9.25	346	42	29.76	1.25	1.82	1.64
40	740	83.75	8.54	330	34	26.47	0.90	1.25	1.69
20	370	80.04	8.07	320	32	18.75	0.60	0.81	2.18

T: Treatment, ET_c: Evapotranspiration, W: Applied water, WUE: Water use efficiency.

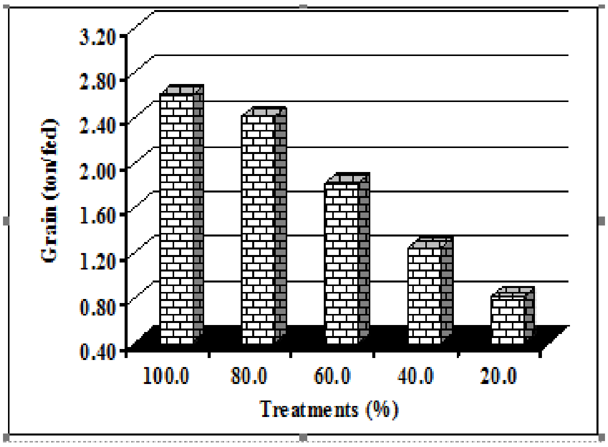

Figure 3. Relationship between water treatment and grain wheat yield.

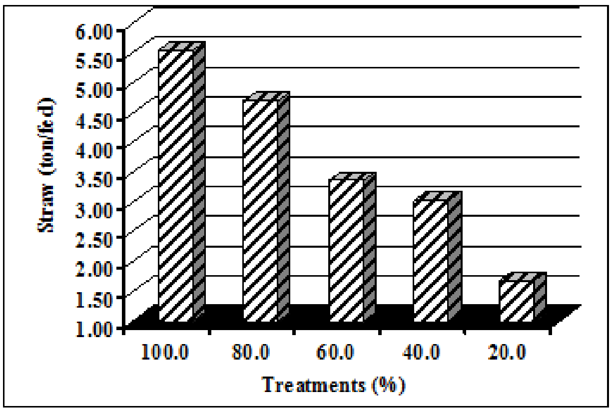

Figure 4. Relationship between water treatment and straw wheat yield.

The maximum wheat yield characteristics plant height, spike length, spike n/m^2, grain number per spike, 1000 grain mass and spike grain mass of wheat were 96.46 cm, 9.95 cm, 356 n/m^2, 46 n, 37.83 g and 1.74 g, respectively at 100% ET_c under overhead floppy. On the other hand, when the ET_c decreased from 100 to 20% the wheat characteristics were decreased of 80.04 cm, 8.07 cm, 320 n/m^2, 32 n, 18.75 g and 0.60 g, respectively at pressure of 200 kPa and height of 3 m. Therefore, this increased might be because off the increased uniformity and soil moisture level.

The water stress of 20% were the lowest value comparing to all treatments, while the water stress of 100% were the maximum values. These results indicated that the grain and straw yield production values were increased by 68.98, 66.55, 55.66 and 35.35% & 69.70, 64.29, 50.00 and 44.44% compared with 20% for overhead floppy. These resultes were due to its maximum water uniformity at pressure of 200 kPa and 3 m height for overhead floppy. Also, the grain and straw yield of floppy were decreased only 7.27 and 15.15% (from 2.60 to 2.41 and from 5.54 to 4.70 ton/fed.), respectively by reducing 20% (80% ET_c) of applied water for overhead floppy. Meanwhile, reduced 80% of water (20% ET_c) were decreased the grain and straw yield of 0.81 and 1.68 ton/fed by 68.98 and 69.70% as shown in figures 3 and 4. Therefore, 20% ET_c could not be suggested for wheat production in sandy soil due to the water deficiency which lead to low soil moisture content, plant stress and minimum grain yield according to Solomon (1998).

The effect of water tress on water use efficiency

The influence of water stress on water use efficiency was presented in table 3 and figure 5. The water use efficiency (*WUE*) was increased by decreasing water stress from 100 to 20% for floppy sprinkler. Also, *WUE* of the values ranged between 40% to 80% were approximately the same and better than 100% ET_c. On the other hand, the obtained results indicated that the highest value *WUE* of 2.18 kg m^{-3} was achieved at 20% ET_c for overhead floppy sprinkler in sandy soil. The presented data suggested that the use of 80% ET_c was saved 20% of water and increased wheat productivity for floppy sprinkler. The utmost goal of this study and similar future studies is dealing with future water scarcity in newly reclaimed lands towards good agriculture production and food security.

