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Adaptation and Evaluation of Portable Gun Type Sprinkler Irrigation for Smallholder Farmers

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ABSTRACT

The effectiveness of irrigation water management practices can be based on the uniformity and efficiency of the irrigation system. The water must be applied uniformly over the field. The study was conducted to fabricate and evaluate rain gun sprinkler irrigation by two factors of treatments on throwing distance, precipitations water depth and distribution uniformity. The three-nozzle sizes of Ø6mm, Ø8mm and Ø10mm were used as one factor of treatment and three pressure gauges 4bar,3bar and 2bar were used the second factor of treatment during prototype evaluation and operation. From the result, all of the interaction effects of different nozzle size and pressure gauge on throwing distance were significantly different from each other's. The interaction effect of 10NS*4PG was the highest value of 40.32 m. The next was the interaction effect of 8NS*4PG that has 39.19 m, but it did not have significant different with 6NS*45PG and its values 38.83 m. For precipitation water depth the maximum result was obtained during interaction effect of 10NS*4BPG and next was 8NS*4BPG. The highest water distribution uniformity was seen at the interaction effect of 6NS*4BPG and its value of 80.77%. But did not significantly different with the interaction effect of 6NS*3BPG and its value of 78.63%. The interaction effect of 8NS*4BPG has second-rank interims of three evaluation parameters of throwing distance, precipitation water depth and distribution uniformity value of 39.19m,26.10mm/mint and 74.9% respectively. So it is recommended to use the interaction effect of 8NS*4BPG for the three-inch water pump.

INTRODUCTION

Utilizable water resources for the agricultural sector are becoming increasingly scarce due to increasing population, abnormalities in weather, depleting groundwater resources, and increasing competition from household and industrial sectors. The surface methods of irrigation cause uneven distribution of water, water loss in the form of seepage and deep percolation, promote excessive weed growth besides creating salinization, water logging thus, affect the land and crop productivity (Shankar *et al.*, 2015). Due to these practices water application results in very low irrigation efficiencies that on-farm irrigation efficiencies range between 30 to 70% (IARI, 2018)

Technological innovations are to be exploited to achieve efficient utilization of water to obtain higher crop productivity and optimal use of water in agriculture to boost the economic status of resources poor farmers (Shankar *et al.*, 2015). One of alternative irrigation is rain gun sprinkler that used to grow grain crops particularly rice and wheat with much less water than required with the conventional methods of irrigation. Sprinkler irrigation is a method of water application, which plays a vital role in achieving these objectives. It is possible to attain high irrigation efficiency using the sprinkler, which is not generally feasible under surface irrigation methods. It is adaptable on hilly terrain and light soil and can save water from 30 to 60 % (IARI, 2018).

The effectiveness of farmers' irrigation water management practices can be based on the uniformity and efficiency of the irrigation system. The amount of water applied should be sufficient to reach field capacity in the root zone but should not exceed it. The water must be applied uniformly over the field so that each part of field will have the same opportunity to take in water (Prado & Colombo, 2020).

For irrigated crops to reach high production, irrigation systems must have satisfactory values of water application uniformity and an acceptable Christiansen uniformity coefficient of around 80% (Darko *et al.*, 2017). The application of irrigation water with rain gun sprinklers has improved on-farm irrigation efficiencies up to 70-80 % under the prevailing climatic conditions. The rain gun is a powerful that throws a large amount of water (up to 500 liters per minute) and radius of throw from 24 m to 36 m and even more as artificial rain (IARI, 2018).

Oliveira *et al.*, (2012) also stated that the water distribution of a gun sprinkler, which works in a traveler irrigation machine, is influenced by controllable factors (sprinkler type, nozzle diameter, working pressure, jet angle, wetted angle, and space between strips) and weather factors (wind speed and direction).

To achieve maximum output per unit of input in agricultural production, the technological innovations are to be exploited to achieve the twin objectives of efficient utilization of every drop of water to obtain higher crop productivity and optimal use of water in agriculture to boost the economic resources of poor farmers (Shankar *et al.*, 2015).

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Therefore, this study was conducted with the objective to adapt and evaluate portable gun type sprinkler irrigation interims of water distribution uniformity and water application depth to overcome problem of water loss during surface methods of irrigation in the form of seepage, deep percolation and creating salinization of command area.

MATERIAL AND METHODS

Materials

The materials used for manufacturing prototype and testing are - 3"pump, hose, wheel, square pipe, clamp, sheet metal, stopwatch, different size nozzle, pressure gauge, water catch cun, meter and water pipe.

Description of the Study Area

The prototype were produced and evaluated at Asela Agricultural Engineering Research Center which is located in Arsi Zone of Oromia National Regional State, Ethiopia. Geographically, it is situated at of 7^0 55' 53" N latitudes and 39^0 8' 9" E longitude.

Methods

Description of Rain Gun Sprinkler Irrigation System

The prototype produced was pressurized rain gun sprinkler system. It has three main components: water pump system assembly, rain gun sprinkler head assembly and transporting frame assembly. During operation, all these assemblies are established on site and connected to each other.

