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EFFECT OF SPRINKLER RISER CHARACTERISTICS ON APPLICATION UNIFORMITY

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ABSTRACT

The sprinkler riser characteristics; height, angle and rigid fixation are of great importance for the sprinkler application uniformity. Single sprinkler pattern tests were carried out to generate data required for field uniformities with different riser characteristics. Data from the single sprinkler tests were then overlapped to simulate system uniformities. Results were compared for different riser heights, riser angles, PVC and steel risers. Trials were carried out using two types of sprinkler heads.

The statistical analysis indicated that riser characteristics affect significantly the application uniformity at 5 % significance level. However, the effect of some treatments was positive and for some others was negative. The negative effects of non-optimum riser characteristics can be minimized by closer spacing pattern.

Keywords: Riser characteristics, Application uniformity**.**

INTRODUCTION

High water application uniformity is a prerequisite for high irrigation efficiency. Proper design of solid-set and set-move sprinkler irrigation systems assumes vertical, rigid risers. It also requires knowledge of the water distribution pattern from a single sprinkler under no-wind conditions. The distribution pattern depends on several factors; riser height and angle with respect to the vertical and flexibility. Hills and Gu 1989 studied the flight path of a 4mm droplet for three different riser tilts. They proved the importance of trajectory angle to the ultimate precipitation pattern, as influenced by riser orientation, for either windy and no wind conditions.

Upon designing a system, the optimal riser height is rarely used. This may be due the current concept of riser design is based on the riser clearing crop height. The riser being as short as possible to reduce water distribution due to high wind speeds. The higher the riser, the more probable the pattern distortion due to increasing wind velocity and increased droplet travel time (Heermann and Kohl, 1983). Short risers achieve best results. On the other hand, where taller crops are grown in a relatively high wind profile the riser height can be an important consideration, as it relates to the wetted diameter and consequently to the sprinkler spacing.

The riser angle to the vertical is likely to affect the application uniformity in a similar way to that observed for nozzle trajectory angle. The relationship between sprinkler distribution uniformity and riser angle was studied by Blanddon and Johnson (1988) for land slopes from 5 – 30 degrees. They found that distribution uniformity peaked with the riser set at an angle halfway between normal to the slope and vertical. Soares *et al.* (1991) carried out experiments to quantify the effects of slope on application distribution. A ballistic trajectory model was developed to simulate precipitation data for a sprinkler working on different ground slopes and at different sprinkler angles. They concluded that a sprinkler riser perpendicular to a sloping soil surface gave the highest distribution uniformity.

Therefore, this research aimed to generate and evaluate field data on the effects of riser height, riser angle to the vertical and riser rigidity on uniformity of water distribution on leveled ground surface for a medium size sprinkler operating at 300 kPa nozzle pressure under low wind conditions.

MATERIALS AND METHODS

Field experiments were carried out where a square area of 26 m with the sprinkler riser installed at the center was used. A grid of catch cans was placed at 2 m apart. The cans were 100 mm in diameter, 70 mm deep. The cans were fixed firmly in the soil and positioned so all tops were level above ground surface. The tests were conducted according to ASAE Standard S330.1 (ASABE, 2006). A booster pump connected to water source was used to maintain stabilized pressure at the sprinkler. A ball valve associated with a pressure gauge was used to keep the pressure wright at the bottom of the sprinkler at 300 kPa. Tests were carried out when winds were less than 2m/s and wind direction was fairly consistent. Therefore, most test runs were at night.

Two sprinkler types were used; Richdel 530 PR gear with 3 mm plastic nozzle and a 22^{o} trajectory angle, and Rainbird 20 JH impact sprinkler with 3.2 mm standard bore brass nozzle and a 23^{o} trajectory angle. The nozzles flow rates were 0.57 and 0.67 m^3/h at 300 kPa respectively. According to the manufacturers' specification at the recommended operating pressure; the sprinkler wetted diameters based on a 0.76 m riser height are 26.2 and 24.7 m for the Richdel and Rainbird sprinkler types respectively.

