Determination of supplementary irrigation requirement and schedule for Sorghum in Kobo-Girana Valley, Ethiopia

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Abstract

Supplemental irrigation is the application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields. The experiment was carried out for two cropping seasons (2011 and 2012) at Kobo irrigation research site, in Northeast Amhara to *determine the net Irrigation requirement) to be supplemented to moisture stressed areas to increase water value and crop productivity. Mean annual rainfall in the area is 630 mm, with considerable year-to-year variation and an average effective rain fall of 232.4mm in the growing season. The soil type is silt loam with average filed capacity and permanent wilting point of 27.57% and 12.3% on volume basis accordingly with PH value of 7.8.* Seven *treatments were tested with RCBD experimental design with three replications. Statistical analysis was applied using SAS soft ware to test the effects of treatments on grain yield, head weight, water productivity. The experimental analysis indicated that there was a significant difference in head weight, grain yield and water productivity. As observed in the experimental years the grain yield widely ranges from 5.397 ton/ha to 1.53 ton/ha. Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass of 11 ton/ha and grain yield 5.397 ton/ha and it had a maximum yield advantage of 2.874 ton/ha compared with the controlled system in 2011 cropping season. In the second year (2012) supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.607ton/ha compared with supplementing of the CROPWAT generated depth (100%) during mid stage (supplementary of 226.5mm seasonal water) at 8 days interval. This research finding recommended that supplementary irrigation starting from development stage (20 days after sowing) is better during development and mid season stage at 8 days interval.*

Key words*:* Supplementary Irrigation, Irrigation requirement, Irrigation schedule, CROPWAT

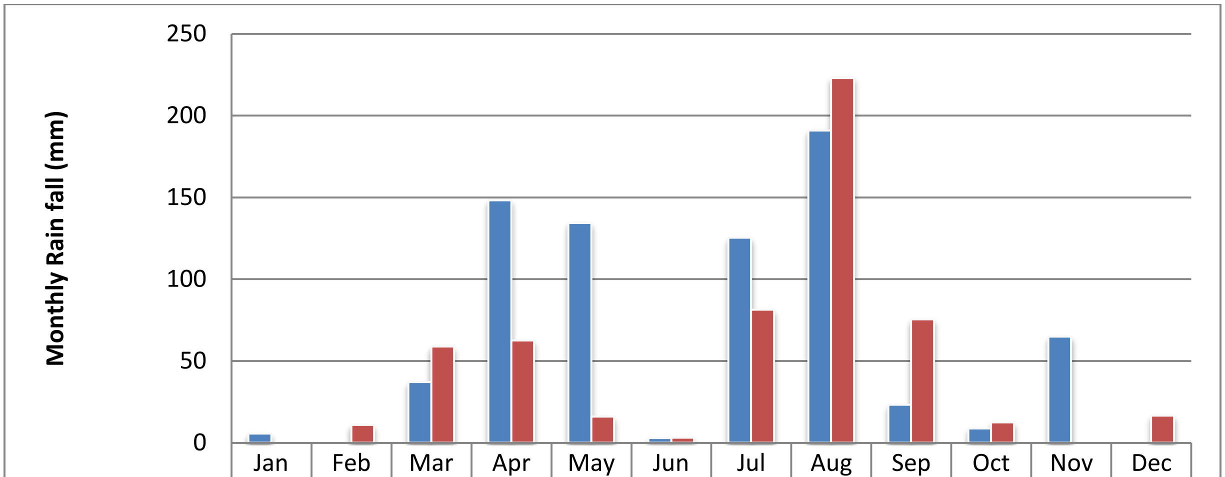
Introduction

Irrigation accounts for about 72% of global and 90% of developing-country water withdrawals. The Ethiopian economy is based on rain fed agriculture. Natural rainfall is the major source of water for agriculture. However, farmers' yield gain in rain fed regions in the developing countries are low largely due to low rainwater use efficiency because of inappropriate soil, water, nutrient and pest management options, lack of seeds of improved cultivars and poor crop establishment (Rockström *et al*.,2007,Wani *et al*., 2008). There are three primary ways to enhance rain fed agricultural production, namely: (i) to increase the effective rainfall use through improved water management; (ii) to increase crop yields in rain fed areas through agricultural research; and (iii) through reformed policies and increased investment in rain fed areas. This chapter focuses on the first way, in which supplemental irrigation (SI) plays a major role in increasing water use efficiency and yields of rain fed crops.

