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Optimizing Tillage and Irrigation Requirements of Sorghum in Sorghum-Pigeonpea Intercrop in Hamelmalo Region of Eritrea

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Abstract

Sorghum (*Sorghum bicolor* L. Moench) is cultivated as monocrop in Eritrea. Efforts were made to grow sorghum-pigeonpea (*Cajanus cajan* L. Millspp.) intercrop on the tillage, fertilizers and supplementary irrigations necessary for sorghum. Experiments were conducted in terraced fields at Hamelmalo during 2013-15 to evaluate growth and yield of sorghum-pigeonpea intercrop in split plot design with conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT) in main plots and rainfed (I_0), 50% of full irrigation (I_1), 75% of full irrigation (I_2) and 100% of full irrigation (I_3) in subplots. All irrigations were stopped 15 days before sorghum maturity. Full irrigation was 60 mm applied at 50% depletion of available soil water in 1 m profile. Sorghum growth was faster than pigeonpea until 85 days from planting and pigeonpea growth accelerated only after sorghum harvesting. About 80% of sorghum roots were within 0.6 m profile but more than 75% of pigeonpea roots were below 0.60 m depth. This showed a weaker competition between the two crops for nutrients, water and light. Both grain and stover yields of sorghum were optimum in RT + I_2 during the 2 years. Highest grain yield was 6900 kg·ha^{-1} in RT + I_3 in 2013, which was at par with that in RT + I_2. Mean residual soil moisture at sorghum harvesting was 74 mm·m^{-1}, which decreased to 8 mm·m^{-1} by pigeonpea harvesting. Residual moisture was more in the irrigated than non-irrigated plots. Pigeonpea yields were optimum (1363 kg·ha^{-1}) in RT + I_3 and lowest (297 kg·ha^{-1}) in ZT + I_0. Average water use by sorghum-pigeonpea was 374 mm by sorghum harvesting and 438 mm by pigeonpea harvesting, producing total sorghum equivalent yield of 7475 kg·ha^{-1}. This raised average water use efficiency from 12.6 kg·ha^{-1}·mm^{-1} at sorghum harvesting to 17.1 kg·ha^{-1}·mm^{-1} at pigeonpea harvesting. Benefit was doubled at 50% of full irrigation and >4 times at 75% of full irrigation.

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Keywords

Residual Soil Moisture, Sorghum-Pigeonpea Intercrop, Supplementary Irrigation, Water Use Efficiency

1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a major crop of Eritrea contributing about 46% of the total cereal production [1]. However, its productivity has been below 0.6 t·ha^{-1} due to improper rainwater management, lack of available soil moisture at grain filling stages, low inputs and poor soil and crop management [2] [3]. Sorghum yields could be optimized through adoption of rainwater management and conservation tillage practices [3]-[6] and minimizing risks due to agricultural droughts through supplemental irrigations [7]-[10]. Water stress at vegetative stage alone reduced sorghum yields more than 36% and that during boot to reproductive stages more than 55% [11]. Sivakumar *et al.* [12] observed that two irrigations increased sorghum yields from 2430 - 5990 kg·ha^{-1}. Single 50 mm irrigation from runoff harvesting in the watershed increased sorghum yields from 2570-3570 kg·ha^{-1} [13] [14].

Among the crop production factors, tillage contributed about 20% to the economic yield [15] through optimization of conditions for germination, seedling establishment and crop growth [14] [16]. Reduced or zero tillage also provided most of these services [17] together with increased carbon and nitrogen storage and soil aggregate stability [3] [18]-[20]. West *et al.* [21] observed 50% - 67% higher water-stable aggregates in soil under zero than conventional tillage. Bear *et al.* [22] observed that micro-aggregates (<2.5 mm) in soil under zero tillage were 21% - 65% higher than under conventional tillage. Mean weight diameter of aggregates increased by 16% in 5 years of zero tillage [23]. A positive correlation was observed between aggregate stability and total soil organic carbon [23]-[26]. Both dry-and water-stable aggregates in soil were better under zero tillage than conventional tillage [27]-[29]. Most farmers in Hamelmalo region till thrice before sorghum planting, which needs to be optimized for reducing not only the cost of cultivation but also land degradation. Canadian studies have shown significantly higher yields (2.8 t·ha^{-1}) without nitrogen applications after 20 years of zero tillage with full stubble retention [30]. Protein content of grains was much higher under zero than conventional tillage.

