

# DESIGN AND EVALUATION OF MICRO-SPRINKLER IRRIGATION SYSTEM USING ONION FOR SUSTAINABLE DRYLAND AGRICULTURE

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## ABSTRACT

*Most irrigated farming clusters in the dry land areas of Nigeria, design micro sprinklers for small scale irrigation farming are lacking. The design of a micro sprinkler irrigation using onion crop is needed for small-holder farmers that grows vegetables using a surface flooding system of irrigation. This practice is unsustainable in the dry lands where resources are scarce. The evaluation parameters used were the operating pressure, discharge efficiency and uniformity of distribution. The result of the average discharge at an operating pressure of 2 kg/cm<sup>2</sup> had an average discharge of 9.32 l/min while at the maximum selected operating pressure of 4 kg/cm<sup>2</sup> the average discharge was 10.38 l/min; hence, the discharge of the sprinkler increases with an increase in operating pressure. micro-sprinkler discharge efficiencies obtained at 2 kg/cm<sup>2</sup>, 3 kg/cm<sup>2</sup> and 4 kg/cm<sup>2</sup> were 61%, 54% and 60.7% respectively, with an average discharge efficiency of 58.6%. The highest distribution uniformity was 79% and was obtained at an operating pressure of 4 kg/cm<sup>2</sup> with 0.95 m riser height while the lowest was 60% which was obtained at an operating pressure of 3 kg/cm<sup>2</sup> with riser height of 1 m. The evaluation revealed that the design meets up the requirement for the standard design of sprinkler irrigation systems and recommends for smallholder farmers in the dry lands.*

**Keywords:** Irrigation, Design, Drylands, Evaluation, Micro Sprinkler

## 1 INTRODUCTION

**T**rickle irrigation comprises drip and micro-sprinkler irrigation systems. Micro-irrigation also called localized, low-volume, low-flow irrigation, is an irrigation method with lower water pressure and flow than a traditional sprinkler system. Micro sprinklers/sprayers are available in a wide variety and many configurations [1]. Like drip emitters, micro-sprinklers and sprayers are designed for areas where drip irrigation is not practical, for keeping plant foliage constantly moist, or when overhead watering is required. They spray water in not more than one meter. It is used for preparing nurseries and lawns in soils with low water holding capacity, and also used in growing vegetables, especially in dry land areas. The micro-sprinkler irrigation design for onion crops in dry land areas requires the understanding of various work under sprinkler irrigation systems, most importantly the wind drift, evaporative loss, and soil infiltration rate. Many scholars have worked on a different aspects of sprinkler designs, in the study conducted by [1] in estimating the quantity of water loss during sprinkler irrigation concludes that three climate variables may be used to correctly quantify evaporation loss: air temperature, relative humidity, and wind speed. [2] also express the causes of sprinkler irrigation losses to be; drift/transport losses (caused mainly by wind) and

evaporation losses (direct evaporation of tiny water particles while dropping from the nozzle to the ground) and further identified experimental and theoretical analysis as the most commonly used approaches in estimating sprinkler irrigation water loss. The wind and evaporation were also reaffirmed by [3] to be the main causes of distortion to water application pattern, which is a major factor that affects the Sprinkler irrigation system's efficiency. The wind and evaporation losses are uncontrollable factors that have a major impact on irrigation, so they must be taken into consideration in any sprinkler irrigation design. These losses and their respective percentage values are presented in Table 1. Table.1 indicated that losses due to evaporation in the air are less than 2% and losses due to Wind drift is less than 3%, thus, it is important to evaluate the losses of Micro-sprinkler irrigation system due to Wind drift and Evaporation in the air by calculating the distribution uniformity and coefficient uniformity of the sprinkler arrangements. The break-up of the water jet is needed to achieve uniform coverage and reduce droplet size. Jets have a normal tendency to break up due to air resistance. Breakup is generally increased by friction and the presence of slots in the nozzle. Slow rotation sprinklers have decent coverage, turning at 0.67 to 1 revolution per minute (rpm) for small sprinklers and 0.25 to 0.5 rpm for large sprinklers. Sprinkler discharge efficiency indicates the relationship between the water collected using catch-cans and that discharged by the sprinkler. [5] adopted the methodology of [6] in the performance evaluation of sprinkler systems operating at a pressure between 200-350 kPa and used catch cans of 16 cm diameter and 15cm height, and the test duration was 2 hours. The discharge efficiency ( $E_d$ ) obtained in the research was relatively large, ranging from 75.2 to 95.8%, with the wind drift and evaporation losses varying between 4.2 and 23.8% with an average of 12% of the water discharge by the sprinkler [7]. Irrigation uniformity is characterized as the variation in irrigation depths over an irrigated area and is a significant performance feature of the sprinkler irrigation system [7] Widespread study on the factors influencing the uniformity of the sprinkler irrigation application uniformity has been carried out. Such variables include the size and pressure of the nozzle, the type of diffuser, the spacing of the sprinkler, the height of the riser, the field topography, the discharge angle, the amount and configuration of the sprinkler, and the wind speed and direction [8] Water uniformity coefficients obtained through a range of measuring devices (i.e., rain gauge) are frequently used to measure the operation of a sprinkler irrigation system [5]. Distribution uniformity is most often used in surface irrigation systems to describe the irrigation water distribution network over the field, but it can also be extended to micro and sprinkler irrigation systems. The low quarter uniformity of distribution (DU) is known as the average depth infiltrated through the low one-quarter of the field divided by the average depth infiltrated throughout the field [9]. The coefficient of variation (CV) in the volume of application can be estimated as the standard deviation of all catch cans and measurements divided by the volume of the average catch for a study. Both distribution uniformity and coefficient of uniformity have been analytically linked to the coefficient of variation (CV) [10] As reported by [11]; Closer to zero coefficient variation values indicate less variability between data values, and closer to one coefficient of variation values indicate more variance in the data. [12] evaluated the use of Statistical quality control tools (statistical quality control refers to the use of statistical methods in monitoring and maintaining the quality of products and services. Monitoring and controlling the process ensure that it operates at its full potential [13] to analyze the uniformity of micro-sprinkler having a wet diameter of 6.0m, and a discharge of 41l/h when working under a pressure of 2.04kg/cm<sup>2</sup> using the method proposed by [14] and that developed by [6] found the mean Christiansen uniformity coefficient (CUC) and the mean distribution uniformity (DU) for seven (7) treatments, with the treatment of sprinkler and lateral spacing of 1m×1m having the highest mean Christiansen uniformity coefficient of 95.97% and mean Distribution uniformity of 94.54%, and the treatment of 2m×2m having the lowest Christiansen uniformity coefficient of 85.92% and distribution uniformity of 79.51%. [15] carried out performance evaluation on micro-sprinkler irrigation systems on two types of arrangements; point arrangement (using a single sprinkler with 34 water containers grid arrangements) and linear arrangements (using more than one sprinkler with water container between the sprinklers arranged in grid form) used the Christiansen's uniformity coefficient and found the maximum uniformity coefficient of 88.7% for point arrangement and it varies from 86.10 to 91.76% for a linear arrangement of the micro-sprinklers and concludes that the water application pattern of sprinkler irrigation is susceptible to wind distortion, though, the effect of the wind velocity during the research on the uniformity coefficient was not significant (it varies between 1.5 to 6 km/hr). The focus

