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Research Article

Analysis of Furrow Irrigation Design Parameters on Sugarcane Growth and Yield Parameters Under Wonji Shoa Climatic Condition

Belay Yadeta Negera[1*], Mekonen Ayana[2], Muluneh Yitayew[3] and Tilahun Hordofa[4]

*[*1]Adama Science and Technology University, Adama, Ethiopia.*
[2]Senior Lecturer and Researcher at Adama Science and Technology University, Department of Water Resource Engineering, Adama, Ethiopia.
[3]Senior Lecturer and Researcher at Arizona State University, Department of Agriculture and Biosystem Engineering, Arizona State University USA.
[4]Senior Researcher at Melkassa Agricultural Research Center, Department of Natural Resource, Irrigation and Drainage, Ethiopian Institute of Agricultural Research, Ethiopia.

Corresponding Author: Belay Yadeta Negera, Adama Science and Technology University, Adama, Ethiopia.

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Abstract

Sugarcane is one of the important industrial crops produced all over the tropical areas. Sugarcane production is highly expanding in developing countries like Ethiopia. However, sugarcane is characterized by very high crop requirements. But sugarcane is produced mostly in Ethiopia using furrow irrigation methods in which more losses of irrigation water is most common due to many factors. Even if there are high losses of water in furrow irrigation, in which its performance influenced by many factors, to improve its performance or reduces the losses of irrigation water proper furrow irrigation decision variables combination is very important. In line with this the current study focused on three main furrow irrigation design parameters. The main purpose of the current study was to analyse effect of furrow irrigation design on sugarcane growth and yield parameters under Wonji Shoa Sugar Estate conditions. The field experiment was conducted using Split-split plot design with three factorial experiments replicated three times. All required data on growth and yield of sugarcane parameters were collected and analysed using SAS 9.4 version statistical software. The effect of furrow slope showed statistically significance variation at 5% significance on growth parameters (cane height, cane weight, cane diameter and number of cane internode per stalk), but non-significance variation on yield components of sugarcane (moisture percent, dry substance, number of millable cane stalk and sugarcane yield). But the effect of furrow length showed statistically significance variation on almost all growth and yield parameters of sugarcane at 5% significance level except sugarcane yield. Finally, the effect of furrow discharge rate on all growth and yield parameters considered were showed statistically significance variation at 5% significance level except number of millable cane stalk. In general, the highest sugarcane yield was obtained from furrow slope three, furrow length three and furrow discharge rate as compared to the other factors level. Therefore, this result it can be recommended that slightly slope, longer furrow length and less properly applied discharge rate resulted in more yield of sugarcane.

Keywords: Experimental Design, Furrow Irrigation Design, Sugarcane Growth Parameters, Sugarcane Yield Parameters, Wonji Shoa Sugar Estate.

1. Introduction

Globally agriculture contributed to more than 80% use of fresh water available especially for irrigated crop production. Agricultural ecosystems are the main consumer of water resources worldwide [1]. The use of agricultural water consumption may vary from region to region as a result of economic development and climatic factors. The irrigation water consumption approximately estimated as 60% and 90% of available water resources in developed and developing countries respectively [1]. In some regions of the world, the expansion of irrigation increased stressing water bodies and aquifers that depleting from time to time. As a result it faces the water scarcity condition, in which the demand of freshwater resource exceeds the availability freshwater resource [2]. But the availability of irrigation water is decreasing from time to time because the demand for fresh water resource by different sectors increasing in the opposite. In the context of global water scarcity for agriculture, the precise management of available water for irrigation is important [3].

The sugarcane (Saccharum spp.) is a crop of great social, economic and environmental importance almost all over the world. It is the world largest crop by production in quantity and produced in 120 countries. The ten (10) largest sugar producing nations represent roughly 75% of world sugar production [4]. In production, Brazil still remains on the top with (33%) of global sugar production followed India (23%), China (7%) and Pakistan (4%). Africa contributed less than 5% of the world sugarcane production. In world, sugarcane is grown between the latitude 36.70 N and 31.00 S of the equator extending from tropical to subtropical zones. About 80% of sugar is obtained from sugarcane and the remaining 20% is produced from sugar beet [5, 6].