The single sprinkler distribution patterns were replicated three times. The procedure described by Branscheid and Hart (1968) was then implemented for other hypothetical sprinklers in a field to develop theoretical field distribution patterns. The excel software was implemented to mathematically superimpose the single sprinkler data and to compute Christiansen's uniformity coefficient (Cu) and the distribution uniformity (Du); equations 1 & 2. Both coefficients are usually used (Christiansen, 1942) to describe the uniformity of water application.

$$Cu = \left[1 - \frac{Average\,abolute\,deviation\,from\,mean}{Mean\,depth\,applied}\right] x\ 100 \quad ....(1)$$

$$Du = \left[\frac{Average\,low\,quarter\,depth\,applied}{Mean\,depth\,applied}\right] x\ 100 \quad ....(2)$$

The data were analyzed using the completely randomized design and the one way analysis of variance described by Schaefer and Anderson (1989). Duncan's statistical test was used to examine differences between the means of the uniformity coefficients. Single sprinkler distribution profiles of the overlapped data were calculated El-Berry *et al.* (2009). The distributions of the cumulative irrigations were divided by the total number of relevant tests to give a mean grid distribution. Cross-sectional distribution profiles were derived from the mean sprinkler grid by averaging the application rates of the rows for the west to east profile, and for the north to south profile.

RESULTS AND DISCUSSION

Effect of riser height on application uniformity:

Data presented in Table (1) show the uniformity coefficients, Cu and Du corresponding to three sprinkler spacing; 10 x 10 m, 12 x 12 m and 14 x 14 m. The statistical analysis of these data indicated that the mean application uniformities at the different heights were the same at the 5 % significance level at 10 m square spacing. For the 12 and 14 m square spacing the mean application uniformities were not. Duncan's test indicated that application uniformity was higher for the 2 m riser than the 1 m at 12 m square spacing. Similarly, the application uniformity was higher for the 3 m riser as compared to the 1 m riser. The statistical analysis also showed that the difference between application uniformities for the 2 and 3 meters risers were not significant at the 5 % level. However, for the 14 m square spacing, the application uniformities were higher for the 3 m riser compared to both the 1 and 2 m risers.

Table 1. Effect of riser height on uniformity coefficients, Cu and Du for three different sprinkler spacing

Riser height (m)	Uniformity coefficients	Sprinkler spacing (m)		
		10 X 10	**12 X 12**	**14 X 14**
1	Cu %	89.3	81.3	82.0
	Du %	80.0	74.0	71.5
2	Cu %	90.2	84.2	82.5
	Du %	81.0	76.8	72.8
3	Cu %	91.1	86.3	85.2
	Du %	82.5	79.7	72.8

No significant difference at the 5 % level was observed between application uniformities for the 1 and 2 m risers at this spacing.

The cross-sectional profiles, west-east and north-south, along the sprinkler diameter for a single impact sprinkler at different heights are shown in Figures 1 and 2 respectively. These profiles indicate that the application rates close to the riser were lower for the 3 m riser than for the 1 m and 2 m. The profile for the 3 m riser has one peak and looks similar to Christiansen's C profile (Christiansen, 1942). The profile for the 1 m riser has one main crest at the center and two smaller ones towards the sprinkler radius and approximately resembles Christiansen's A profile. The same is true of the profile for the 2 m riser, but the smaller crests are relatively oblate than those for the 1 m riser.

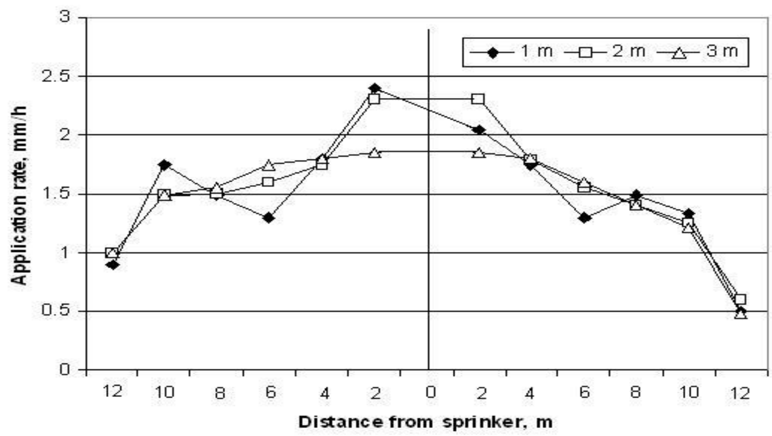

Figure 1. Distribution profiles (west-east) for a single impact sprinker placed at three different riser heights