of this study was the design and evaluation of the one-hectare micro-sprinkler irrigation system using onion crops. Designing a small-scale micro-sprinkler irrigation system would be beneficial to the smallholder farmers for various reasons among which are affordability of the facilities, farmers can use boreholes and small solar-powered pumps in the villages and practice dry season farming, this design can be upscaled to significantly enhance productivity at village level to improve livelihood.

Table 1. Water losses in Sprinkler irrigation system

Water losses components	Range (%)
Leakages in pipes	0-10
Evaporation in air	0-10
Wind drift	0-20
Interception	0-10
Surface runoff	0-10
Application depth and rates	5-80

Source [4]

## 2 METHODOLOGY

### 2.1 Study Area

The study area is situated at the Centre for Dryland Agriculture (CDA) Training and Research farm, Bayero University, Kano. As shown in figure 3.1, It lies on latitude and longitude ranging from 11°58.984'N to 11°58.955'N and 8°24.995'E to 8°25.003'E an altitude of 467 m respectively. The source of the irrigation water is a mixture of seven Tube wells. The water is pumped from the tube well to a reservoir of 2.8 million litres capacity for irrigation. The study area weather is fairly hot and dry; the monthly peak temperature varies from 29°C to 39°C. The temperature is generally very hot throughout the year, though from December through February, the city is relatively cool. The average night temperature in the cold months ranges from 11°C to 14°C.



Figure 1. An image of the study location

### 2.2 Design of 1-Hectare Sprinkler Irrigation System

Crop: Onion, Area: 100 x 100 m = 10,000 m<sup>2</sup> = 1-hectare

#### Peak Water Requirement (PWR)

According to [6].

$$\text{Peak water requirement (PWR)} = \frac{A \times B \times C}{E} \quad (1)$$

Where, A is Peak evapotranspiration rate, mm/day; B is the crop factor; C is the canopy factor and E is the efficiency of the sprinkler irrigation system, which is 90% by the manufacturer.

### Design and Selection of Sprinkler

It is proposed to use over-head Sprinkler model AR 044 with specifications:

Radius (R) = 11.0 m, Discharge, Q = 0.510 m<sup>3</sup>/hr, Operating pressure = 2.5 bar = 2.5 kg/cm<sup>2</sup> and nozzle size: 2.3 x 1.8 mm.

Sprinkler spacing = 50 % of Sprinkler diameter [17] as the evaluated wind speed of the field was an averagely of 10.08 km/h, therefore, sprinkler spacing = 0.5 x 22m = 11 m (Square pattern spacing).

$$\text{Precipitation/Application Rate} = \frac{\text{Sprinkler discharge (lph)}}{\text{Sprinkler spacing (m)} \times \text{Lateral spacing (m)}} \quad (2)$$

### Locate the end/corner Sprinkler

$$\text{End/corner distance of Sprinkler} = \frac{\text{Radius}}{\sqrt{2}} \quad (3)$$

$$\text{No of Sprinklers along one side (100m) of the field} = \frac{\text{Length} - 2 \times \text{End distance of Sprinkler}}{\text{Sprinkler spacing}} + 1 \quad (4)$$

### Design of Sprinkler Lateral

According to [16], the Specific Discharge Rate (SDR) of lateral =  $\frac{\text{Sprinkler discharge (lph)}}{\text{Sprinkler spacing (m)}}$  The computed SDR value could be used to obtain the frictional head loss and the maximum length of lateral to use on the field on a polygraph. Otherwise, the head loss was estimated using the Hazen William's frictional head loss equation for the selected lateral diameter of 50 mm with I.D. = 42.6 mm and Length, L = 100 m, using the formula.

$$hf = \frac{[L(Q/Cr)^{1.81}]}{994.62D^{4.81}} \quad (5)$$

where, Q is discharge (m<sup>3</sup>/sec); Cr = pipe smoothness coefficient (Cr = 1 for smooth pipe and <1 for rough pipe); L = Length of pipeline in m; D = Internal diameter of the pipe (m); Q = no. of sprinklers on 1-lateral x discharge of 1-sprinkler, = 9 x 510 lph = 1.275X10<sup>-3</sup>m<sup>3</sup>/sec, L = 100 m and Diameter 50 mm with internal diameter, I.D = 42.6mm = 0.0426 m, C=1.