Rainfed sorghum is open to serious risks due to water stress during critical growth stages and agricultural droughts. Assured sorghum yields of about 4 t·ha^{-1} were possible by irrigating once in the terraced plots leaving significant amount of residual soil moisture [4] [6]. Intercropping of pigeonpea would be step towards achieving food security and soil quality improvements. Soils of Anseba region are deep alluvium, medium to coarser in texture but rainwater rapidly runs off due to highly sloping traditional cultivated fields and that infiltrating percolates beyond the crop root zone in the terraced fields [3] [4] accelerating agricultural droughts. About 80 - 150 mm residual moisture per 2 m of soil profile was observed at sorghum harvesting in the well managed watersheds ensuing zero runoff [4]-[6]. Considerable residual soil moisture at sorghum harvesting in managed watersheds provided opportunity for growing a legume intercrop like pigeonpea of shorter duration with sorghum that could survive on the residual moisture [4]. Pigeonpea grows slowly during the early vegetative phase and because of its longer duration and deep rooting character to exploit residual moisture, it is eminently suitable as intercrop that does not adversely affect the yield of sorghum [31]-[35]. Gwata and Shimelis [36] reported that Eastern Africa is secondary centre of diversity for pigeonpea. Crop duration ranged from 130 days (short) to 150 days (medium), or 180 days (long). It can produce 2.5 - 5 t dry peas ha^{-1} and provide 4 - 8 t·ha^{-1} of stalk for thatch building material, fuel wood and fodder [37] [38]. Pigeonpea adds substantial amount of organic matter in soil and can fix up to 235 kg N ha^{-1} [38] [39]. Pigeonpea produces more N per unit area from plant biomass than many legumes. Pigeonpea intercropped with sorghum fixed 35.94 - 164.82 kg N ha^{-1} [40]. Pod borer infestation is a major problem in pigeonpea, which is greatly controlled by harbouring and nourishing of its predator *Trichogramma* spp. in sorghum-pigeonpea intercrop [41]. Intercropping with sorghum reduced wilt incidence in pigeonpea [20]. Vijayalskshmi *et al.* [42] reported that supplemental irrigations increased sorghum-pigeonpea yields by 560%. Supplementary irrigations not only improved sorghum yields but also facilitated stored rainwater use efficiency and residual soil moisture use by pigeonpea [5]. Objective of this research was thus to optimize tillage and supplementary irrigations for sorghum in sorghum-pigeonpea intercrop and demonstrate the possibility of raising pigeonpea on the inputs applied for sorghum.

2. Materials and Methods

2.1. Soil

The experimental soil was sandy loam comprising of 60% sand, 29.5% silt and 10.5% clay in block C of the model watershed at Hamelmalo Agricultural College (15˚52'20.6"N and 38˚27'57.6"E at 1280 msl), in the semiarid region of Eritrea. Annual rainfall in the past seven years ranged from 370 - 663.1 mm with a mean of 488 mm and average annual pan evaporation of 1931 mm. Highest mean monthly temperature occurred in May (35.7˚C) and lowest in January (11.1˚C). Total rainfall was 388 mm in 2013 and 429 mm in 2014 (**Figure 1**).

