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Determination of Crop Water Requirements of Sugarcane and Soybean Intercropping at Metahara Sugar Estate

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Abstract

Intercropping of short duration crop with sugarcane is a remunerative practices under different irrigation levels. This study was initiated with the objective of determining and evaluating different irrigation depth and intervals under intercropping of sugarcane with soybean on yield and water use efficiency. The experiment was carried out with three depth of (75, 100 and 125% ET) in combination with three irrigation interval of (7, 12 and 16 days) with three replication of randomized complete block design (RCBD). The result revealed that it was noted highly significant difference among treatment on stalk count, tillering, stalk weight and stalk height with a highest value of 116 × 10^3 ha^{-1}, 126.44 × 10^3 ha^{-1}, 1.89 kg $stalk^{-1}$ and 2.87 cm, respectively at 100% ET Irrigation depth with interval of 7 days, 75%ET irrigation depth with 12 days interval, 75%ET with 7 days and 75% ET irrigation depth with 12 days irrigation interval. However no significant difference was observed among treatments on cane yield, sugar quality parameters and sugar yield. It was observed highly significant difference among treatments on biomass, plant population, pod per plant and seed per pod of soybean while no significant difference was noted on weight of 1000 seeds and soybean yield. Based on the result obtained it was concluded that intercropping is good practices in realizing and achieving a sustainable advantage of farming at different irrigation levels. It is recommended to use the treatment received 75% ET of irrigation depth and 12 days of irrigation interval especially when shortage of water supply is occurred. It has a net benefit cost ratio of with the advantage of 86.47% and 83.34% over the control. For further recommendation of the treatment it is better to verify T4 (75% ET with 12 days), T6 (125% ET with 12 days) and T10 (Conventional) irrigation depth and irrigation interval.

Keywords: Intercropping; Irrigation depth; Irrigation interval; Water use efficiency; Net benefit cost ratio

Introduction

Sugarcane (*Saccharum officinarum* L.) is a long duration and widely spaced crop in comparison with other field crops. It offers a great scope for using its interspace by growing short duration crops thereby helping to harvest the potential productivity. The concept of intercropping is to obtain optimum plant population of companion crops with the adoption of sustainable planting geometry. Intercropping of short duration crop with sugarcane is a remunerative practices [1]. Intercropping has been a common practice in the tropics and it is often the general assumption that intercropping of field crops with sugarcane increases total productivity per unit area of land that lead to increase food production and income. It is the agricultural practice of cultivating two or more crops in the same space at the same time with the aims to match efficiently crop demands to the available growth resources and labor [2]. It helps in maintaining the soil fertility and making efficient use of nutrients and ensures economic utilization of land, labour and capital resources [3]. In the sugar industry, effective utilization of available resource is one of the means to minimize cost of production and maximize profit. Thus in major sugar producing countries like India, Brazil, Australia, Mauritius and South Africa intercropping is considered as one of the management options, especially for small scale farmers with limited land and inputs [4].

Soya bean is a warm season crop and it is one of the important pulse crops cultivated in Ethiopia. Soya bean is most susceptible to drought damage during flowering and grain filling. It performs well in areas where rainfall is more than 700 mm. While sugarcane being a long duration crop producing huge amounts of biomass is classed among those plants having a high water requirement and yet it is drought tolerant. The critical stages for irrigation of sugarcane are formative or vegetative period (tillering and steam elongation) stage. Due to scarcity of water resources, increasing crops productivity and saving irrigation water are the two interrelated issues raising a lot of concern these days. For achieving higher water use efficiency careful use of water resources is essential. Water use efficiency measures the quantity of water taken up by the crop during its crop life to produce a unit quantity of the output i.e., crop yield. In general, the lower the water resource input requirement per unit of crop yield produced, the higher the efficiency [5]. During intercropping the available water has been used more efficiently and more water has been made available due to the interference of deeper penetrating roots of the intercrop. The water use efficiency for harvested yield of soya bean is 4 to 7 kg/ha-mm [6].