Irrigation water sources are one of the most limiting factors in crop production in arid and semi-arid regions specially for perennial crops like sugarcane since the annual rainfall is low and erratic in time and space. Once sugarcane water requirement determined and its crop coefficient developed, the irrigation water required for the designed command area is computed based on the availability of water resource which highly influence the sustainability of irrigated area. But design of surface irrigation systems depends mostly on irrigation canals without considering the water requirement of the crop which resulted in over or under irrigation practices that resulted in reduction of the crop yield [7].

Surface irrigation is the most commonly used in the developing countries of which the furrow irrigation methods largely covered from farm house hold to large machanized farms. But the performance of furrow irrigation affected by many factors due to its nature of water application. The main factors that impact on the performance of furrow irrigation can be categorised as design, soil and water management variables. Design variables include the longitudinal slope of the field which affects both the rate of advance and recession, and the length of the furrow which determines the flow rate required [8].

In surface irrigation, the design procedure requires the determination of the main decision variables that highly influence the efficiency of irrigation. In designing of furrow irrigation, the design consideration focused on furrow geometry, advance time and required depth of application since the irrigation water applied across the furrow channel if not properly considered resulted in erosion problem [9]. The most common furrow geometry considered during design are furrow length, furrow width, furrow bottom depth and furrow slope. Furrow discharge largely dependent on soil type and crop water requirement and advance time depends on the required depth of irrigation. Furrow irrigation is the most common type of surface irrigation but in most cases the design of furrow systems is not optimized for water use in arid regions [10].

Worldwide, sugarcane occupies area coverage of 20.42 Mha with a total production of close to 1.6 billion tons per year with the average productivity of 59.4 ton/ha. Sugarcane also produced in Africa with a total area coverage of 1.5 Mha with a productivity of 53.2 ton/ha. South Africa is the leading country in sugarcane production in Africa with the total production of 1.8 million tons/year and productivity of 58.7 ton/ha from Africa. In Ethiopia, sugarcane area coverage is 0.32 Mha with average productivity of 45.2ton/ha [11]. Even if the sugarcane is highly demanded, due to many factors its production and productivity is not much attractive especially in developing countries particularly, Ethiopia. From many factors affecting sugarcane production in Ethiopia, the main reasons are mismanagement of irrigation, inadequate knowledge of irrigators, lack of regular operation and maintenance [12].

Sugarcane is a perennial water intensive crop and with water becoming increasingly scarce resource particularly due to high competition on water resources from different sectors. In the global context, around 80% of sugarcane is grown in the regions that have a history of water scarcity in rift valley of the country [13]. On average, the water requirement of sugarcane varies from 1200 to 3500 mm depending on soil types, crop growing duration and the climatic conditions of the area [14]. Scarcity and growing competition for fresh water resource reduce water availability for irrigation but in the other hand, water losses in surface irrigation are very high. To increase the efficiency of surface irrigation, for commonly used as furrow irrigation, appropriate furrow irrigation design parameters is essential for effective planning and management of water resources [15].

Surface irrigation is the most dominant irrigation methods practiced in sugarcane production in Ethiopia. Especially, in Wonji Shoa Sugar Estate all the area coverage (5000 ha) under the Estate produced by furrow irrigation however, the rest area under out growers (7000 ha) are produced by sprinkler and furrow irrigation. The performance of furrow irrigation under Wonji Shoa Sugar Estate is very poor. To improve the performance of furrow irrigation, identifying the appropriate combination of the furrow irrigation decision variables are very important. In line with this the current study was focused the identifying appropriate furrow irrigation design parameters that can improve the performance of furrow irrigation under Wonji Shoa Conditions. The main objective of the current study was to analysis effect of furrow irrigation design parameters on sugarcane growth and Yield parameters Wonji Shoa Sugar Estate.

2. Materials and Methods

2.1. Description of the Study Area

The Wonji Shoa Sugar Estate (WSSE) is located in the South East Shoa Zone of Oromia Regional State, at a distance of 110 km from Addis Ababa, the capital city of Ethiopia. Geographically, it is situated at 8021'- 8029' N and 39012'- 39018'E and altitude of 1223 to 1550m above MSL (Figure 1). The area is characterized by gentle and regular topography making it most suitable for irrigation. Sugarcane is grown in the area, mostly as a monoculture. The climate of the area is characterized as semi-arid with the main rainy season during the months of June to September. The rainfall of the area is erratic both in quantity and distribution. The area receives mean annual rainfall of 831mm with mean annual maximum and minimum temperature of 27 and 15oC respectively. The soil of the area varies from sandy loam to heavy clay types.