The soil was non-saline (EC 0.18 $dS{\cdot}m^{-1}$) with pH of 8.2 and average bulk density of 1.5 $Mg{\cdot}m^{-3}$ (**Table 1**). Field capacity and wilting points of soil were 0.175 and 0.053 $m^3{\cdot}m^{-3}$, respectively. The organic matter content was 0.27% and available N was 0.05%. The available P and K were 0.88 $mg{\cdot}kg^{-1}$ 0.25 $cmol{\cdot}kg^{-1}$, respectively.

2.2. Treatments

The experiment was conducted in split plot design with three tillage treatments viz., conventional tillage (CT), reduced tillage (RT) and zero tillage (ZT) in main plots and four irrigation treatments viz., rainfed (I_0), 50% of full irrigation (I_1), 75% of full irrigation (I_2) and full irrigation (I_3) in subplots in three replications. CT refers to three passes of traditional bullock-drawn plough followed by row planting and RT refers to one pass of bullock-drawn plough 4 days after heavy rainfall followed by row planting. Zero tillage (ZT) was direct planting in rows. Full irrigation was 50% depletion of available soil water in 1 m profile. All irrigations were stopped 15 days before sorghum maturity. Each subplot was 4.0 m × 4.5 m, separated by 2 m passage. Bunds of width 0.4 m and height 0.3 m were formed around each plot to avoid any runoff or run-on.

Sorghum variety *ICSV* 210 (*BUSHUKA*) and pigeonpea variety *ICEAP* 00040 were planted at a seed rate of 12 and 10 $kg{\cdot}ha^{-1}$, respectively, on July 7 in 2013 and July 14 in 2014 in alternate rows, 0.375 m apart. The

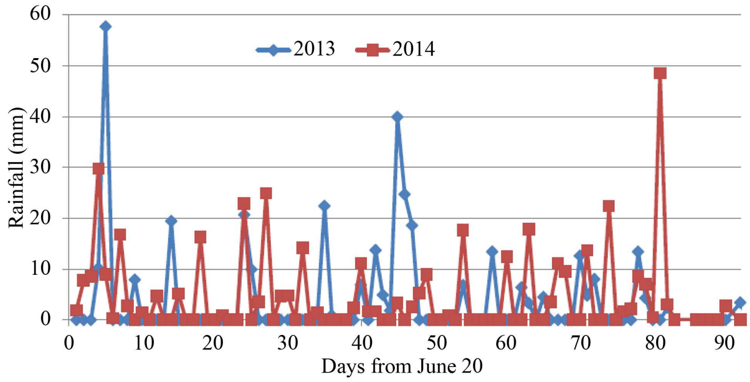

Figure 1. Rainfall during the crop season of 2013 and 2014 at Hamelmalo.

Table 1. Properties of the experimental soil.

Depth, m	Soil Fractions, %			Texture	pH (1:5)	EC $dS{\cdot}m^{-1}$	OM, %	N, %	P, mg kg^{-1}	Exchangeable Cations, cmolc kg^{-1}			
	Sand	Silt	Clay							Ca^{++}	Mg^{++}	K^+	Na^+
0 - 0.2	83	11	6	Loamy sand	7.8	0.08	0.65	0.06	9.32	11.5	3	0.15	0.35
0.2 - 0.5	70	14	16	Sandy loam	8.2	0.08	0.42	0.05	3.71	15.0	5	0.10	0.47
0.5 - 0.3	61	20	19	Sandy loam	8.2	0.14	0.42	0.05	2.91	20.0	5	0.14	0.55
>1.3	89	7	4	Sand	8.4	0.15	0.32	0.04	3.61	29.0	8	0.11	0.51