The most important times for soybean plants to have adequate water are during pod development and seed fill. These are the stages when water stress can lead to a significant decrease in yield. Stressful conditions, such as moisture deficiency reduces soybean yield. Since the practice of soya bean intercropping with sugarcane is new no research was done on the determination of appropriate depth and interval of irrigation water on soya bean and sugar cane intercropping. Therefore the objective of this research was to determine appropriated depth and interval of irrigation water for intercropped sugarcane and soya bean.

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Objectives

- To determine appropriate depth and interval of irrigation water for soybean-sugarcane intercropping at MSF.
- To evaluate the effect of different irrigation schedules on the yield of soybean intercropping.
- To determine the water use efficiency of the crop under different irrigation depth and interval.

Materials and Methods

Description of the study area

Metahara Sugar Factory is located 200 km from Addis Ababa in the southeast direction. It is situated at 8° 53' N latitude and 39° 52' E longitude at an altitude of 950 meters above sea level (masl). The area has a semiarid climatic condition. Most of soils of the area are Haplic Cambisols and a few are Hypersalic or Haplic Solonchaks because of salinity. The long term climatic condition of the area has a minimum and maximum temperature of 17.36°C and 32.97°C, respectively with the annual rainfall is 533 mm. Whereas the average relative humidity, sunshine hour and wind speed of the area is 77.44%, 8:46 AM, 4.12 respectively.

Experimental design and lay out

The treatments were laid out in randomized complete block design (RBCD) with three replications having three levels of irrigation water depth with three levels of irrigation interval. The experiment was based on daily evapotranspiration of the estates with the value of 75%, 100% and 125% of the irrigation water requirement and an interval of 7, 12 and 16 days respectively. The irrigation water requirement was calculated from the irrigation schedule of Methara and arranging the irrigation interval by a systematic method. The plot size was 14.5 m width (10 furrows) and 10 m furrow length with furrow spacing of 1.45 m. The middle eight furrows were used as net plot furrows for data collection. Space between plots was 2 m while 2 furrows between replications.

Crop establishment and management

Sugarcane was planted on 04 April 2013 whereas soybean was planted after 15 days of the major crop was planted on 19 April 2013. The varieties used were B52-298 for sugarcane and Williams for soya bean, respectively. Soybean was sowing double row at side of ridges and sugarcane was planted in furrows.

Irrigation practice

Equal amount of shallow irrigation was applied to every furrow of each treatment in each plot two days before planting as well as frequently for 15 days to encourage a full and even plant stand at the time of emergence. Treatments application was started the moment soya bean was sown and irrigation was stopped for furrow irrigation systems, two inches parshall flume was installed at the inlet of experimental plots for measuring the amount of water applied for each plot. At each volume of water applied for each plot of a given interval, the height of water in the parshall flume was measured using a ruler. Each depth of water passing through the parshall flume has known amount discharge rate in litter per second.

Water use efficiency (WUE)

Field water use efficiency is a ratio between marketable crop yield and field water supply which includes water used by the plant in metabolic activities, ET and deep percolation losses [5].

$$WUE = \frac{Y}{WR}$$

Where,

- WUE=Field water use efficiency, kg/ha-mm
- Y=Crop yield, kg/ha
- WR=Water used in metabolic activities, ET and deep percolation losses, mm.

Data collection

The major sugarcane and soybean yield and yield components had been collected following the standard procedure of data collection. The data for sugarcane encompasses stalk count, tillering, length, cane yield, sucrose percent, pol (%), Brix (%) and juice purity and sugar yield whereas the data for soybean were plant population count, number of pods/plant, number of seeds/pod, weight of 1000 seeds, aboveground biomass and yield.

Data analysis

The result of analysis was subjected and analyzed by SAS software 9.1 version [7] to saw the effect of among the treatments.