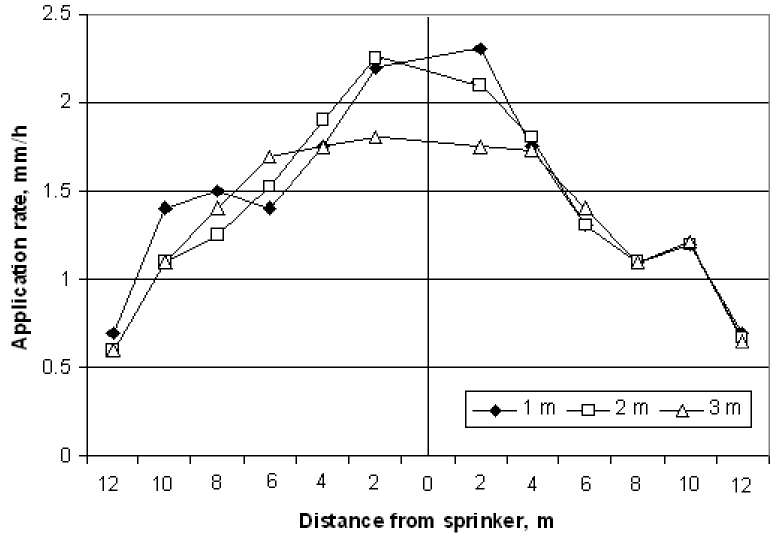

Figure 2. Distribution profiles (north- south) for a single impact sprinker placed at three different riser heights

One possible explanation for the smaller crests with higher risers is that high risers allow longer spray travel time, during which a greater volume of air acts on the spray, possibly increasing droplet breakup and consequent droplet redistribution. A lower crest at the center for the 3 m profile is probably due to longer trajectories of the droplets from the higher sprinklers and consequently larger area covered by the same volume of water. These results are similar to that obtained by Nderitu and Hills (1993).

Effect of riser angle on application uniformity:

Table (2) shows the Effect of riser angle on uniformity coefficients, Cu and Du for the impact and gear sprinklers at two spacing; 12 and 14 m. The analysis of variance indicated that the mean application uniformities at the different angles for the impact sprinkler were not the same at 5 % significance level. For the two different spacing, Duncans's test showed that the mean application uniformity was higher for the zero degree compared to the 20º inclination of riser from the vertical. The mean application uniformity was also higher for the 10º compared to the 20º riser inclination at 5 % level of significance. There was no significant difference between the mean application uniformities at 0º and at 10º. The uniformity values related to sprinkler type are also shown in Table (2). It may be noticed that the mean application uniformities were not the same at the 5 % significance level for the sprinkler spacing. At the 12 m spacing vertical risers resulted in higher application uniformity compared to those with the risers inclined either 10º or 20º. No significant difference was observed between the mean application uniformities for the risers inclined 10 and 20 degrees. The highest uniformity was achieved at 12m spacing and zero inclination. The application uniformities with the 10º and 20º were lower at the same spacing. There was no difference in application uniformity for the sprinklers whose risers were inclined at 10º or 20º. At the larger spacing, the application uniformities were higher for the vertical risers than for those inclined at 20º. No significant differences were observed between all other application uniformities at this spacing.

Table 2: Effect of riser angle on uniformity coefficients, Cu and Du for the impact and gear sprinklers at two spacing

Riser angle (degree)	Uniformity coefficients	Sprinkler type			
		Impact		Gear	
		Sprinkler spacings(m)		Sprinkler spacings (m)	
		12 X 12	14 X 14	12 X 12	14 X 14
0	Cu %	**82.9**	**83.7**	**78.0**	**74.1**
	Du %	**77.0**	**73.0**	**69.0**	**55.6**
10	Cu %	**83.5**	**83.5**	**73.5**	**72.4**
	Du %	**75.0**	**72.4**	**61.1**	**52.2**
20	Cu %	**76.5**	**74.0**	**71.2**	**69.0**
	Du %	**67.4**	**62.5**	**60.1**	**51.5**