The design Tolerance = 10% of Operating pressure, the Operating pressure of the sprinkler system = 2.5bar = 2.5kg/cm<sup>2</sup> = 25m. hence, the design Tolerance is taken as 10% X 25m = 2.5m. This means that the frictional losses of the lateral should be less than or equal to 2.5 m. Design check: Frictional head losses in the Lateral is 0.159 m, which is less than 2.5 m, hence, the design is safe.

### Design of Sub-main line

A sub-main PVC of diameter 75mm is selected with its internal diameter, D = 70.6mm = 0.0706m, and Length, L = 50m and Q = 5.67x10<sup>-3</sup>m<sup>3</sup>/sec. The head loss is calculated as.

$$f = \frac{[L(Q/Cr)^{1.81}]}{994.62D^{4.81}} \quad (6)$$

### Design of the Mainline

$$\text{The discharge in mainline} = \frac{\text{Nos. of sprinklers operated at a time} \times \text{discharge of one sprinkler}}{3600}$$

It is proposed to use Main line of 90 mm with inner diameter = 84.6 mm = 0.0846 m, Q = 5.67X10<sup>-3</sup>m<sup>3</sup>/sec, L = 100 m.

$$\text{The frictional head loss, } f = \frac{[L(Q/Cr)^{1.81}]}{994.62D^{4.81}} \quad (7)$$

The Pump required is calculated as used by [16].

$$H_p = \frac{Q \times H}{75 \times a \times b} \tag{8}$$

### 2.3 Performance Evaluation of the Micro Sprinkler Irrigation System

#### Determination of effective radius of throw and area of coverage

$$R_o = 4\mu^2 H \left[ \sin \right]^2 \gamma (\cot. \gamma - 0.216 H^{(0.94)/d}) \tag{9}$$

$$A = \pi R^2 \tag{10}$$

Where, A = area of coverage by the sprinkler, m<sup>2</sup> and R = effective radius of throw, d = diameter of sprinkler nozzle, mm and h = pressure head at the nozzle, m, μ = flow rate coefficient (0.88-0.90), γ = nozzle elevation angle (degree).

#### Sprinkler discharge

The discharge of twenty (20) randomly selected sprinklers was calculated, with each measurement taken three times and the average recorded at operating pressure of 2 kg/cm<sup>2</sup>, 3 kg/cm<sup>2</sup>, and 4 kg/cm<sup>2</sup>. For each measurement, a bucket of 20 liters was used to collect the water for 60 seconds.

$$Q = (\text{Volume (litre)}) / (\text{Time (min)}) \tag{11}$$

#### Determination of micro-sprinkler discharge efficiency

The discharge efficiency of the micro-sprinkler at 2, 3, and 4 kg/cm<sup>2</sup> operating pressures was determined using the average discharge of the micro-sprinkler at the different operating pressure, and the quantity of water collected in the catch-can during the irrigation. The discharge efficiency was estimated using the formula suggested by [16].

$$E_d = 100 \times \frac{\frac{1}{n} (\sum X_i)}{q_s \cdot t / (n \times S_x \times S_y)} \tag{12}$$

Where E<sub>d</sub> = sprinkler discharge efficiency (%); ∑X<sub>i</sub> = summation of the depth of water collected in the catch cans (mm); Q<sub>s</sub><sup>-1</sup> = sprinkler nozzle discharge (m<sup>3</sup>/h); t = duration for nozzle discharge measurement (h); S<sub>x</sub>×S<sub>y</sub> = catch cans grid spacing; n = number of catch cans.