Results and Discussion

Effect of different irrigation depth and interval on sugarcane response under intercropping with soybean

The result depicted in Table 1, stalk count showed highly significant difference ($P<0.01$) among treatments and it was noted a maximum of 116 × 000 ha^{-1} the treatment received the 100%ET and an Irrigation interval of 7 days as compared with the controlled T10. The highest tiller count (126.44 × 10^3 ha^{-1}) was observed at the treatment having a combination of an irrigation depth of 75% ET and 12 days interval followed (125.58 × 000 ha^{-1}) with irrigation depth of 75%ET and 16 days. To this effect, it was observed no significant relationship among treatments on sugarcane yield though it was noted a numerical difference. These results are in agreement with the findings of Hossain [8]. Whereas the smallest tiller count (111.81 × 000 ha^{-1}) was noted at the treatment received 125% ET of irrigation depth and 16 days of irrigation interval and this might be due to the presence of waterlogging by the application of high irrigation water which hinders the sprout of the tillering. Similarly it was observed highly significant difference on the stalk weight of sugarcane while comparing with the controlled practice with the highest stalk weight of 1.89 kg per stalk at 75% ET and 7 days of irrigation interval. This might be due to less competition of the tillering in utilization of the applied water. Even though there were no significant relationship observed on stalk height between the treatment having the maximum value and the controlled, it was

Treatment	Irrigation depth, % ET	Irrigation Interval, days
T1	75	7
T2	100	7
T3	125	7
T4	75	12
T5	100	12
T6	125	12
T7	75	16
T8	100	16
T9	125	16

Table 1: Treatment combination.

noted that highest stalk height (T4=2.84 cm) at the treatment with an irrigation depth of 75% ET and 12 irrigation interval.

Brix (%): Irrigation depths in combination with irrigation intervals had no significant effect on brix percent at different treatments which was shown in Table 2. Even though no significant difference among treatments it was noted highest brix per cent (19.11%) at the treatment received an irrigation depth of 75% ET with 16 days of irrigation interval as compared with the controlled. While the lowest brix percentage (17%) was observed at irrigation depths of 75% ET and 7 days of irrigation intervals.

Pol (%): Table 2 showed no significant difference among treatments but numerically it was seen that highest pol percent at (T4=17.29%) with an irrigation depth of 75% ET and 12 days of irrigation intervals while lowest was observed at (T1=15.98) with an irrigation depth of 75% ET and 7 irrigation intervals.

Purity (%): Irrigation depths in combination with irrigation intervals had shown significant effect on purity percent among all treatments which was shown in Table 2. The treatment received an irrigation depth of 100% ET with 7 days of irrigation interval revealed highest purity (92.14%) as compared with the controlled. This might be due to the presence of low soluble solids in the sugar cane. While the lowest purity percentage (89.31%) was observed at irrigation depths of 75% ET and 7 days of irrigation intervals. This result is in consonance with the findings of MS Rahman [8]. Though it was observed no significant variation among treatments, the highest sugar yield was noted at an irrigation depth of 75% ET and 12 days of irrigation intervals.

Effect of soybean as influenced by different irrigation depth and interval under intercropping of sugarcane

Table 3 revealed that highly significant difference in biomass of soybean among treatments of different irrigation depth and interval under intercropping. The highest biomass (20.95 Qt ha^{-1}) was seen the treatment received 125% ET and an irrigation interval of 16 and the lowest (15.34 Qt ha^{-1}) was observed. Similarly, it was observed highly significant difference among treatments on plant population, pod per plant and seed per pod. On the contrary, no significant difference was seen both weight of 1000 seed and yield of soybean at different levels of irrigation depth and irrigation intervals under intercropping with sugarcane.

Overall performance of the water use efficiency of the crops

It was observed a highly significant difference on the water use efficiency of sugarcane while intercropped with soybean as depicted on the Table 1. The highest water use efficiency of sugarcane (906.75 kg/ha-mm) was noted on the treatment received 75% ET of irrigation depth and 12 days of irrigation interval while the smallest was 442.79 Kg/ha-mm on the treatment received at 125% ET irrigation depth and 16 intervals of irrigation. This might be due to less completion of the tillering during the extraction of the water. Similarly, Table 3 revealed highest significant difference with the highest water use efficiency of (1.35 kg/ha-mm) on the treatment received 75%ET irrigation depth and 7 days of irrigation interval but it was noted a smallest water use efficiency (0.69 kg/ha-mm) on the treatment 125% ET irrigation depth and 7 days interval (Tables 4 and 5).