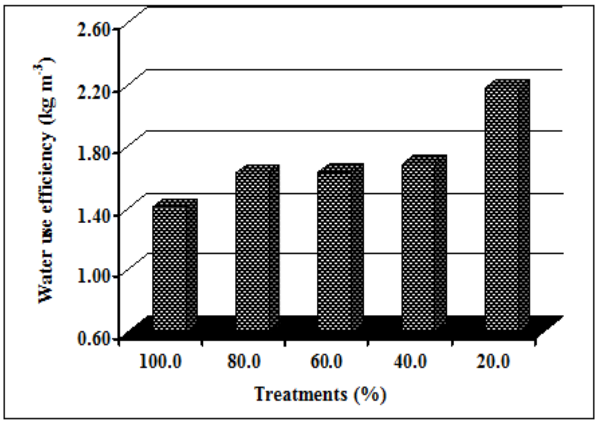

Figure 5. Relationship between water treatment and *WUE*.

CONCLUSION

This study is one of the most important studies and considered as strategic for the country. The results showed that overhead floppy sprinkler is recommended and achieved high yield production of wheat. The results could be summarized as follows:

1- Maximum of uniformity *UC* and *UD* were recorded at pressure of 200 kPa and 3 m height for overhead floppy sprinkler.

2- Characteristics of plant wheat, grain yield and straw yield were increased by increasing of ET_c % and values *UC* and *UD*.
3- The maximum yield and yield components were obtained by 100%, meanwhile the maximum values of *WUE* by 20%.
4- The present research suggested the using of 80% ET_c was saved water which will lead to deal with future water scarcity.

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تأثير الرشاش المرن المعلق والإجهاد المائي على إنتظامية المياه وإنتاج القمح

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يهدف هذا البحث لدراسه تأثير إرتفاع الرشاش، ضغط التشغيل والإجهاد المائي لتحديد أعلى كفاءة إنتظامية توزيع المياه للرشاش وأفضل إنتاج محصول القمح لنظام الرى بالرشاش المرن المعلق تحت ظروف الأراضى الحديثة. تم حساب معامل إنتظامية توزيع المياه *CU* وكفاءة إنتظامية توزيع المياه *DU* تحت تأثير ضغوط تشغيل (100، 150، 200، 250، 300، 350 ك باسكال)، إرتفاع للرشاش (1.0, 2.0, 3.0, 4.0 متر) وإجهاد مائي (100، 80، 60، 40، 20% من الإحتياجات المائيه). أظهرت النتائج أن أعلى قيم لمعامل إنتظامية التوزيع *CU* وكفاءة إنتظامية التوزيع *DU* كانت 72.14 ٪ و 58.13 ٪ على التوالي عند ضغط تشغيل 200 ك باسكال و إرتفاع 3.0 متر لنظام الرى بالرشاش المرن المعلق. زادت مكونات وإنتاجية محصول القمح مع تقليل الإجهاد المائي للمحصول. وزاد المحصول الكلى لحبوب القمح بنسبة 56.97، 53.74، 37.50 و 32.26% ومحصول قش القمح بنسبة 66.67، 60.54، 45.85 و 44.0% مقارنة بنسبه 20% من الإحتياجات المائيه للرشاش المرن المعلق. وبتالي كانت أعلى إنتاجية لمحصول القمح عند 100% من الإحتياجات المائيه وبينما كانت أعلى كفاءه إستخدام مياه عند 20% من الإحتياجات المائيه ولذلك يوصى بتشغيل الرشاش المرن المعلق عند ضغط تشغيل 200 ك باسكال وإرتفاع 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. وأعلى إنتاجية لمحصول القمح عند 100% وأعلى كفاءه إستخدام مياه عند 20% من الإحتياجات المائيه. بينما المعاملة 80% من الإحتياجات المائيه كانت أفضل معاملة فى إنتاج القمح وتعمل على توفير فى إستهلاك المياه بنسبة 20% من كمية المياه المضافة وذات كفاءة إستخدام مياه عالية