The Estate is the first commercial large-scale irrigation scheme in Ethiopia and was established in 1951 at Wonji by Netherland's Hender Verneering Amsterdam (H.V.A.) Company private investors and the Ethiopian government. When the factory started production in 1954 its initial pro-

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duction was 140 tons/year (WSSF, 2018). The two factories are known by the name Wonji and Shoa, Sugar Factory altogether had the capacity of producing 75,000 tons of sugar per year till recent time (prior to the completion of the new Wonji Shoa Sugar Factory at Dodota site far apart in the old factories). After serving for more than half a century and getting obsolete, the two factories viz., Wonji and Shoa sugar factories were closed in 2011 and 2012 respectively. Replacing these pioneer factories, the new and modern factory had started production in 2013 with higher production capacity. Currently, the WSSE sugarcane plantation covers and irrigated area of 12,000ha of which 5,000 ha is managed by the Estate itself and 7,000 ha is managed by an out-growers. The irrigation water source is Awash River. The Wonji Shoa Sugar Estate location map is presented in Figure 1.

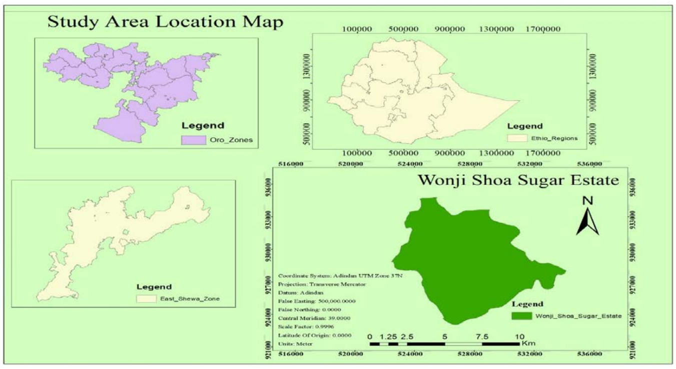

Figure 1: Location map of the study area.

2.2. Materials and Treatment Combinations

For this experiment, different materials were used from the field layout to the final data collection. For field layout preparations, measuring tape, spade, rake and pitchfork were used. Planting materials and inputs used were sugarcane variety NCO334, with two buds, fertilizers and chemicals. For soil data sample collection, auger, shovel, soil moisture can and sensitive weight balance were used and for soil moisture analysis, oven dry and sensitive balance were used. For irrigation management purpose, Par shall flume, ruler for measuring water depth, stop watch for recording advance and recession time. After the crop matured also different material used were cane cutter (machete), weight balance, length measuring meter and caliper. Finally, for sugarcane yield and quality parameters analysis different laboratory materials were also used.

For this experiment, three different factors with different levels were used. Based on numbers of factors included in the factorial experiment (split-split plot design) were selected. The treatment combinations were as following present in the following table 1.

Table 1: Treatment combination of the factors including all levels of factors.

FS 1								
FL 1			FL 2			FL 3		
Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q1
FS 2								
FL 1			FL 2			FL 3		
Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q1
FS 3								
FL 1			FL 2			FL 2		
Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q1

Key: Furrow slope (FS), Furrow length (FL) and Furrow discharge (Q), FS 1 = 0.05%, FS 2 =0.08%, FS 3 = 0.11%, FL 1 = 30m, FL 2 = 50m FL 3 = 70m, Q 1 = 4 l/s, Q 2 = 5 l/s, Q 3 = 6l/s

2.3. Experimental Design and Layout

The treatments were laid out in a split-split plot design with three factors arranged as the main plot, sub plot and sub-sub plot with three replications in which all factors having three levels. Those factors were arranged as per the experimental design as main factor plot furrow slope (FS), sub plot factor furrow length (FL) and sub-sub plot factor furrow discharge rate (FQ) which applied to all furrow slope and furrow lengths. For all treatments the furrow width was 1.45m and there were three furrows under each discharge rate for all replications.

Figure 2: Layout of the experimental design.