Rain fall pattern of kobo Girrana valley

Assessing seasonal or dekadal1 rainfall characteristics based on past records is essential to evaluate drought risk and to contribute to development of drought mitigation strategies such as supplementary irrigation. Rainfall variability has been reported to have significant effect on the country's economy and food production for the last three decades. There have been reports of rainfall variability and drought associated food shortages (Tilahun, 1999; Bewket and Conway, 2007). In most cases, what determines crop production in semiarid areas of Africa is the distribution rather than the total amount of rainfall, because dry spells strongly depress the yield (Barron et al., 2003; Segele and Lamb, 2005; Meze-Hausken, 2004).Water scarcity in North - Eastern Amhara, particularly in Kobo Girana Valley rain fed water scarcity is sever. Due to these; moisture stress is the major limiting factor for crop production which highly reduces the crop yield in the moisture stressed areas. Sorghum is an important food cereal crop used and the major production crop in rain fed agriculture in the Eastern Amhara particularly in Kobo Girana valley, where rainfall is not only low or not enough for production but also variable, it begins later and ceases earlier. It stops for certain days in the growing period as major contributor for yield reduction. As a result of such problems, farmers have been continuously affecting with sever grain yield shortage through their traditional agricultural practices.

This research was also conducted in such challenging climate variability; for the experimental year 2011 late onset and early cessation with relatively highest amount than 2012 experimental year were observed. In the second year rainfall distribution and variability is very high and observed with late onset and also long dry spell in the month of July and having highest rainfall record in August compared to the first experimental year (2011) as shown in figure-1.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year 1 (2011)	5.6	0	37	148.2	134.2	2.8	125.2	190.9	23.2	8.7	64.8	0
Year 2 (2012)	0	10.8	58.7	62.6	15.9	3	81.2	222.9	75.4	12.5	0	16.6

Figure 1: Rain fall pattern of the experimental years (2011-2012)

Irrigation practices of kobo Girrana Valley

Amhara Regional State was emphasized on developing irrigation-based agriculture to attain food security at household and state levels which is very important that appropriate technologies are available for adoption by the farmers in the study area. Ground water exploration and extraction is the major irrigation water sources in the region. Kobo Girrana Valley Development Program (KGVDP) has already established about 5500 ha under irrigation and planned to reach about 17000 ha. One of the approaches taken as a counter measure to the unpredictability of rain and to overcoming such problems is using supplementary irrigation during the rain fed agriculture season in addition to the main season full irrigation developemnt. Supplemental irrigation (SI) is a highly efficient option to achieve this strategic goal by providing the crop with the needed amount of water at the required time (Oweis and Hachum, 2001). Supplemental irrigation is defined as “the addition of a limited amount of water to otherwise rain fed crops, when rainfall fails to provide essential moisture for normal plant growth, in order to improve and stabilize productivity". Unlike in full irrigation, the timing and amount of SI cannot be determined in advance, because the basic source of water to rain fed crops is rainfall, which is variable in amount and distribution and difficult to predict (Oweis *et al*., 1999). Alleviating soil moisture stress during the critical crop growth stages is the key to improved production. It was concluded by many authors that avoiding drought, through early flowering and maturity, was the main factor underlying higher seed yield under severe drought conditions.

In this area supplementary irrigation (SI) is necessary for the increment of sorghum grain yield and enhancement of food security. Therefore, the research was proposed to quantify and set both the required net Irrigation requirement (depth of water) to be supplemented in the moisture stress period and the time of water application (irrigation schedule) during the rain fed agriculture and to increase water value and crop productivity.

Materials and Methods

Description of the study area

The experiment was carried out over two cropping seasons (2011 to 2012) at Kobo agricultural irrigation main research station at Kobo Girana District, in North Eastern Amhara at 12.08^0 N latitude and 39.28^0 E longitude. The altitude of experimental area is 1470 m.a.s.l. The mean annual rainfall in the area is 630 mm, with considerable year-to-year variation. Such rain fall variation results in a range of conditions under which the use of SI is a useful option with which to improve and stabilize yields. There was an average effective rainfall of 232.4mm in the growing season. But this amount of rainfall didn't fulfill the crop water demand in the growing season. The soil type in the experimental site is Silty-Clay loam with average FC and PWP of 27.57% and 12.3% on volume basis accordingly. The site is characterized by average infiltration rate of 8 mm/hr and pH value of 7.8.