Figures 3 and 4 show the distribution profile for a single impact sprinkler placed at riser tilts of zero, 10 and 20 degrees. The distribution profiles were recognized along the sprinkler diameter from west to east and north to south at different riser angles. It is evident that the application rate close to the riser is higher for the riser at 10 and 20 degrees compared to that at zero degree. This may be due to greater jet break-up resulting in smaller droplets which fall nearer the sprinkler. The significant differences evident in application values between the 20º and the 10º, and the 20º and the 0º riser angles appear to result from the northern side of the sprinkler where water fell on a smaller area due to the reduced radius of coverage.

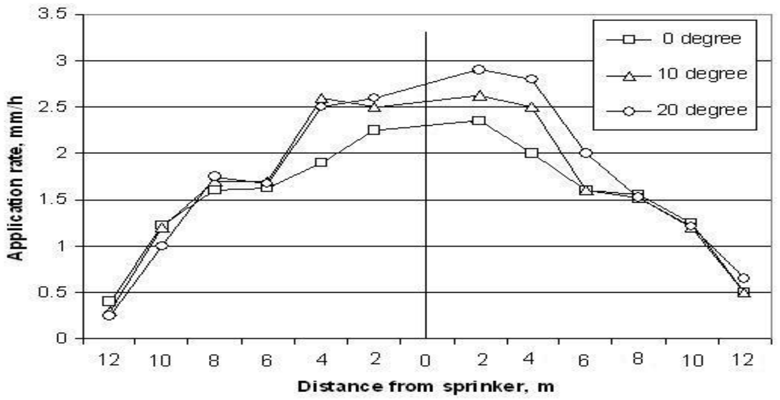

Figure 3. Distribution profiles (west-east) for a single impact sprinker placed at three different riser tilts

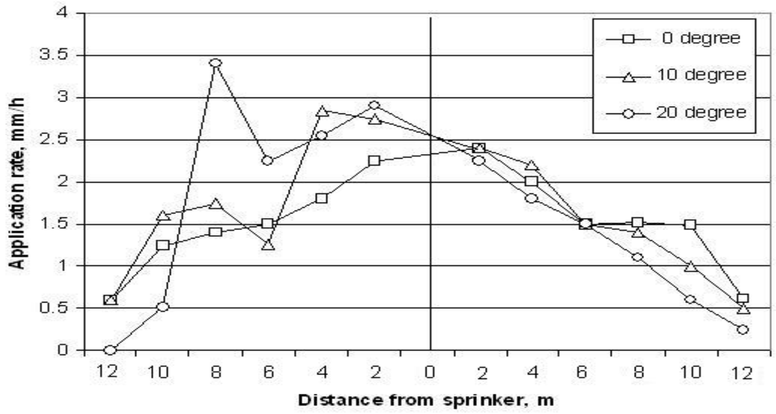

Figure 4. Distribution profiles (north-south) for a single impact sprinker placed at three different riser tilts

Figures 5 and 6 represent the distribution profile for a single gear sprinkler placed at riser tits of zero, 10 and 20 degrees. The application rates were a minimum close to the sprinkler riser and increased to a maximum before falling again.

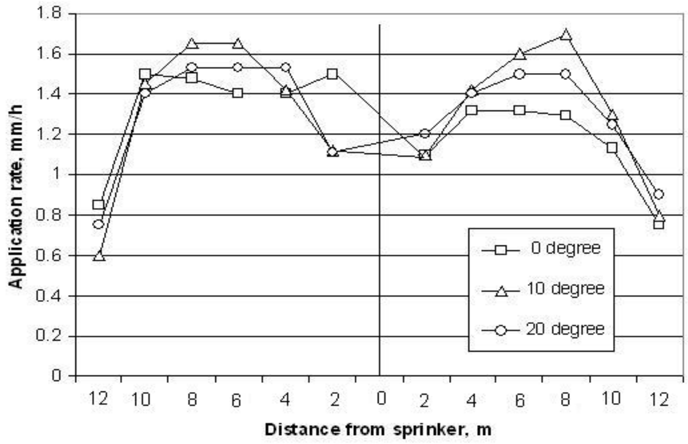

Figure 5. Distribution profiles (west-east) for a single gear sprinker placed at three different riser tilts