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2.4. Soil Moisture Analysis

In the determination of the soil moisture content of the field experiment, the soil sample was taken from the field in the Z fashion across the whole field at two depths (0-30 and 30-60cm). To determine the soil moisture content, the wet weight of soil sample taken from the field at each depth was weighted at the field using sensitive balance and taken to oven dry at 1050C for 24hrs. The oven dried soil sample was weighted to obtain dried weight and the gravimetric moisture content of the soil was determined using (Equation 1)

$$\theta_g = \frac{W_{wet} - W_{dry}}{W_{dry}} \quad (1)$$

Where W_{wet} = Wet eight of soil (g), W_{dry} = Dried weight of soil (g) The volumetric soil moisture content was determined using (Equation 42) and the change in soil moisture content (ΔSM) before irrigation (SM_{BI}) and after irrigation (SM_{AI}) was computed using (Equation 2 and 3) before the next irrigation application.

$$\theta_v = \left(\frac{W_{wet} - W_{dry}}{W_{dry}}\right) * \rho d \quad (2)$$

$$\Delta SM = SM_{AI} - SM_{BI} \quad (3)$$

The total available water (TAW) for plant use can be determined from the soil water content at field capacity (FC) and permanent wilting point (PWP). The total available water within the given soil depth is determine using (Equation 4).

$$TAW = (\theta_{FC} - \theta_{PWP}) \quad (4)$$

Where, = total available water (mm/m), FC, PWP = soil moisture content at field capacity and permanent wilting point

2.5. Irrigation Application and Management

After the selected sugarcane variety with two bud setts were planted, irrigation was applied uniformly until the crop established well. The irrigation treatments were started after the crop established and irrigation water applied was managed with Parshall flume always installed at 5m far apart from the experimental field inlet. The time of cut off was calculated for all furrow lengths and discharge rate for the management of irrigation water applied according to each treatment. Before irrigation water applied, always the available soil moisture was determined by taking the soil sample from the field from each treatment, and available rain fall within intervals also recorded and the effective rainfall was computed using CropWat 8.0 model. Irrigation water was applied as full or supplemental irrigation based on the available soil moisture and effective rain fall throughout the crop growth periods. The net irrigation water requirement was computed using Equation 5.

$$d_{net} = TAW * \rho * Zr \quad (5)$$

Where: d_{net} = net depth of irrigation water applied, TAW = total available soil moisture, p = depletion fraction for the crop, Zr = required depth of application

The required depth of application computed from the furrow geometry and inflow of water (discharge) using (Equation 6)

$$Z_r = \frac{Q_i * 3600}{L * W} \quad (6)$$

Where: Q = Inflow rate of water to the furrow (L/s), L and W = Furrow length and width (m), After the required depth of application was known, the cut off time for each furrow length was computed from the general irrigators' equation (Equation 7)

$$T_{co} = \frac{A * d}{Q} \quad (7)$$

Where: Tco = cut of time (min), A = area for the furrow (m^2), d = Zr = required depth of application (m), Q = inflow rate to the furrow (L/s)

2.6. Data Collection

This study was conducted from March 2019 to August 2021 at Wonji Shoa Sugar Cane Estate. From the beginning of the experiment, different data were collected. The major data collected were Soil data, weather data, irrigation data, sugarcane growth parameters, analysis of sugarcane quality parameters with some observational data records throughout the crop growth periods.

For the growth and yield component analysis of sugarcane, millable cane stalks were taken from all the treatments. The numbers of millable cane stalks were considered for each treatment in all replications in the analysis. The collected data on sugarcane growth and yield parameters were described as followed

Cane Height (CH): The data on cane height was recorded from randomly selected five sugarcane stalk samples taken from each treatment from all replications. The cane height was measured and then the average cane height was worked by following Sweet and Patel (1985) using equation 8.

$$\text{Average cane height (cm)} = \frac{(\sum 5 \text{ cane stalk height})}{5} \quad (8)$$

Cane Weight (CW): The data on cane weight was recorded from randomly selected five sugarcane stalk samples taken from each treatment for all replications. The weight of five millable cane stalk was measured by simple balance at field level. Then, the average cane weight was worked by following Sweet and Patel (1985) using equation 9.