sorghum was planted at a distance of 0.2 m and pigeonpea at 0.4 m within rows. Fertilizers applied were DAP at 100 kg·ha^{-1} before sowing and urea at 50 kg·ha^{-1} at 25 and 45 days from planting recommended for sorghum by National Agricultural Research Institute, Halhale, Eritrea. Hand weeding was done before topdressing urea. Soil moisture was determined gravimetrically by sampling 0.05 m length and diameter soil core from the midpoint of 0.25 m depth increment down to 1 m at sowing and 20 days interval until first week of September and at 10 days interval thereafter to determine irrigation date. Irrigation day was at 50% depletion of available soil moisture in 1 m profile. Net irrigation was 60 mm in I_3 (full irrigation), 45 mm in I_2 (75% of full irrigation) and 30 mm in I_1 (50% of full irrigation) applied on September 11 and 21 and October 2 in 2013 and September 24 and October 4 in 2014. Hand weeding was done twice and CARBARAYL insecticide was applied two times @ 2 g per litre of water to control pod borer. Grain and stover yields were determined by harvesting central 3 m × 3 m area and threshing manually. Pigeonpea was harvested when over 80% of the pods become brown. The grain was dried to 14% moisture.

2.3. Water Use

Crop water use (ET, mm) was determined using water balance equation as

$$\mathrm{ET} = \mathrm{RF} + \mathrm{SI} \pm \Delta\mathrm{S} - \mathrm{DP} - \mathrm{RO} \tag{1}$$

where RF is rainfall, mm, SI is supplemental irrigation, mm, ΔS is change in soil moisture storage, mm, DP is deep percolation, mm, and RO is runoff, mm. Both DP and RO were zero because all plots were well bunded and storm rainfall never exceeded available water storage capacity of the root zone.

2.4. Root Length Density

Root length density (RLD) was determined at harvesting of the two crops by line intersection method of Tennant [43]. Root samples were drawn from each treatment in 0.15 m soil depth increments down to 1.2 m by placing 0.1 m diameter root sampler on the harvested hill. Root samples were collected in plastic bags for saturation overnight followed by washing in soil-root wash basin. Soil-root mixture in the wash basin was stirred to disperse roots and water was supplied continuously to allow suspended roots to pass through the drain pipe into the sieves arranged in the order of 2, 0.650, and 0.355 mm. Roots were randomly spread by tweezers in a dish containg a film of water and number of roots with vertical and horizontal grid lines of 10 mm were counted and RLD (cm·cm^{-3}) was calculated as

$$\mathrm{RLD} = \frac{R}{V} \tag{2}$$

where R is root length, cm, expressed as

$$R = \frac{11}{14} N \text{ Grid units} \tag{3}$$

where N is number of intersections and V is soil core volume, cm^3. Percent root distribution was calculated as

$$\%\ \text{Root distribution} = \frac{\text{RLD in ith layer}}{\text{Total RLD}} \tag{4}$$

2.5. Sorghum Equivalent Grain Yield

The sorghum equivalent grain yield (SEY) was calculated to express total yield in terms of sorghum for sorghum-pigeonpea intercrop. The SEY was based on per kg market price of the two crops using the relation:

$$\mathrm{SEY} = \mathrm{Ys} + (\mathrm{MRp}/\mathrm{MRs}) \times \mathrm{Yp} \tag{5}$$

where Ys is sorghum yield (kg·ha^{-1}), MRp is market rate of pigeonpea (Eritrean NKF kg^{-1}), MRs is market rate of sorghum (Eritrean NKF kg^{-1}), and Yp is pigeonpea yield (kg·ha^{-1}). Prevailing market price of the crops kg^{-1} was collected from the open market in ERN (Eritrean Nakfa). Pigeonpea is not common in Eritrea but it is one of the costliest pulses in the international market and, therefore, Its market price was considered twice that of the sorghum.

3. Results and Discussion

3.1. Growth Pattern of Sorghum and Pigeonpea

Sorghum vegetative growth was relatively better in CT and RT plots than in ZT, perhaps because ZT was more affected by weeds in the initial establishment period. Irrigations were applied from reproductive phase. Sorghum growth was faster than pigeonpea during the initial 85 days from sowing although both were planted on the same date (**Figure 2**). Pigeonpea grew faster only after sorghum harvesting in 115 - 120 days and thus did not compete with sorghum crop in the initial stages. At sorghum harvesting, only 3% of pigeonpea plants were approaching flowering. Pigeonpea is known to lack synchronous flowering and maturity. However, variety planted in the experiment appears to be wilder type because flowering and maturity continued for several months after sorghum harvesting. Pigeonpea plants survived green even beyond March but net plot was harvested by end of January. Shorter duration improved pigeonpea varieties are now available and would be better option.