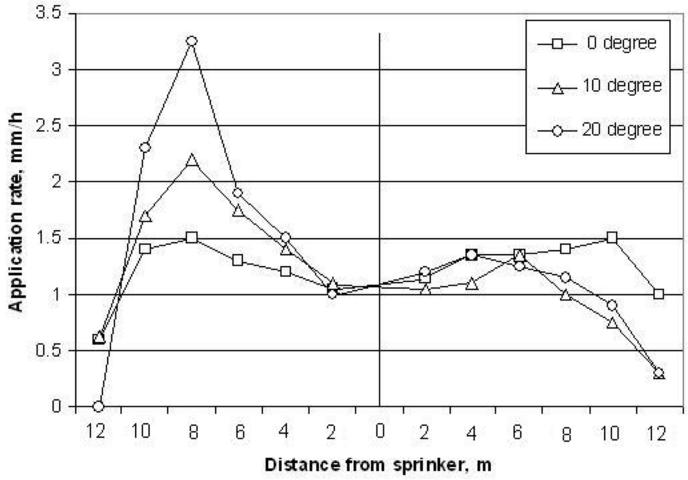

Figure 6. Distribution profiles (north-south) for a single gear sprinker placed at three different riser tilts

The profiles from west to east were alike for the three angles. Similarly, as with the impact sprinkler, the highest precipitation differences among all the profiles were observed on the northern side of the grid, suggesting that the change in the wetted area may be the major contributing factor affecting uniformity of water application from inclined risers. The gear sprinkler pattern was similar to Christiansen's E profile.

Effect of riser flexibility on application uniformity:

Table 3 represents uniformity mean data for the 3 m unsupported flexing PVC and rigidly supported 3 m steel riser.

Table 3. Effect of sprinkler flexibility on uniformity coefficients, Cu and Du at two sprinkler spacing.

Sprinkler flexibility	Uniformity coefficients	Sprinkler spacing (m)	
		12 X 12	14 X 14
Unsupported	Cu %	80.3	65.0
	Du %	70.0	45.1
Supported	Cu %	86.8	84.0
	Du %	80.0	75.2

The analysis of variance of the data shown in Table 3 indicated that the mean application uniformity values for the supported risers were higher than those for the unsupported risers at the 5 % significance level. Figures 7 and 8 represent the distribution profile for a single impact sprinkler fixed on supported and unsupported risers. The data shown in these figures proved that the application rates close to the sprinkler for the unsupported risers were more than double the rates for the supported risers. This may be attributed partly to the PVC pipe supporting risers.

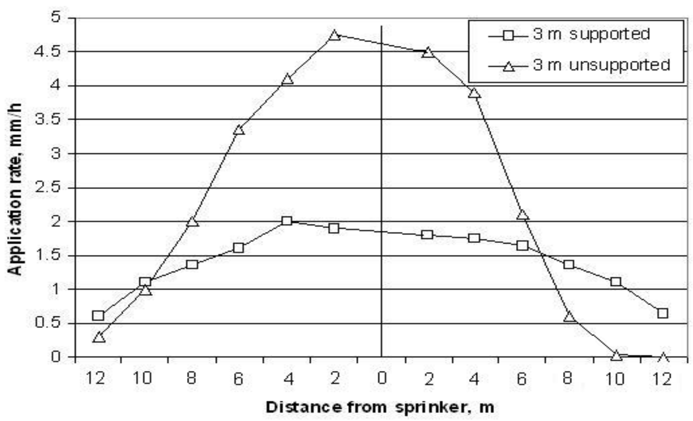

Figure 7. Distribution profiles (west-east) for a single impact sprinker mounted on 3 m riser supported and unsupported