Partial budget analysis

The net benefit cost ratio (NBCR) under intercropping of sugarcane at different irrigation levels was ranged between 2.34 to 2.81. It was observed the highest at the treatment received 75% ET and 12 days of irrigation inter while the lowest was on the treatment of 125% ET of irrigation depth and 7 days interval. This might be due to the reason that the highest return achieved by the good practice of the intercropping of sugarcane with soybean. The higher NBCR was noted at (T4=2.81 and T6=2.72) with an irrigation depth of 75% ET and 12 days of irrigation intervals in 125% ET and 12 days irrigation interval. This might be due to the advantage of higher water use efficiency by both crops and less application cost of the irrigation water. Similarly, it might be due to higher sugar yield 20.71 t ha^{-1} of the former treatment.

Conclusions and Recommendation

From this study, the highest tiller count (126.44 × 103 ha^{-1}) was observed at the treatment having a combination of an irrigation depth of 75% ET and 12 days interval. It has an advantage of having a tiller with an increasing order of T9>T1>T8>T3>T6>T5>T2>T7 and T4 with 76.54, 79.23, 80.94, 81.91, 82.37, 83.44, 83.72, 85.96, 86.55% as compared with the controlled. Similarly the highest cane yield 170.36 t/ha was observed though there was no significant difference among treatment with same irrigation intervals. The treatment received an irrigation depth of 100% ET with 7 days of irrigation interval revealed highest purity (92.14%) as compared with the controlled. Though no significant difference among treatments it had highest sucrose percent (12.14%) with an irrigation depth of 75% ET with 7 days of irrigation

Treatments	Stalk Count (x'000 ha^{-1})	Tillering (x'000 ha^{-1})	Stalk height (cm)	Stalk weight (Kg/ stalk)	Cane Yield(t/ha)	Water use efficiency (Kg/ha-mm)
T1	110.26^{c}	115.75^{de}	2.76^{abc}	1.89^{a}	166.99	817.79^{ab}
T2	116.00^{bc}	122.30^{bcd}	2.52^{bc}	1.66^{abc}	153.80	625.25^{cd}
T3	115.26^{bc}	119.66^{bcde}	2.78^{ab}	1.69^{abc}	156.08	459.91^{def}
T4	116.87^{abc}	126.44^{b}	2.87^{a}	1.82^{a}	170.04	906.75^{a}
T5	115.11^{bc}	121.90^{bcd}	2.73^{abc}	1.74^{abc}	159.89	598.79^{cde}
T6	117.36^{abc}	120.34^{bcd}	2.84^{a}	1.82^{a}	170.36	530.20^{cde}
T7	121.15^{ab}	125.58^{bc}	2.48^{c}	1.48^{c}	145.25	675.03^{bc}
T8	117.56^{abc}	118.25^{cde}	2.67^{abc}	1.76^{abc}	165.44	540.01^{cde}
T9	116.98^{abc}	111.81^{e}	2.79^{ab}	1.79^{ab}	168.34	442.79^{ef}
T10	125.98^{a}	146.09^{a}	2.80^{ab}	1.49^{bc}	150.78	319.05^{f}
Mean	117.25	122.81	2.72	1.71	160.70	591.54
CV (%)	4.77	3.81	6.04	10.28	11.76	17.30
Significance level	**	**	**	**	ns	**
LSD (0.05)	11.15	9.32	0.28	0.30	32.42	175.63

Table 2: Effect of Cane yield under intercropping of Sugarcane with soybean as affected by different irrigation depths and intervals.