3.2. Rooting Pattern of Sorghum and Pigeonpea

About 80% sorghum roots in sorghum-pigeonpea intercrop were within 0.6 m soil profile, of which more than 60% were in the top 0 - 0.20 m layer (**Figure 3**). On the contrary, more than 75% pigeonpea roots were below 0.60 m depth in the soil. Rooting patterns of sorghum-pigeonpea intercrop thus have a weak competition between them for water and nutrient extraction zone in the soil profile.

3.3. Grain yield of Sorghum

Mean sorghum yields due to tillage were not significant in both the years (**Table 2**). But mean yields due to supplementary irrigations were significantly greater in I_2 than in I_1 both in 2013 and 2014. Yields were at par in

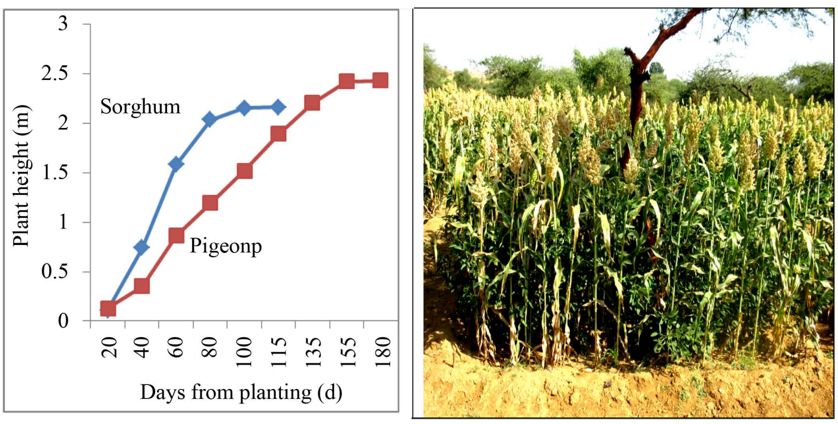

Figure 2. Average growth pattern of sorghum and pigeonpea.

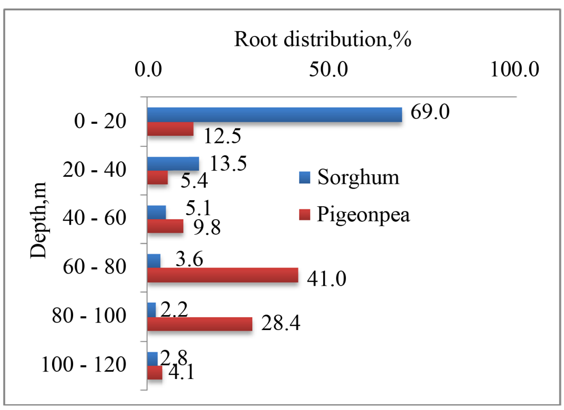

Figure 3. Average root distribution patterns of sorghum and pigeonpea.

I_2 and I_3. Interaction of tillage and irrigations showed that grain yields in RT + I_2 and RT + I_3 were at par in both the years and significantly greater than in RT + I_1. However, despite more and better distributed rainfall in 2014 yields were lower than in 2013 except in I_0. Decreasing trends in yield indicate growing deficiency of nutrients other than applied N and P. Potassium deficiency symptoms were common.

3.4. Stover Yield of Sorghum

Mean stover yields were independent of tillage but were significantly higher in I_2 and I_3 than in I_1 (**Table 3**). Interaction effects showed significantly higher yields in RT + I_3 in 2013 and in RT + I_2 in 2014. Halving *et al.* [20] also observed greater stover production in sorghum due to improved nutrient uptake.