Methodology

Sorghum (Teshale Variety) with a growing period of 120 days was used as a test crop. The fertilizers used for the experiment were DAP 100 kg ha^{-1} (applied at planting) and urea 111 kg ha^{-1} (applied in two splits i.e. 36 kg at planting and 75 kg at knee height). The experiment was laid out in simple RCBD in three replications with experimental plot size of 3m by 6m. Totally six treatments were tested in the 1st year. While in the second year, one treatment (user adjustment) was added and hence seven treatments were examined. The treatments include**:** C-controlled (treatment under rain-fed condition no supplementary irrigation). Five supplementary irrigation levels (S1-S5) in different growing stages (Table1) were determined using CROPWAT 8 software program and **U-**daily user adjusted treatment (this treatment were included in the second year to adjust the rainfall event during irrigation and irrigation were also supplemented when the available soil moisture was below the allowable depletion without using model). Irrigation water was applied to the treatments using siphon tubes in furrow irrigation system, which was equipped with time duration to measure the amount of water applied in each furrow.

Table 1: The supplemental treatments in the experimental area

S.no	Treatments	Total crop water requirement (mm/season)	Effective rain fall (mm/season)	Seasonal irrigation requirements (mm/season)
1	Controlled (rain fed farming) **(C)**	232.4	232.4	0
2	Supplementing the CROPWAT generated depth (100%) starting from DSt **(S1)**	658.70	232.4	330.6
3	Supplementing the CROPWAT generated depth (100%) starting from DSt at 8 days interval **(S2)**	563	232.4	426.3
4	Supplementing the CROPWAT generated depth (100%) starting from MSt at 8 days interval **(S3)**	536	232.4	316.2
5	Supplementing the CROPWAT generated depth (100%) during DSt & MSt at 8 days interval **(S4)**	548	232.4	304.2
6	Supplementing the CROPWAT generated depth (100%) during MSt only at 8 days interval **(S5)**	458	232.4	226.5
7	User adjustment **(U)**	417.7	206	211.7

Water productivity, also known as water use efficiency, was determined as the ratio of crop yield per unit area, in terms of grain, to crop evapotranspiration (mm), and was expressed as kg of grain or biomass per m^3 of consumed (evapotranspired) water. Statistical analysis of the data included analysis of variance (ANOVA), using SAS software, to test the effects that season, SI had on grain yield, stalk biomass, and water productivity.

Results and Discussions

The results distinguish that year -to -year variations occurred in treatment effects (Table 2). Even though the actual rainfall amount occurred in the second year was less than the long term mean value, more amount existed at initial stage affects the growth performance and became stunted growth. Furthermore, the grain yield and yield components in the second year were highly affected by the occurrence of stalk borer disease at development stage.

Table 2: Analysis of variance

Source of variation	Degree of freedom	Mean square		
		Grain yield	Stalk biomass	Water productivity
Replication	2	0.7818	1.138	0.0271
Treatment	5	1.2255	3.664*	0.0958**
Year	1	59.6017**	126.875**	2.4701**
Treatment*year	5	0.4915	1.165	0.0196
Error	33	0.48	1.105	0.0196

** = Significant at (0.05) level of significance, ** = Significant at (0.01) level of significance*

The combined analysis of variance for both years showed that there was none significant interaction effect between treatments across years on grain yield, stalk biomass and water productivity (Table 3).

The experimental analysis indicated that there was significant difference in stalk biomass, grain yield and water productivity in the first year. Sorghum grain yield, biomass yield and water productivity were highly decreased in the second year, with the adverse effect of high rain in the initiation stage and disease infestation. However, grain yield, stalk biomass and water productivity showed statistically significant different. The grain yield widely ranges from 5.4 t ha^{-1} to 1.5 t ha^{-1} (Table 3).

Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application gave the highest stalk biomass (11 t ha^{-1}) and grain yield (5.4 t ha^{-1}) and it had a maximum yield advantage 2.9 t ha^{-1} compared to the control in 2011 cropping season (Table 3). Sorghum yield under rain fed condition (control treatment) consistently had lower yield in both years (Table 3). The production potential of the crop was extremely affected by rainfall amount and distribution conditions. Combined result of the two cropping season showed that stalk biomass and water productivity were statistically significant, but grain yield didn't.

In water productivity supplementing the CROPWAT generated depth (100%) during Mid stage only (mid stage supplementary of 226.5mm seasonal irrigation water) at 8 days interval had a maximum value of 1.67 kg m^{-3} which didn't significantly differ from 330.6mm/seasonal water application at both development and mid stage at eight days interval (Table 3). Supplementing the CROPWAT generated depth (100%) starting from development stage at optimal time of application with a seasonal water amount of 330.6mm had a yield advantage of 1.61 t ha^{-1} compared to supplementing with the CROPWAT generated depth (100%) during MSt (mid stage supplementary of 226.5mm seasonal water) at 8 days interval in 2011. Water productivity was about 0.96 kg of wheat grain per unit volume of water (m^3) of water under rain fed conditions and 1.36 kg of wheat grain m^{-3} under supplemental irrigation (Zhang and Oweis, 1999). Water productivity for sorghum grain yield in 2011 was in the range of 1.02 to 1.7 Kg m^{-3} with lower observation in the second year production season as shown in figure-2 and figure-3.