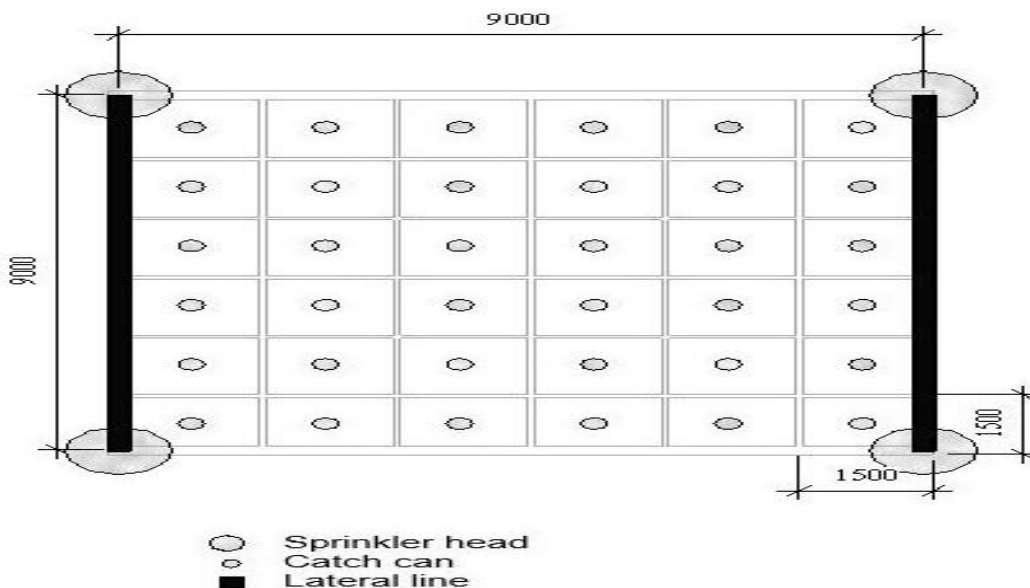


Figure 2. Catch cans spread in the field

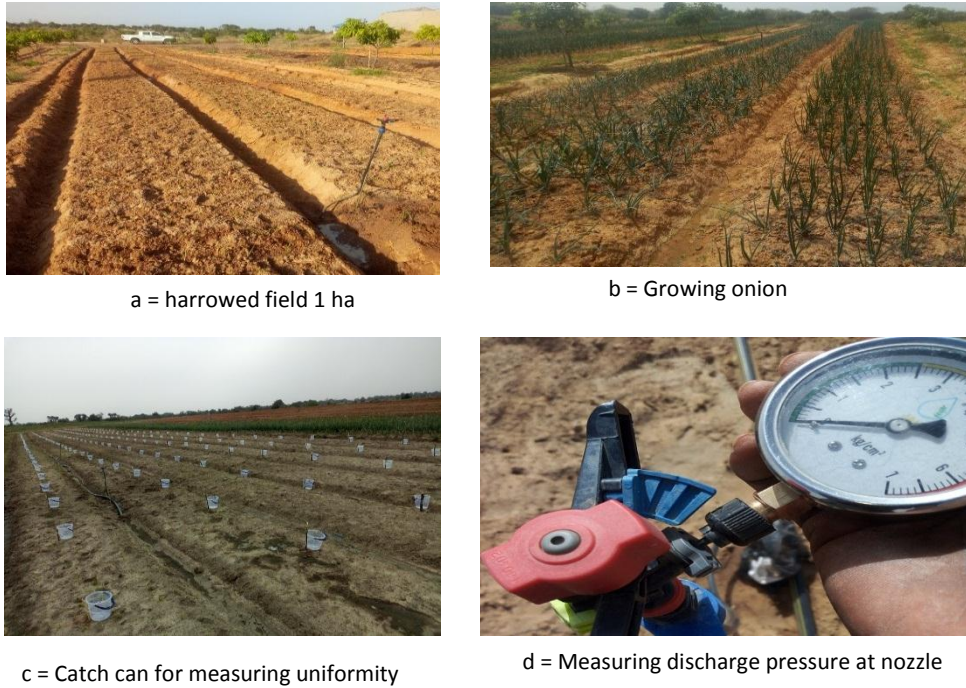


Figure 3. Field experiments and data collection

### 3 RESULTS AND DISCUSSION

The results obtained from the design and performance evaluation of the micro sprinkler were presented and discussed under this section. The design of the field and its layout as presented in Figure 4.

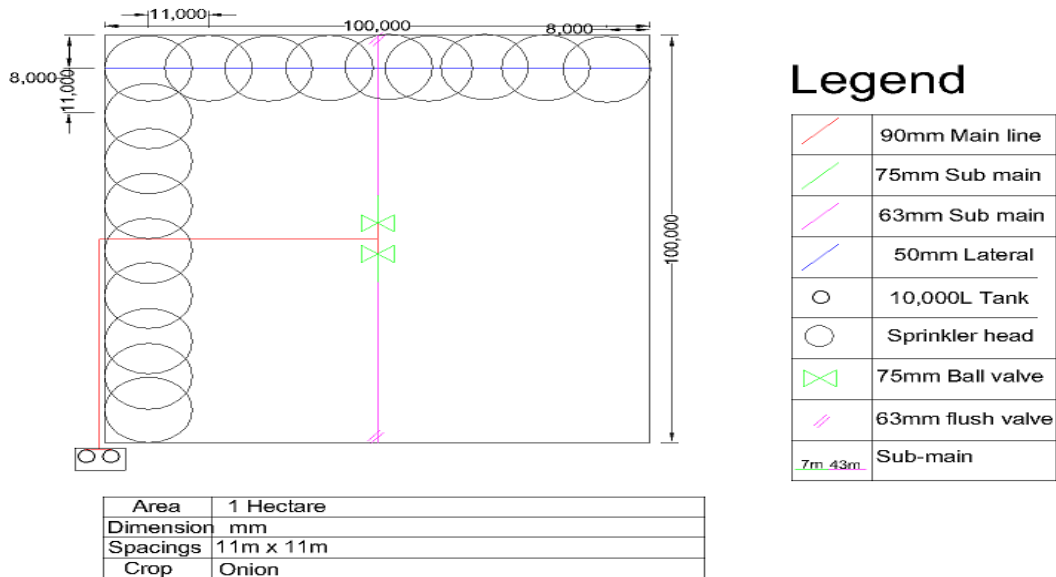


Figure 4. Field dimension and layout

Table 2. Selection and design of Pump

S/no	Total head required	Value	Unit	Remark
1	Suction + delivery	6	m	Assumed
2	Frictional head loss in filter unit	0		not required
3	Frictional head loss in the Main line	1.25	m	designed
4	Frictional head loss in Sub main	1.49	m	designed
5	Operating pressure	25	m	As per manufacturer
6	Riser height	1	m	As per design
7	Frictional head loss in fittings	2	m	Estimated
8	Frictional head loss in Lateral	2.27	m	Per design
9	Fertigation	0		not required
10	Elevation	0		As per the contour map
Total		39.01		

The total head is 39.01m approximately 39 m. The Pump required is calculated as used by [16].

$$Hp = \frac{Q \times H}{75 \times a \times b} = \frac{5.667 \times 39m}{75 \times 0.85 \times 0.8} = \frac{221.013}{51} = 4.33hp, \text{ say } 5 \text{ Horse power}$$

The power required = Hp x 0.75 = 5 x 0.75 = 3.75 kW.