Pumping System Assemble

The water pump system assemble consisted of 3" diesel pump, suction hose and delivery hose. Using this three material assembles water pumped from water source and deliver to rain gun sprinkler head assembly.

Rain Gun Head Assemble

It has two wings. The large wing have used to throw long distance and smaller wing was use to throw short distance of water and used as attaching of water disturber of large wing. As general, it has three main parts of rain gun head are: - pressure gauge, tap shape nozzle, throwing water disturber, and 360 were rotating elbow connecter. The pressure gauge was attached to large wind and use to measure flow of water pressure in pipe. The tap shape nozzle was attached to end of large rain gun head and used to compress and throw water come from large rain gun head. Throwing water distributer distribute water through the nozzle.

Transporting Frame

The transporting frame was made from two standing square pipe and three supporting frame. It used for transporting the rain gun assembly along the irrigating field and for adjusting the angle of rain gun head.

Experimental Set and Performance Test

To evaluate the performance of the fabricated prototype, rectangular plot size of 45m*45m was used. The experiment had two factors arranged by RCBD design with three replications. The treatments considered were two factors namely three-nozzle size and three rain gun pressure guage. The three-nozzle sizes are 6mm, 8mm and 10mm diameters and three-pressure guage are 4bar, 3bar and 2bar were used at angle 450 of rain gun sprinkler operation.

Data Collection

The pressure gauge was adjuster to required pressure by gate valve coupled at the end of delivery pipe. The operating nozzle size fit to tip of gun and operated for 10 minutes. The throw radius distances of each nozzle were measured using measuring tape and a built-in dial-type pressure gauge for the operating pressure. To collect boom of water by rain gun, cutch can of 7.5cm diameter was putted on plot at distance of 1.5m from each other. After precipitation collected for 10 minutes, it measured in cylinder gauge to quantify the amount of water depth per area.

Pressure- Discharge Relationship

The coefficient of discharge for rain gun with different nozzle sizes was computed by the following formula (Michael, 2009):

$$Q = ca\sqrt{2gh} \quad (1)$$

Where:

Q = nozzle discharge, m^3/s

a = cross sectional area of nozzle, m^2

h = operating pressure head at the nozzle, m

g = Acceleration due to gravity, m/s^2

c = coefficient of discharge

Distribution Uniformity

Rain gun with different sizes of nozzles was operated for ten minutes duration under selected range of pressures guage. The sprinkled water was collected in the catch cans and depth of water was measured after the closure of the Rain gun. The coefficient of uniformity of the Rain gun was estimated using the following relationship (Christiansen, 1942):

$$CU=100(1.0-(\sum X)/nm) \quad (2)$$

$$CU= 100\,(1.0 - (\sum|Z-M|)/(\sum Z) \quad (3)$$

Where:

CU = Equal distribution coefficient developed by Christiansen (%)

Z = The amount of water measured in each container while testing uniformity (mm, mL)

x = |z-m|=The total absolute value of deviations from average of the amount of water measured in all accumulation containers (mm, mL)

m = (Σz)/n=Average amount of water (mm, mL)

n = The number of water accumulation containers

Water application rate: Application rate of the rain-gun gives information whether the nozzle size properly matched to the sprinkler head for the soil, crop and terrain on which they operate. The application rate of the rain gun was calculated

$$Ra = (Q/A)*k \quad (4)$$

Where, Q= rain-gun discharge, l/m

a= wetted area of sprinkler, m^2

k= constant, K= 60.00

Statistical Analysis

The collected data were statistically analyzed using Statistix 8 software. Mean comparisons were performed using least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

The Main Effect of Different Nozzle Size on Throwing Distance, Precipitation Water Depth and Distribution Uniformity of Water

The effect of different nozzle size on throwing distance, precipitation water depth and distribution uniformity of water result are presented in Table 1. From this result, the main effect of three nozzle size of diameter 6,8 and 10 mm on throwing distance, precipitation water depth and distribution uniformity of water was significant different from each other. From the three treatments of nozzle size result, Ø10mm nozzle size have maximum mean distance of 36.47m at two direction and precipitation water depth of 6.17mm/minute, but distribution uniformity was 66.67% which are less than recommendation according to (Darko *et al.*, 2017) of sprinkler DU less than 70% not recommended. The result of Ø8mm nozzle have precipitation water depth of 5.52mm/minute, which are in range of large volume sprinkler precipitation greater than 25mm/hr as stated by Shankar *et al.*, (2015).

Table 1: The main effect of different nozzle size on throwing distance, precipitation water depth and distribution uniformity of water

Nozzle size in (mm)	Mean distance in (m)	Precipitation water depth in mm/minute.	Distribution uniformity in (%)
10	36.47^{A}	6.17^{A}	66.67^{C}
8	35.61^{B}	5.52^{B}	70.78^{B}
6	34.51^{C}	3.82^{C}	78.04^{A}
S.Em±	0.26	0.12	0.93
CV	1.56	5.09	2.75
LSD (5 %)	0.55	0.26	1.97

Main Effect of Different Pressure Gauge on Throwing Distance, Precipitation Water Depth and Distribution Uniformity of Water

The main effect of three pressure gauge on throwing distance, precipitation water depth and distribution uniformity of water were significant different to each other and the value were increase as pressure increase. This result was agreed with the finding of Yaseen *et al.* (2019) as operation pressure increase throwing distance, precipitation water depth and distribution uniformity were increase.