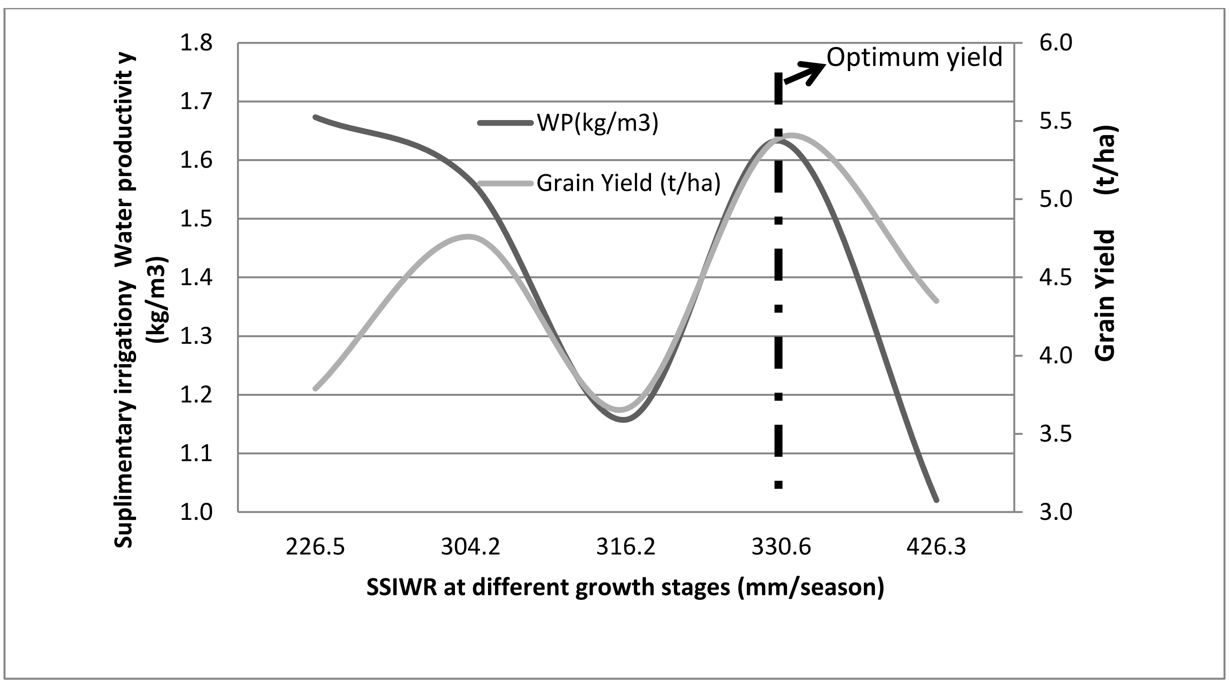


Figure 2: SSIWR at different growth stage in the first year (2011)