$$\text{Average cane weight (kg)} = \frac{(\sum 5 \text{ cane stalk weight})}{5} \quad (9)$$

Cane Diameter (CD): The data on cane diameter was recorded from randomly selected five sugarcane stalk samples taken from each treatment for all replications. The cane diameter was measured by caliber and then the average cane diameter was worked by following Sweet and Patel (1985) (Equation 10)

$$\text{Average cane diameter (cm)} = \frac{(\sum 5 \text{ cane stalk diameter})}{5} \quad (10)$$

Number of Cane Internodes (NCI): The data on the number of internodes per stalks was recorded from randomly selected five sugarcane stalk samples taken from each treatment for all replications. Then, the average number of internodes per stalks was worked by following Sweet and Patel (1985) (Equation 11)

$$\text{Average NIC per stalk} = \frac{(\sum 5 \text{ cane stalk NI})}{5} \qquad (11)$$

Moisture Percent (MP): The weight of the clean empty container used for drying cane sample in the oven was recorded as mass (M1). Then about 100 gm of the shredded cane sample was placed in empty container and weighed to record the mass of the container plus cane (M2). Thereafter, the container with sample of cane was placed in the drying oven and moisture teller for drying samples at 110 ^{0}c temperatures. When the temperature was stabilized, the drying time was set for about 45 minutes. Finally, the hot container with dried cane sample was weighed to record mass, (M3). The moisture percent in cane was determined from the mass loss by the formula (Hundito) using equation 12

$$\text{Moisture \% cane} = \left(\frac{M_2 - M_3}{M_2 - M_1}\right) * 100 \qquad (12)$$

Where, M1 = weight of empty container, M2 = weight of empty container plus cane sample, M3 = weight of empty container plus dried cane sample

Dry Substance: The dry substances were determined for all treatments from the moisture % cane determined using equation 13

Dry substance % cane = 100 - moisture % cane (13)

Number of Millable Cane Stalk: The total number of millable cane was counted at 10m intervals for all treatments and converted to furrow length to know the total cane stack population that have greater than 1.0m in length and visible internodes. The total sugarcane stalk per furrow area for each treatment were converted to hectare.

Cane Yield: The sugarcane yield was estimated from the average weight of 20 randomly sampled millable canes multiplied by the total number of millable cane in each treatment from all replications following (Sweet and Patel) using equation 14.

$$\text{Cane yield } \left({}^{\text{ton}}/_{\text{ha}}\right) = \frac{\text{Weight of 20 MC}}{20} * \frac{\frac{\text{TNMC}}{\text{FL}} * 1000}{\text{sampling area FL } (m^2)} \qquad (14)$$

Where: MC = millable cane stalk, FL = Furrow length, TNMC = total number of millable cane stalks per furrow length,

2.7. Data Analysis

All the data collected on growth and yield parameters of sugarcane were subjected to analysis using SAS 9.4 version. The least significance between the treatments were test at 5% significance level.

3. Result and Discussion

The effect of furrow irrigation design parameters was analysed on sugarcane growth, yield and quality parameters. Also, the effect of different rate of irrigation applied analysed on sugarcane water productivity.

3.1. Effect of Furrow Slope on Sugarcane Growth and Yield Parameters

The effect of furrow slope on sugarcane growth and parameters were evaluated on different growth and yield components of the crop. To evaluate this the sugarcane growth and yield parameters evaluated were cane height, cane weight, cane diameter, number of cane internodes, cane moisture percent, dry substance, number of millable cane stalk and cane yield. The minimum and maximum values of those parameters were cane height (228.60 and 235.93cm), cane weight (6.44 and 7.39kg), number of cane internode (23.93 and 27.69), cane diameter (2.61 and 2.80cm), moisture percentage (50.22 and 65.91%), dry substance (34.09 and 49.78%), number millable cane stalk (290.82 and 1175.67 000/ha), and cane yield (115.24 and 198.91 ton/ha) respectively. The effect of furrow slope on cane height, cane weight, cane diameter and number of cane internodes were statistically showed significance variation at 5% significance level (Table 2). This may be due to the effect of furrow slope on the water retention in the crop root zone across the furrow length affected since the irrigation water applied flow across the furrow by gravity force. In the other side, since the sugarcane crop is sensitive to both water stress and water logging, the variation of furrow slope may cause water logging at some part and water shortage at other part of the furrow in which both conditions affects the crop growth.