### 3.1 Estimation of tank capacity

Considering the peak water requirement of 8.1mm/day, the tank is designed as. Area of field = 1 hectare = 10,000 m<sup>2</sup>. Quantity of water to irrigate the field = 10,000 m<sup>2</sup> x 8.1 x 10<sup>-3</sup> m = 81 m<sup>3</sup>.

### 3.2 Hydraulic Performance of Micro-Sprinkler System

The hydraulic evaluation was performed based on the method defined by [16] The method involves analyzing the radius and area of coverage of the sprinkler, evaluating the pressure and discharge relationship of the sprinkler system, and analyzing the Christiansen's uniformity coefficient, the distribution uniformity, the mean application rate, the sprinkler discharge efficiency, the variability of discharge and pressure along laterals.

### 3.3 Radius and Area of coverage

Figure 5 shows a graphical representation of the interactions between the operating pressure, the measured radius of coverage, and the area of coverage, while Figure 6. resents the interactions between operating pressure, the calculated radius of throw, and the area of coverage In Figure 5 (using measured values) as the operating pressure increases from 2 to 4 kg/cm<sup>2</sup>, this caused a corresponding increase in both the radius of coverage and area of coverage somewhat uniformly. While, in Figure 6 (using formula) as the operating pressure increases from 2 to 4 kg/cm<sup>2</sup>, the calculated radius of throw and area of coverage increase with the lines coinciding at 3.9 kg/cm<sup>2</sup> operating pressure [17][18]. Thus, the measured values and calculated were not in good agreement as to the average difference between the measured radius of throw and calculated is 24%. This is contrary to the observation made by [19] where the difference between the measured radius of throw and calculated radius of throw was in good agreement with the difference of 8.5 %. and in accordance to [19]. There are two observations for the difference between measured and calculated values. Firstly, because the model was derived based on the hypothesis that the part of water jet trajectory close to the horizontal plane could be approximated by a straight line; second, the model assumes that the sprinkler operating pressure remains constant and rotation speed is uniform, but there was a very small pressure fluctuation due to water supply by a centrifugal pump'.

$$R_o = 4\mu^2 H \sin^2 \gamma (\cot. \gamma - 0.216 \frac{H^{0.94}}{d}) \quad (11)$$

### 3.4 Discharge efficiency

Table 3 presents the computed micro-sprinkler discharge efficiencies obtained at 2kg/cm<sup>2</sup>, 3kg/cm<sup>2</sup> and 4kg/cm<sup>2</sup> as 61%, 54% and 60.7% respectively, averaging 58.6%. Thus, 41.4% of the water discharged was lost through evaporation and drift losses during the irrigation process and data collections. The standard ranges for evaporation and drift losses are stated as 0-10% and 0-20% respectively [20] The obtained losses (41.4%), exceeds the standard ranges (30%) and the calculated losses (12.7%), these differences can be attributed to the leakages observed at some of the laterals.

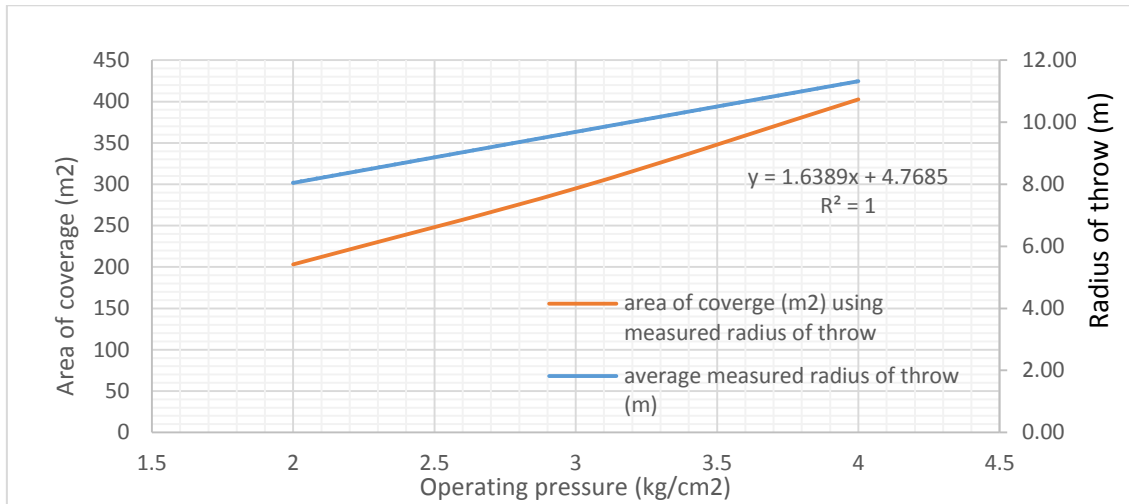


Figure 5. Measured radius of throw and area of coverage at varied operating pressure