3.5. Grain and Stalk Yields of Pigeonpea

Two-year average grain and stalk yields of pigeonpea are shown in **Table 4**. Mean grain yields of pigeonpea due to tillage were significantly higher in CT (1098 kg·ha^{-1}) and that due to irrigations were higher in I_3 (1271 kg·ha^{-1}). Increases in yields were 215% in I_1 from I_0 and 153% in I_2 from I_1. Interaction effects showed that pigeonpea yields increased significantly with irrigations for sorghum in ZT and RT. Yields were at par in CT + I_2 and RT + I_3. Since all inputs such as tillage, fertilizers and irrigations were applied based on requirements for sorghum, possibility of raising pigeonpea on residual soil moisture in sorghum-pigeonpea intercrop are promising.

Table 2. Grain yield of sorghum under different tillage and irrigations.

Tillage	Grain Yield (kg·ha^{-1}) in 2013 under					Grain Yield (kg·ha^{-1}) in 2014 under				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
ZT	1700	4300	5700	5400	4200	2833	4222	5389	4667	4278
RT	2600	4700	6200	6900	5100	3556	4222	5444	5389	4653
CT	2600	5000	6600	6600	5200	3333	3778	4889	4944	4236
Mean	2300	4600	6100	6200		3241	4074	5241	5000	
Factors	T	I	T × I			T	I	T × I		
LSD, 5%	NS	467	989			NS	458	1217		

Table 3. Stover yield of sorghum under different tillage and irrigation levels.

Tillage	Stover Yield (kg·ha^{-1}) in 2013 under					Stover Yield (kg·ha^{-1}) in 2014 under				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
ZT	1811	4744	8222	8033	5700	4000	4889	6111	8111	5778
RT	2633	5444	9522	11033	7156	4222	6611	9611	9056	7375
CT	2667	5811	7811	9189	6367	4944	5889	8222	6833	6472
Mean	2367	5333	8522	9422		4389	5796	7981	8000	
Factors	T	I	T × I			T	I	T × I		
LSD, 5%	NS	1078	2866			1994	9552	2153		

Table 4. Two-year average grain and stalk yields of pigeonpea under different tillage and irrigations to sorghum.

Tillage	Grain Yield (kg·ha^{-1}) under Iirrigations					Stalk Yield (kg·ha^{-1}) under Irrigations				
	I_0	I_1	I_2	I_3	Mean	I_0	I_1	I_2	I_3	Mean
ZT	297	556	881	1046	694	2011	3556	4000	4444	3511
RT	322	500	1074	1363	814	2122	2911	4378	5222	3644
CT	409	1156	1422	1406	1098	2000	5556	5778	5333	4700
Mean	342	737	1126	1271		2044	4022	4722	5000	
Factors	T	I	T × I			T	I	T × I		
LSD, 5%	117	97	167			389	511	822		

Mean stalk yields of pigeonpea due to tillage were significantly higher under CT than ZT and RT (**Table 4**) and that due to irrigations were significantly higher under I_2. Interaction effects showed significantly higher stalk yield in RT + I_3. Since sorghum is main crop and water is a most limiting factor of crop production in Eritrea, RT + I_2 would be better choice.

3.6. Sorghum Equivalent Grain Yield

Mean sorghum equivalent grain yields due to tillage were at par in RT and CT but significantly greater than in ZT (**Table 5**). However, mean sorghum equivalent yields (SEY) due to irrigations increased significantly from I_0 to I_3. Interaction effects showed that yields were at par in RT + I_3, CT + I_2 and CT + I_3. Since sorghum was the main crop for which RT was most optimum, the choice would go for RT + I_2, which was the next best tillage + irrigation combination. Choice for I_3 should depend on availability of irrigation resources with the farmer.