The effect of furrow slope showed statistically non-significance variation on moisture percentage dry substance, number of millable cane stack and cane yield at 5% significance level. Specially, the number of millable cane stack affected if there is water logging or water stress occurred since the later tillering stack are unable to survive in both conditions. Finally, all the cane yield attributes were directly corresponding to the final cane yield. Hence the effect of furrow slope showed significance variation on some parameters the final and most important parameters number of millable cane stalk and cane yield showed statistically non-significance variation (Table 2).

Table 2: Effect of furrow slope on growth and yield of sugarcane.

Treatments (Furrow slope)	Parameters							
	CH (cm)	CW (kg)	CD (cm)	NCI (/stk)	MP (%)	DS (%)	NMC (000/ha)	CY (ton/ha)
1	235.89[a]	8.63[a]	2.94[a]	29.62[a]	64.15[a]	45.41[a]	673.11[a]	166.75[a]
2	231.62[b]	6.91[b]	2.62[b]	25.79[b]	61.55[ab]	38.45[b]	657.53[a]	172.91[a]
3	227.16[c]	5.81[c]	2.42[c]	22.42[bc]	57.30[c]	35.64[bc]	733.15[a]	181.31[a]
Mean	231.56	7.12	2.66	25.94	61.00	39.83	687.93	173.66
LSD (at 5%)	3.56	0.95	0.11	3.24	4.24	6.48	94.52	19.38
CV	1.44	6.02	1.77	7.3	6.18	9.47	6.06	4.92
SIGN	0.024*	0.018*	0.007**	0.022*	0.24ns	0.24ns	0.33ns	0.39ns

CH = cane stalk height, CW = cane weight, CD = cane diameter, NCI = number of cane internode, DS = Dry substance, NMCS= number of millable cane stalk, CY = sugarcane yield

Note: Means for sugarcane growth parameters within a column followed by the same letter are not significantly different from each other at p < 0.05. However, mean values of different letters within a column are indicate significant differences by a > b > c

Keys: ***, **, * and ns indicate very high significant at P < 0.001, high significant at P < 0.01, significant at P < 0.05 and non-significant at P > 0.05 respectively

Similar to the current study findings, study finding by Hase (2019) revealed that the effect of furrow slope showed significance variation on cane stack height, cane weight and number of cane internode. Similarly, the other study findings by indicated that the effect of furrow slope showed significance variation on cane stack height, cane weight and number of cane internodes [16]. Similar to the current study, cane height, cane weight, number of cane internodes, moisture percentage and dry substance were highly affected by furrow slope and showed highly significance variation [17]. As this author concluded, the cane weight is directly related to its height and diameters that substantially contributes towards final cane yield. In opposite to the current study result, the study findings by revealed that the effect of furrow slope showed non-significance variation on the sugarcane number of millable cane stalk and cane yield. The study findings by showed the yield of sugarcane variety NCO-334 ranges from 150.81 to 170.37 ton/ha under normal condition [8, 18].

3. 2. Effect of furrow Length on sugarcane growth and yield parameters

Similar to furrow slope, the effect of furrow length on sugarcane growth and yield parameters were analysed. The sugarcane growth and yield parameters evaluated were cane height, cane weight, cane diameter, number of cane internodes, cane moisture percent, dry substance, number of millable cane stalk and cane yield. The minimum and maximum values of those parameters were the same as it indicated under the furrow slope. The effect of furrow length on cane height, cane weight, cane diameter, number of cane internodes, moisture percentage, dry substance and number of millable cane stack were statistically showed significance variation at 5% significance level (Table 3). Due to the effect of furrow length on the water runs, in the longer furrow length the amount of irrigation water distributed is not uniform because in the inlet direction the water has more opportunity time for water infiltration as compared to the furrow length at end. On the other hand, since the furrow condition was closed ended, more water stored at the end of the shorter furrow length which causes water logging problems. In line with those conditions almost all sugarcane growth and yield parameters showed significant variation between different furrow lengths considered.