Table 3. Micro-sprinkler discharge efficiencies

Date, Time	Average temp (°C)	Average relative humidity (%)	Average wind speed (m/sec)	Evaporation & wind drift losses (%)
28/2/2020, 3:53pm-4:53pm	38.2	21.2	2.2	11.57
18/3/2020, 4:00pm-5:00pm	38.3	21.2	2.8	15.08
04/4/2020, 4:00pm-5:00pm	36.7	22.8	1.8	11.55

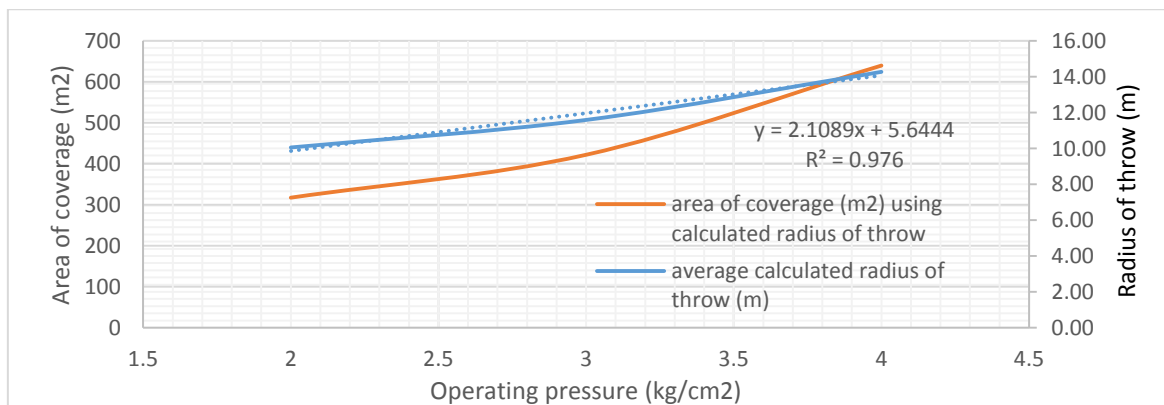


Figure 6. Calculated radius of throw and area of coverage at varied operating pressure

### 3.5 Evaporation and wind drift losses

Table 4 presents the average results of the evaporation and wind drift losses using an empirical equation developed based on the regression relationship and the geometry of the Frost and



Schwalen nomograph. As can be observed from the Table 4, evaporation and wind drift losses increase with the increase in average temperature and wind speed. The average calculated wind drift and evaporation losses were 12.7%, and according to [21] the threshold value for evaporation and drift losses in sprinkler irrigation was  $\leq 20\%$ , favorably, the obtained results of this study were below the threshold value for the period.

Table 4. Evaporation and wind drift losses at different operating pressure

operating pressure (kg/cm <sup>2</sup> )	2	3	4
sum of water collected (mm)	379.8	341.27	418.05
discharge (m <sup>3</sup> /h)	0.56	0.57	0.62
Discharge efficiency	61%	54%	60.70%

### 3.6 Discharge-pressure relationship

The result of the average discharge of some randomly selected micro-sprinkler is presented in Figure 7 It could be seen that at an operating pressure of 2kg/cm<sup>2</sup>, the average discharge is 9.32l/min and at the maximum selected operating pressure of 4kg/cm<sup>2</sup> the average discharge is 10.38l/min, hence, the discharge of the sprinkler increases with an increase in operating pressure. In consideration of the soil type of the research area (Sandy clay loam), it is advisable to operate the micro-sprinkler at an operating pressure of 2kg/cm<sup>2</sup> to maximize the efficiency of the system and as well prevent erosion. The observed increase in discharge with an increase in operating pressure is similar to the research done by [22] A linear relationship was developed between the discharge and the operating pressure, and the R square value was obtained as 0.8917, this indicates that there exists a strong relationship between the operating pressure and the discharge of the sprinklers.

### 3.7 Index of jet break-up (Pd)

The averaged discharge of some selected micro-sprinklers was used to calculate the index of jet break-up at 2 kg/cm<sup>2</sup>, 3 kg/cm<sup>2</sup> and 4 kg/cm<sup>2</sup>. The result is presented in Table 5 the Index of jet break-up increases from 4.21 at 2kg/cm<sup>2</sup> to 8.07 at 4kg/cm<sup>2</sup>. The research done by 23 using mini sprinkler irrigation systems at operating pressures from 1 kg/cm<sup>2</sup> to 2 kg/cm<sup>2</sup> noticed an increase in the index of the jet break-up to be 4.65 at 2 kg/cm<sup>2</sup> operating pressure; which is above the result obtained in this research of 4.21 at 2 kg/cm<sup>2</sup>, this could be attributed to the size of the nozzle of the mini sprinkler being used. As stated by researchers the index of the jet break-up of sprinklers is poor when it is less than 2, good when it is 4, and a waste of pressure when it is greater than 4 [23] Hence, the micro-sprinkler should be operated at 2 kg/cm<sup>2</sup> as this gives an index of the jet break-up of slightly above 4.