Table 2: The main effect of different pressure gauge on throwing distance, precipitation water depth and distribution uniformity of water

Pressure gauge in (bar)	Mean distance in (m)	Water depth in mm/mint	Distribution uniformity in (%)
4	39.45^{A}	5.86^{A}	76.21^{A}
3	35.27^{B}	5.26^{B}	71.64^{B}
2	31.88^{C}	4.39^{C}	67.63^{C}
S.Em±	0.26	0.12	0.93
CV	1.56	5.09	2.75
LSD (5 %)	0.55	0.26	1.97

Interaction Effect of Different Nozzle Size and Pressure on Throwing Distance, Precipitation Water Depth and Distribution Uniformity

The interaction effects of different nozzle size and pressure gauge on throwing distance, precipitation water depth and distribution uniformity were presented in Table 3.

All of the interaction effects of different nozzle size and pressure gauge on throwing distance were significant different from each other. The interaction effect of 10NS*4PG was the highest values of 40.32 m. The next was interaction effect of 8NS*4PG; that has 39.19 m. But it did not have a significant different with 6NS*4PG and its value is 38.83 m. The result comparable with the finding of Yaseen *et al.* (2019) for constant pressure (3bar) the large nozzle size (Ø24mm) have high throwing distance 38m than small nozzle size (Ø18mm) of throwing distance 32m.

For precipitation water depth, the maximum result was obtained during interaction of 10NS*4PG and next was the interaction between 8NS*4PG. The highest water distribution uniformity was obtained from the interaction of 6NS*4PG and its value of 80.77%. But did not have a

Table 3: Interaction effect of different nozzle size and pressure on throwing distance, precipitation water depth and distribution uniformity

(Nozzle size and pressure gauge)	Mean distance in (m)	Precipitation water depth in mm/mint	Distribution uniformity in (%)
10NS*4bar	40.32[A]	7.13[A]	70.97[C]
8NS*4bar	39.19[B]	6.10[B]	74.90[B]
6NS*4bar	38·83[B]	4.35[DE]	80.77[A]
10NS*3bar	35.99[C]	6.07[B]	65.63[D]
8NS*3Bar	35.73[C]	5.75[BC]	70.67[C]
6NS*3bar	34.08[D]	3.95[E]	78.63[A]
10NS*2bar	33.10[E]	5.31[C]	61.40[E]
8NS*2bar	31.92[F]	4.70[D]	66.77[D]
6NS*2bar	30.62[G]	315[F]	74.73[B]
S.Em±	0.45	1.13	1.61
CV	1.64	4.43	2.39
LSD (5 %)	0.96	2.39	3.42

NS=Nozzle Size

significant different with the interaction of 6NS*3PG and its value of 78.63%. The interaction effect of 8NS*4PG have second rank in three evaluation parameters. This result also agrees with the finding of Yaseen *et al.* (2019) the application rate increase as nozzle size increase.

CONCLUSION

The surface methods of irrigation causes uneven distribution of water, water loss in the form of seepage and deep percolation, promotes excessive weed growth besides creating salinization, water logging thus, affect the land and crop productivity. Technological innovations are to be exploited to achieve efficient utilization of water to obtain higher crop productivity and optimal use of water in agriculture. One of alternative irrigation is rain gun sprinkler. To overcome this problem, the Asella Agricultural Engineering Research Center (AAERC) was conducted the study. To evaluate the performance of the fabricated prototype, rectangular plot size of 45m*45m was used. From the result all of the interaction effects of different nozzle size and pressure gauge on throwing distance were significant different from each other. The interaction effect of 10NS*4PG was the highest values of 40.32 m. The next was interaction effect of 8NS*4PG that has 39.19 m. But, the interaction effect of 6NS*45PG did not have a significant different and its values 38.83 m. For precipitation water depth the maximum result was obtained during interaction effect of 10NS*4BPG and second was the infraction between 8NS*4BPG. The highest water distribution uniformity was obtained at interaction effect of 6NS*4BPG and its value of 80.77%. But, the interaction effect of 6NS*3BPG did have not a significant different and its value of 78.63%. The interaction effect of 8NS*4BPG have second rank interims of three evaluation parameters of throwing distance, precipitation water depth and distribution uniformity and it's value of 39.19 m,26.10 mm/minute and 74.9% respectively. So, it is recommended to use the interaction effect of 8NS*4BPG for three inch water pump.

RECOMMENDATION

It is also recommended that further study was done on-farm evaluation with furrow irrigation to identify amount of water saved by using rain gun sprinkler.

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