The effect of furrow length showed statistically non-significance variation on cane yield at 5% significance level. The moisture and fiber percentage are inversely proportional as one increased, the other decreased. Specially, the cane yields highly affected if there is water logging or water stress occurred because the sugarcane crop by its nature, it is sensitive to extreme water conditions. Finally, the effect of extreme water condition in sugarcane resulted in reduction of total cane yield. Hence the effect of furrow length showed significance variation on almost all growth parameters but is showed non-significant on the final requirement of the crop or cane yield (Table 3).

Table 3: Effect of furrow length on the growth and yield of sugarcane.

Treatments (Furrow Length)	Parameters							
	CH (cm)	CW (kg)	CD (cm)	NCI (/stk)	MP (%)	DS (%)	NMC (000/ha)	CY (ton/ha)
1	237.49[a]	7.95[a]	2.92[a]	26.81[a]	69.78[a]	43.22[a]	399.49[c]	168.99[a]
2	228.03[b]	6.93[b]	2.70[b]	25.57[ab]	62.90[b]	39.10[b]	684.72[b]	172.49[a]
3	222.57[bc]	6.05[bc]	2.60[c]	24.71[bc]	58.94[c]	38.06[bc]	979.59[a]	179.49[a]
Mean	229.36	6.98	2.74	25.70	63.87	40.13	687.93	173.66
LSD (at 5%)	5.84	0.91	0.07	1.34	3.98	3.98	90.50	17.72
CV	1.11	5.74	1.19	2.30	2.89	4.49	27.28	4.38
SIGN	0.023*	0.006**	0.047*	0.068*	0.044*	0.047*	0.0005***	0.47ns

CH = cane stalk height, CW = cane weight, CD = cane diameter, NCI = number of cane internode, DS = Dry substance, NMCS= number of millable cane stalk, CY = sugarcane yield

Note: Means for sugarcane growth parameters within a column followed by the same letter are not significantly different from each other at p < 0.05. However, mean values of different letters within a column are indicate significant differences by a > b > c

Keys: ***, **, * and ns indicate very high significant at P < 0.001, high significant at P < 0.01, significant at P < 0.05 and nonsignificant at P > 0.05 respectively.

3. 3. Effect of furrow Discharge rate on growth and yield parameters of sugarcane

Similar to furrow length, the effect of furrow discharge on sugarcane growth and yield parameters were analysed. The sugarcane growth and yield parameters evaluated were the same as in the case of furrow slope and furrow lengths. The minimum and maximum values of those parameters were the same as it indicated under the furrow slope. The effect of furrow discharge rate on all growth and yield parameters considered (cane height, cane weight, cane diameter, number of cane internodes, moisture percentage, dry substance and cane yield were statistically showed significance variation at 5% significance level (Table 4). But the effect of discharge showed non-significance variation on the number of millable cane stack. This indicates that the effect of furrow discharge rate has high impact on the growth and yield parameters of sugarcane. As it already stated, sugarcane crop is highly sensitive to water logging as well as water stress, the growth and yield parameters affected by both irrigation conditions.

Based on the result obtained, in general furrow discharge rate 1 (4lit/sec) resulted in good performance of the sugarcane growth parameters and more yield as compared to the other two discharge rates. As the furrow discharge rate increased from 4 to 5 and 5 to 6lit/sec the growth and yield parameters of sugarcane decreased (Table 4). This indicates as the furrow discharge rate increased beyond the optimum point, the growth and yield parameters of the sugarcane starts to declined. From current study result it can be concluded that furrow discharge rate 4lit/sec is optimum rate of furrow discharge to harvest more yield of sugarcane crop under the Wonji Shoa conditions.

Table 4: Effect of discharge rate on the growth and yield of sugarcane.

Treatments (Furrow Discharge)	Parameters							
	CH (cm)	CW (kg)	CD (cm)	NCI (/stk)	MP (%)	DS (%)	NMC (000/ha)	CY (ton/ha)
1	237.74[a]	7.54[a]	3.17[a]	27.54[a]	63.01[a]	39.99[a]	688.89[a]	176.18[a]
2	225.45[b]	6.83[b]	2.97[b]	25.72[b]	61.07[b]	37.93[b]	696.31[a]	173.59[b]
3	213.92[c]	5.93[c]	2.72[c]	25.08b[c]	58.43[c]	36.37[c]	678.61[a]	171.20[c]
Mean	225.70	6.77	2.95	26.11	60.84	38.10	687.94	173.66
LSD (at 5%)	2.91	0.54	0.07	1.02	1.43	1.43	24.00	1.28
CV	0.55	3.46	1.06	1.75	1.05	1.60	42.07	3.19
SIGN	0.002**	0.045*	0.043*	0.044*	0.001**	0.001**	0.38ns	0.005**