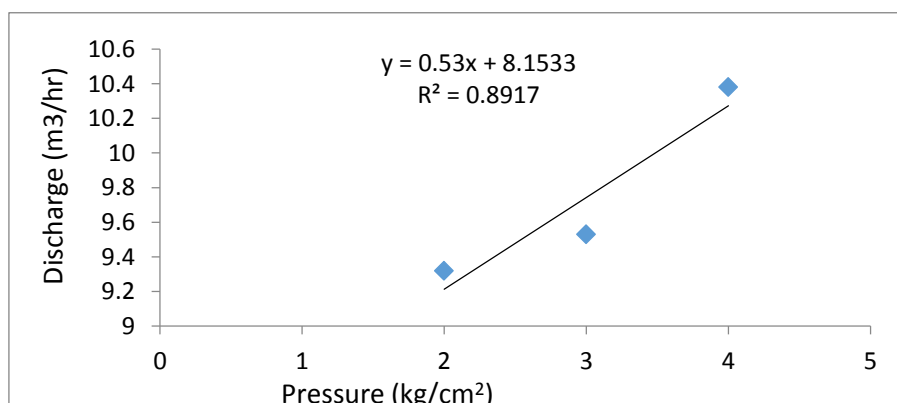


Figure 7. Average discharge rate at various operating pressure

Table 5. Operating Pressure and Index of Jet Break-up

Operating pressure (kg/cm <sup>2</sup> )	2	3	4
Index of jet break-up	4.21	6.26	8.07

### 3.8 Christiansen's uniformity coefficient

Figure 8 presents the result obtained of Christiansen's uniformity coefficient at different operating pressures and riser heights 1m, 0.95m, and 0.85m and uniform sprinkler to sprinkler and lateral to lateral spacings of 9×9 m. The Christiansen's uniformity for the operating pressures and riser heights are within the acceptable range of greater than 75% [16] The highest uniformity coefficient was obtained at a riser height of 0.85 m and at 4 kg/cm<sup>2</sup> operating pressure which is 84%. There was a significant effect of riser height and operating pressure on the uniformity coefficient of the micro-sprinkler system. As shown in Figure 8 the uniformity coefficient increases with a decrease in the riser height that is from 1m to 0.85m, and a corresponding increase in operating pressure from 2 kg/cm<sup>2</sup> to 4 kg/cm<sup>2</sup>. Hence, it is recommended that the micro-sprinkler could be operated at any of the operating pressures and 0.85 m riser height.

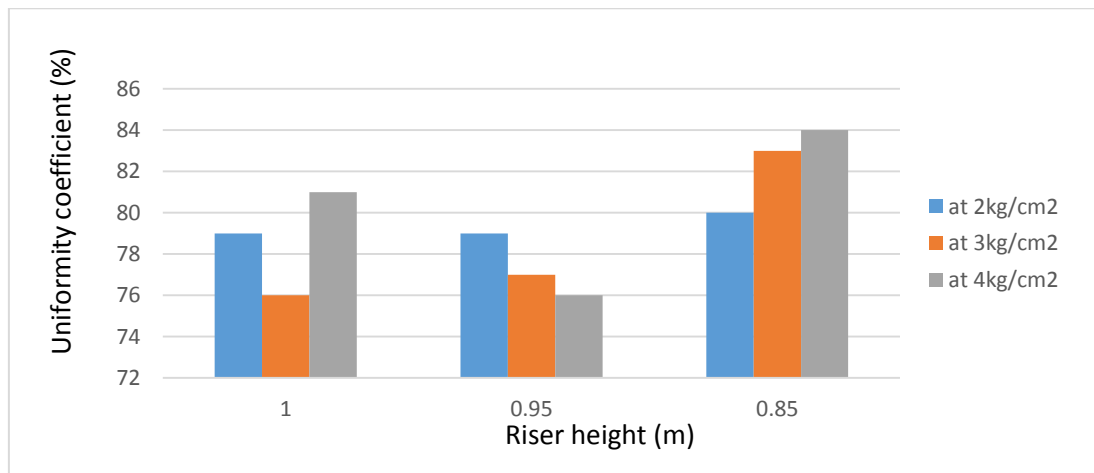


Figure 8. Uniformity coefficient  $C_u$  (%) at various riser heights and operating pressure

### 3.9 Distribution uniformity

Figure 9 shows the results of distribution uniformity of the micro-sprinkler irrigation system at three different operating pressure and riser heights, and at uniform sprinkler to sprinkler spacing of 9 by 9 m. The highest distribution uniformity was 79% and it was obtained at an operating pressure of 4kg/cm<sup>2</sup> and 0.95 m riser height while the lowest was 60% which was obtained at an operating pressure of 3kg/cm<sup>2</sup> and riser height of 1m. The results obtained were all within the recommended Distribution uniformity of the Sprinkler irrigation system of greater than 65% [16] as the minimum acceptable performance level for economic system design, except at riser heights 1 m and 3 kg/cm<sup>2</sup> operating pressure. Hence, there is a strong correlation between the riser height and operating pressure of the micro-sprinkler irrigation system; as in the case of the operating pressure of 2 kg/cm<sup>2</sup>; the Distribution uniformity increases with a decrease in riser height, but changes invariably at operating pressure of 3 kg/cm<sup>2</sup> and 4 kg/cm<sup>2</sup>.

### 3.10 Coefficient of variation

The computations of the coefficient of variation were performed in Appendix D-1, and the result is presented in Table 6. The percentage coefficient of variation tends to increase with an increase in operating pressure at a riser height of 0.85 m but decreases invariably at a riser height of 1 m and 0.95 m with an increase in operating pressure. The highest percentage coefficient of variation was observed at 1m riser height and 3kg/cm<sup>2</sup> operating pressure; that is 37.69%, while the lowest was observed at 0.95m riser height and 4kg/cm<sup>2</sup> operating pressure; is 22.74%. In addition, the average coefficient of variation at riser height of 0.95 m decreases with an increase in operating pressure, this is in agreement with the research work done by [24].