3.7. Residual Soil Moisture

Mean residual soil moisture at sorghum harvesting increased from 60 $mm \cdot m^{-1}$ under rainfed to 80 $mm \cdot m^{-1}$ under 75% of full irrigation (**Table 6**). Results thus show that supplementary irrigations to optimize sorghum yields leave considerable quantity of residual moisture, which can be used by the pigeonpea crop. About 85% - 90% of residual moisture was consumed by pigeonpea.

3.8. Water Use by Sorghum + Pigeonpea and Water Productivity

Water use by sorghum-pigeonpea intercrop was almost independent of tillage but increased with irrigations (**Table 7**). Highest water use was recorded in RT + I_3 (522 mm) and lowest in ZT + I_0 (276 mm). Average water use by sorghum-pigeonpea was lowest (366 mm) under RT and highest (440 mm) under CT.

Production function showed that sorghum equivalent yield increased with water use rapidly to 9363 $kg \cdot ha^{-1}$ for which water use was 478 mm (**Figure 4**). At harvesting of pigeonpea mean water use increased to 438 mm from 374 mm at sorghum harvesting. As shown in **Figure 5**, sorghum yield of 6600 $kg \cdot ha^{-1}$ and pigeonpea yield of 1422 $kg \cdot ha^{-1}$ could be obtained by water use of 478 mm. The water use efficiency was maximum (19.6 $kg \cdot ha^{-1} \cdot mm^{-1}$) in CT+$I_2$ and minimum (6.8 $kg \cdot ha^{-1} \cdot mm^{-1}$) in ZT + I_0.

Table 5. Sorghum equivalent grain yield under different tillage and supplementary irrigations.

Tillage Treatments	Sorghum Equivalent Yield ($kg \cdot ha^{-1}$) under Irrigations				Mean
	I_0	I_1	I_2	I_3	
ZT	2315	5445	7430	7536	5681
RT	3237	5815	8315	9633	6750
CT	3374	7348	9363	9441	7382
Mean	2975	6203	8369	8870	
Factors	T	I	T × I		
LSD (p = 0.05)	914	472	1014		

Table 6. Residual soil moisture ($mm \cdot m^{-1}$).

Tillage Treatments	Residual Moisture (mm) at Harvesting of Sorghum (1^*) and Pigeonpea (2^*) under							
	I_0		I_1		I_2		I_3	
	1^*	2^*	1^*	2^*	1^*	2^*	1^*	2^*
ZT	6.47	0.00	7.7	0.00	7.8	0.00	7.70	2.30
RT	5.70	0.90	6.90	0.80	8.00	1.63	7.10	0.93
CT	5.90	0.00	7.30	0.00	8.10	0.50	8.30	2.80
Mean	6.00	0.30	7.30	0.27	8.00	0.70	7.70	2.00

Table 7. Water use by sorghum + pigeonpea under different tillage and irrigations.

Tillage Treatments	Water Use (mm) by Sorghum + Pigeonpea under Irrigations								Mean	
	I_0		I_1		I_2		I_3			
	1*	2*	1*	2*	1*	2*	1*	2*	1*	2*
ZT	276	341	349	426	406	484	445	498	369	437
RT	290	338	365	426	350	464	460	522	366	437
CT	291	350	360	433	402	478	446	501	375	440
Mean	286	343	358	428	386	475	450	507	370	438