CH = cane stalk height, CW = cane weight, CD = cane diameter, NCI = number of cane internode, DS = Dry substance,NMCS= number of millable cane stalk, CY = sugarcane yield

Note: Means for sugarcane growth parameters within a column followed by the same letter are not significantly different from each other at p < 0.05. However, mean values of different letters within a column are indicate significant differences by a > b > c

Keys: ***, **, * and ns indicate very high significant at P < 0.001, high significant at P < 0.01, significant at P < 0.05 and nonsignificant at P > 0.05 respectively.

Similar to the current study findings, the study findings by revealed that both irrigation rate has a significant variation on the growth and yield parameters of sugarcane [19]. The amount of irrigation water applied throughout the sugarcane crop was highly affects the yield and growth parameters, specially, the moisture percentage and dry substance of sugarcane affected by amount of irrigation applied which indirectly affect the other parameters [16]. In the other case, the study findings by indicated that the irrigation rate applied to the sugarcane crop affects the growth parameters like cane height, number of cane internodes, cane diameter than the yield parameters like dry substance, fiber percentage, moisture percentage since irrigation water withhold (stopped) at the later time before harvesting [17]. The study findings by showed that irrigation intervals from the establishment of the crop has a statistically significance on the growth and yield of sugarcane for the plantation cane but it has statistically non-significance variation for ratoon cane crops [20].

The other study findings by showed that the effect of irrigation withholding significantly affects the sugarcane growth parameters and yield [21]. From all parameters, moisture percentage of cane at harvest showed very high significant variation with the same cane variety of the current study. The result of those author showed higher moisture percentage of cane as compared to the current study findings. The study findings by revealed that the total millable cane stack reduced from 25 to 50% reduction from the normal cane stack population due to water logging problems since the late tillering stacks were unable to survive and able to give yield. The other study findings by Raza et al. (2012) revealed that cane yield was significantly affected as the yield directly related to the optimum amount of irrigation water applied [22].

4. Conclusion

Sugarcane is perennial water intensive crop and produced for commercial purpose all over the world. It is a crop which is very sensitive to both high and low water application throughout the growing season. Since the crop is highly demanded and requires more amount of water to produce yield throughout the year in which competition in water resource from other sectors and new irrigation development increased from time to time. But furrow irrigation method is one of the most commonly used method in sugarcane production in Ethiopia like Wonji Shoa Sugar Estate. In the other side, in furrow irrigation there is a high loss of water or less efficiency which requires more amount of irrigation water application to satisfy the crop water requirement of the crop that resulted the adverse effect of the irrigation on crop as well as soil productivity. To overcome those problems, appropriate furrow irrigation design can improve the performance of furrow irrigation and reduces the water losses as well as the adverse effect of irrigation for future production. In the large-scale irrigation conditions like Wonji Shoa Sugar Estate which covers large area, appropriate irrigation design is very important for sustainability of the irrigated area. In line with this, the current field experiment was conducted to evaluate the effect of three furrow irrigation design parameters on sugarcane growth and yield parameters that laid out using split-split plot experimental design replicated three times. All the required data on the growth and yield of sugarcane crop was collected and analysed using SAS 9.4 version. The result obtained showed that the effect of furrow slope showed statistically significance variation on almost all growth parameters of sugarcane at 5% significance level. Similarly, the effect of furrow length showed statistically significant variation on almost all sugarcane growth and yield parameters at the same significance level except cane yield. But the effect of furrow discharge rate on all growth and yield of sugarcane showed statistically significant variation at 5% significant variation. When all those factors compared hight yield was obtained from furrow slope three, furrow length three and furrow discharge one. Therefore, to harvest more yield of sugarcane, slightly slope and longer furrow length with less but appropriate irrigation application is required under Wonji Shoa Sugar Estate conditions.

4. 1. Declarations

Availability of data: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request," in the journal submission question regarding data availability.

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