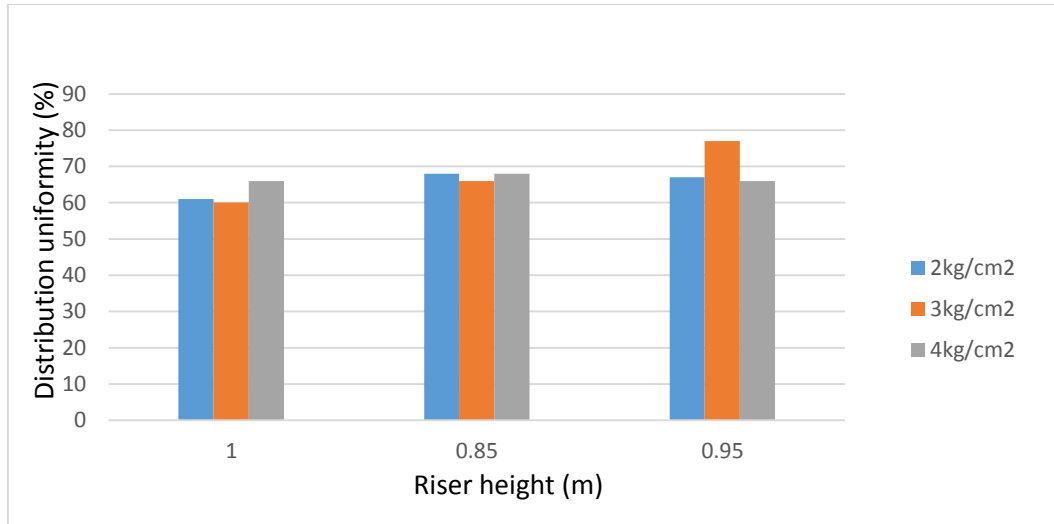


Figure 9. Distribution uniformity at various operating pressure and riser heights

Table 6. Coefficient of variation at varied operating pressure and riser height

	Riser height =1m	Riser height=0.95m	Riser height=0.85m
Operating pressure (kg/cm <sup>2</sup> )	CV (%)	CV (%)	CV (%)
2	31.64	32.08	28.26
3	37.69	25.62	30.60
4	32.73	22.74	30.61

### 3.11 Mean application rate

As presented in Figure 10 the maximum mean application rate was obtained at 2 kg/cm<sup>2</sup> operating pressure at a Riser height of 0.95 m and the least was at 4 kg/cm<sup>2</sup> operating pressure at a riser height of 1m. Although there is no significant difference in the mean application rate of the riser heights, the result shows that the riser height of 1m has the lowest mean application rate and the riser height of 0.95 m has the highest mean application rate. Hence, to obtain the optimum mean application rate it is advisable to operate the micro-sprinkler using a riser height of 0.95 m and at 2 kg/cm<sup>2</sup> operating pressure. In the current condition where a riser height of 1m is being used, to obtain a good mean application rate, the micro-sprinkler should be operated at 2kg/cm<sup>2</sup> operating pressure as it gives the highest mean application rate.

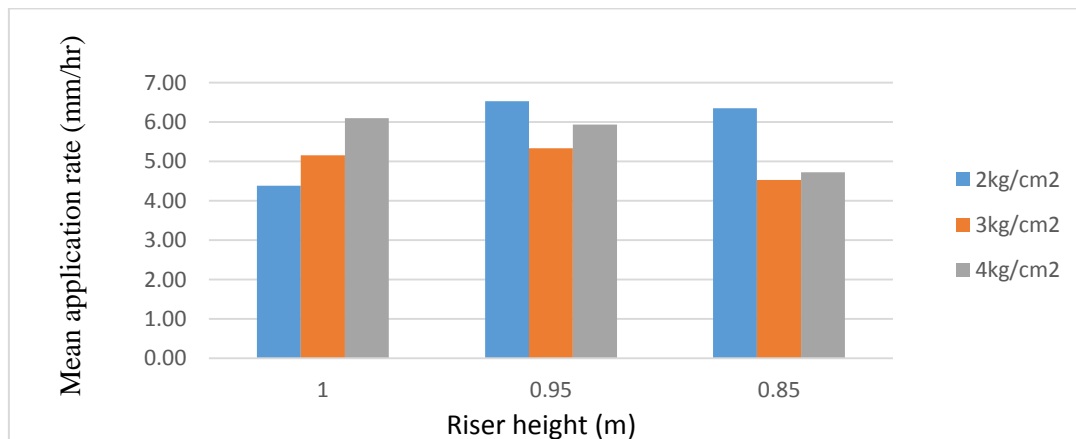


Figure 10. Mean application rate at various operating pressures and riser heights

#### 4 CONCLUSIONS

The evaluation indices showed the design was within the range of acceptable standards. The average discharge of the micro-sprinkler at operating pressure of 2 kg/cm<sup>2</sup>, 3 kg/cm<sup>2</sup> and 4 kg/cm<sup>2</sup> were found to be 9.32 l/min, 9.53 l/min, and 10.38 l/min respectively, in comparison with the manufacturer's discharge of 9.40 l/min at 2 kg/cm<sup>2</sup>, 9.67 l/min at 3 kg/cm<sup>2</sup> and 11.17 l/min at 4 kg/cm<sup>2</sup>, were not consistent, except at operating pressure of 2 kg/cm<sup>2</sup> that was almost the same, this difference was attributed to the age of use. The uniformity coefficient (UC) of the combination of the operating pressures and riser heights was observed to be greater than the recommended range of 75% with operating pressure of 4 kg/cm<sup>2</sup> and 0.85 m riser height.

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