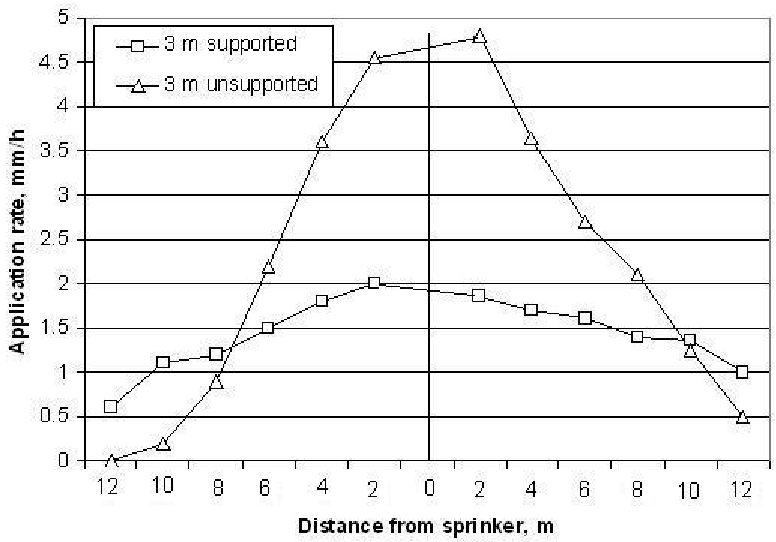

Figure 8 . Distribution profiles (north -south) for a single impact sprinker mounted on 3 m riser supported and unsupported

Which allowing sprinkler vibration, inclined from the vertical, thereby effectively increasing the trajectory angle. It may be concluded that well-supported risers made from steel pipe lead to very little vibration. Plastic pipe could be used as riser material, but it is more flexible and will undergo more vibration. To minimize riser vibration interference with sprinkler operation, plastic risers need to be rigidly supported.

Conclusions

It may be concluded that:

- The riser height affects the water distribution pattern of a sprinkler. As a result it affects the uniformity of application for overlapping sprinklers.
- There is negligible difference in the uniformities of water application for impact sprinklers mounted on 1 m risers inclined between 0 and 10 degrees to the vertical operating on level ground under low wind conditions. A 20 degree riser tilt inversely affects the uniformity.
- Impact sprinklers on rigidly supported risers have higher water application uniformities than the unsupported ones.
- The negative effects of non-optimum riser height, riser angle and riser support can be minimized by closer spacing pattern.

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تأثير خصائص حامل الرشاش علي انتظامية توزيع المياه

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تعتبر خصائص حامل الرشاش (ارتفاع الحامل – زاوية ميل الحامل من الاتجاه الرأسي – درجة ثبات الحامل أثناء دوران الرشاش) من أهم العوامل التي تؤثر علي انتظامية توزيع المياه. تم اجراء مجموعة من التجارب الحقلية علي نوعين من الرشاشات بغرض تحديد أشكال أنماط التوزيع وانتاج البيانات المطلوبة لحساب انتظامية توزيع المياه الحقلية تحت ظروف مختلفة من خصائص حامل الرشاش. من خلال النتائج المتحصل عليها من الرشاش تم محاكاة عملية التداخل لعدد ٤ رشاشات مثبتة علي رؤوس مربعات (١٠ × ١٠)، (١٢ × ١٢) ، (١٤×١٤) متر. تمت مقارنة انتظامية توزيع الرشاشات لارتفاعات مختلفة من حامل الرشاش (١ ، ٢ ، ٣ متر) ، وزاوية ميل الحامل من الاتجاه الرأسي (صفر ، ١٠ ، ٢٠ درجة) ، درجة ثيات الحامل أثناء دوران الرشاش (استخدام مواسير PVC ، حامل صلب).

أوضحت التحليلات الاحصائية أن خصائص حامل الرشاش تؤثر معنويا علي انتظامية توزيع المياه عند مستوي معنوية ٥ %. وفي حين كانت أنماط معدل التساقط متشابهة للرشاش من النوع التصادمي والمثبت علي حامل رشاش علي زاوية صفر ، ١٠ درجات من الاتجاه الرأسي ، أثرت معاملة الزاوية ٢٠ درجة سلبيا علي انتظامية التوزيع. كما أثبتت النتائج المتحصل عليها أن أعلي انتظامة توزيع تحصل عليها كانت مع حوامل الرشاش من النوع الصلب بالمقارنة بالحوامل PVC . كما بينت الدراسة أنه يمكن تقليل التأثيرات السلبية لخصائص حامل الرشاش عن طريق استخدام مسافات أقل لأنماط توزيع الرشاشات.