Treatments	Pol (%)	Brix (%)	Purity (%)	Sugar Yield (t/ha)
T1	15.98	17.88	89.31^{ab}	18.67
T2	17.28	18.76	92.14^{a}	19.04
T3	16.17	18.11	89.28^{ab}	17.50
T4	17.29	19.05	90.76^{ab}	20.71
T5	16.37	18.37	89.12^{ab}	18.23
T6	17.04	19.10	89.18^{ab}	20.19
T7	17.19	19.11	89.97^{ab}	17.62
T8	16.54	18.83	87.87^{b}	18.79
T9	16.28	18.17	89.30^{ab}	19.26
T10	17.46	19.30	90.47^{ab}	18.50
Mean	16.75	18.66	89.73	18.85
CV (%)	6.32	5.26	2.01	16.10
LSD (0.05)	1.82^{ns}	1.68^{ns}	3.10	5.206^{ns}

NB: Treatments in the same column having the same letters are not significantly different but with different letters are significant at P=0.05

Table 3: Response of Sugar yield under intercropping with soybean as affected by different irrigation depths and intervals.

Treatments	Biomass (Qt/ha)	Plant population	Pod/plant	Seed/pod	Wt of 1000 seed	Yield (kg/ha)	Water use efficiency (Kg/ha.mm)
T1	17.54^{ab}	388.77^{b}	31.57^{ab}	2.31^{d}	103.70	309	1.35^{a}
T2	19.95^{ab}	671.67^{a}	34.95^{a}	2.40^{abcd}	107.43	264	0.87^{bc}
T3	16.57^{ab}	664.33^{a}	19.59^{b}	2.36^{bcd}	111.10	266	0.69^{bc}
T4	19.12^{ab}	617.33^{a}	24.46^{ab}	2.56^{a}	106.93	294	1.28^{a}
T5	15.34^{b}	598.00^{a}	21.94^{ab}	2.35^{cd}	110.27	256	0.84^{bc}
T6	15.61^{ab}	588.67^{a}	21.27^{b}	2.51^{abc}	119.53	216	0.56^{c}
T7	18.07^{ab}	635.00^{a}	22.84^{ab}	2.54^{ab}	106.53	266	1.02^{ab}
T8	19.89^{ab}	656.33^{a}	26.44^{ab}	2.33^{cd}	105.07	299	0.86^{bc}
T9	20.95^{ab}	695.33^{a}	25.61^{ab}	2.24^{d}	102.43	334	0.78^{bc}
Mean	18.11	612.82	25.40	2.40	108.11	280	0.92
CV (%)	17.27	17.70	30.64	4.58	9.23	25.99	25.02
Significance level	*	*	*	*	Ns	Ns	*
LSD(0.05)	5.41	13.48	13.48	0.19	17.28	126	0.39

NB: Treatments in the same column having the same letters are not significantly different but with different letters are significant at P=0.05

Table 4: Response of Soybean yield and yield attributing components under intercropping of Sugarcane as affected by different irrigation depths and intervals.

Treatments	Net return, birr	Gross Benefit Cost Ratio (GBCR)	Net Benefit Cost Ratio (NBCR)
T1	212857	4.16	2.52
T2	217377	3.59	2.56
T3	195041	3.37	2.34
T4	242490	3.83	2.81
T5	205745	3.47	2.46
T6	233471	3.74	2.72
T7	197050	3.39	2.37
T8	214733	3.56	2.55
T9	222131	3.64	2.62
T10	204991	3.46	2.43

Table 5: Partial budget analysis of sugarcane with soybean intercropping at different irrigation levels.

interval. Biomass of soybean revealed highly significant difference in among treatments of different irrigation depth and interval under intercropping. The highest biomass (20.95 Qt ha^{-1}) was seen the treatment received 125% ET and an irrigation interval of 16 and the lowest (15.34 Qt ha^{-1}) was observed. While highest soybeans yield (334 Kg ha^{-1}) was noted at 125% ET of irrigation depths and 16 days of irrigation intervals. Based on the result obtained it was concluded that intercropping is good practices in realizing and achieving a sustainable advantage of farming at different irrigation levels. It is recommended to use the treatment received 75% ET of irrigation depth and 12 days of irrigation interval especially when shortage of water supply is occurred. For further recommendation of the treatment it is better to verify T4 (75% ET with 12 days), T6 (125% ET with 12 days) and T10 (Conventional) irrigation depth and irrigation interval.

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