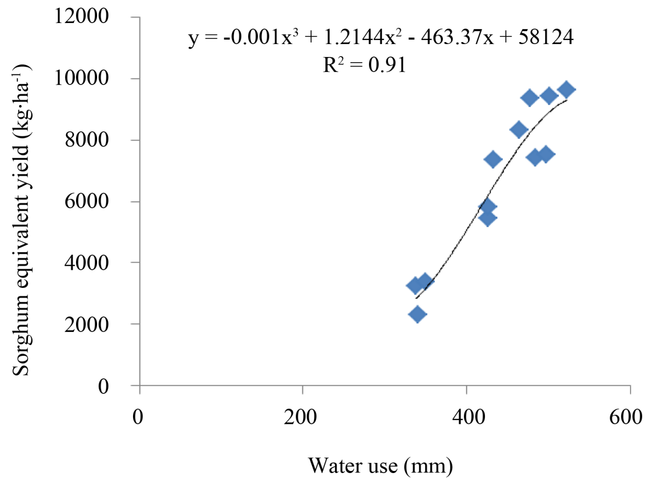

Figure 4. Sorghum equivalent grain yield of sorghum-pigeonpea intercrop as a function of water use.

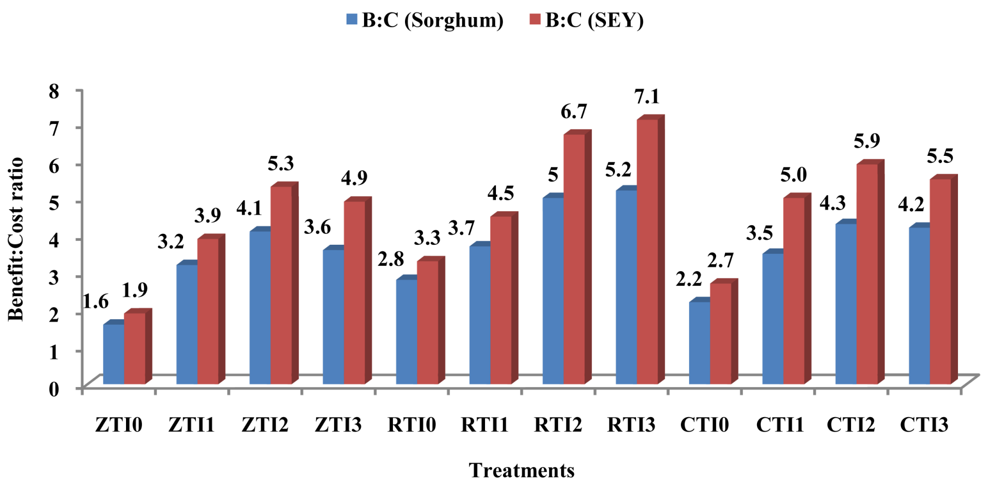

Figure 5. Benefit: Cost ratio of sorghum and sorghum equivalent yields in sorghum-pigeonpea intercrop.

3.9. Benefit-Cost Ratio

Benefit-cost ratio (B:C) of sorghum and sorghum equivalent yields (SEY) show that sorghum-pigeonpea intercrop was beneficial at all tillage and irrigation levels (Figure 5). Maximum benefit was 7.1 from SEY as against 5.2 from sorghum alone in RTI3 followed by that in RTI2 and CTI2. Residual soil moisture after sorghum harvesting was more important for pigeonpea than tillage. Benefit was doubled by even 50% of full irrigation and was 4 times in RTI2 (75% of full irrigation) compared to ZTI0.

4. Conclusions

1) Pigeonpea does not compete until sorghum maturity and accelerates growth after sorghum harvesting.

2) About 80% sorghum roots in sorghum-pigeonpea intercrop are within 0.6 m profile whereas >75% pigeonpea roots are below 0.60 m indicating weak competition.

3) Single tillage 4 days after heavy rainfall and 75% of full irrigation at 50% depletion of soil moisture from 1 m profile was sufficient for optimum yields of sorghum and pigeonpea.

4) Average water use efficiency increased from 12.6 $kg \cdot ha^{-1} \cdot mm^{-1}$ for sorghum to 17.1 $kg \cdot ha^{-1} \cdot mm^{-1}$ for sorghum + pigeonpea.

5) Benefit-cost ratio increased from 5.2 for sorghum alone to 7.1 for sorghum + pigeonpea.

6) Pigeonpea can be produced successfully on the inputs made for sorghum in sorghum-pigeonpea intercrop.

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