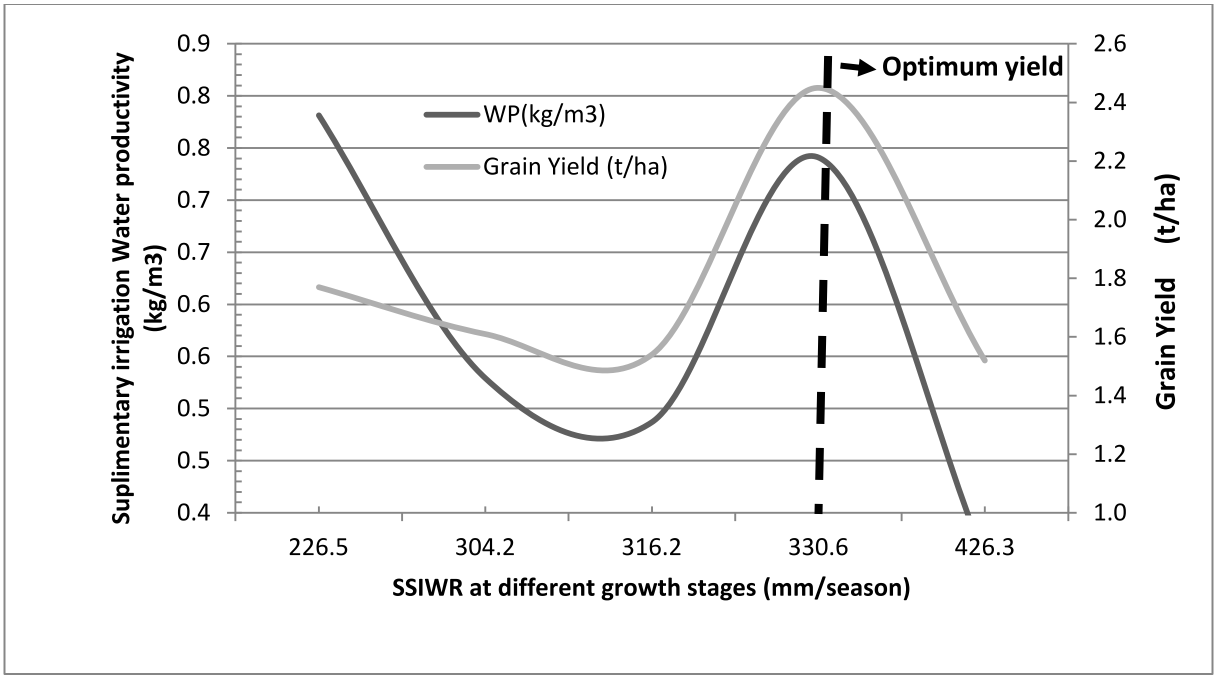


Figure 3: SSIWR at different growth stage in the second year (2012)

The above two figures (2 & 3) showed that for both experimental seasons water productivity versus and grain yield was coincided optimally at 330.6mm/season supplementary irrigation during development stage at none fixed interval giving the supplementary irrigation following different indicators like crop physiological appearance and soil moisture stress.

Table 3: Mean separation result of plant height, stalk biomass, grain yield and water productivity

S. no	Treatments (SSIWR in mm/season)	First year /2011/ Stalk biomass (t ha-1)	Pure grain yield (t ha-1)	water productivity (kg m-3)	Second year /2012/ Stalk biomass (t ha-1)	Pure grain yield (t ha-1)	water productivity (kg m-3)	combined Stalk biomass (t ha-1)	Pure grain yield (t ha-1)	water productivity (kg m-3)
1	C (0)	8.077b	2.523d	1.23b	4.873b	1.53b	0.78ab	6.49b	1.88	0.81a
2	S 1(330.6)	11a	5.397a	1.56ab	6.422ab	2.45a	0.74ab	8.35a	3.13	0.54b
3	S 2(426.3)	8.86b	4.35b	1.02c	6.400ab	1.52b	0.45c	8.34a	3.03	0.48b
4	S3(316.2)	9.2b	3.663c	1.16bc	7.790a	1.54b	0.49c	8.44a	2.82	0.52b
5	S4(304.2)	9.13b	4.763b	1.56ab	5.540b	1.61ab	0.53bc	7.24ab	2.8	0.49b
6	S5(226.5)	10.56a	3.79c	1.67a	5.243b	1.77ab	0.72ab	7.65ab	2.95	0.65ab
7	U(211.7)	-	-	-	6.022b	1.95ab	0.85a	-	-	-
	CV (%)	7.6	6.2	11.3	13.3	24.4	30.6	13	25	24.2
	LSD (0.05)	1.314**	0.458**	0.173**	1.467*	0.811*	0.2179*	1.716*	ns	0.239**
	Grand mean	9.47	4.08	0.84	6.04	1.77	0.378	7.75	2.77	0.58

*The same letters are not significantly different (P <0.05), ** significant (p<0.01) & * significant (p<0.05) according to a supplementary irrigation water requirement, GD= generated depth, DSt=development stage, LSt=late stage, OPT= optimum Time of application MSt=mid stage . Treatment : Controlled (rain fed farming)* ***(C),*** *Supplementing the CROPWAT generated depth (100%) starting from DSt* ***(S1)*** *without fixed interval****,*** *Supplementing the CROPWAT generated depth (100%) starting from DSt at 8 days interval* ***(S2),*** *Supplementing the CROPWAT generated depth (100%) starting from MSt at 8 days interval* ***(S3),*** *Supplementing the CROPWAT generated depth (100%) during DSt & MSt at 8 days interval* ***(S4),*** *Supplementing the CROPWAT generated depth (100%) during MSt only at 8 days interval* ***(S5),*** *User adjustment based on soil moisture sensor measurement to re-fill to field capacity and based on plant physiological responses****(U)***

Conclusion and Recommendation

Supplemental irrigation is a feasible option that can be used by farmers in the Kobo area to increase and stabilize their rain fed sorghum production. The application of supplemental irrigation can help the crop to escape the critical stages particularly terminal drought or moisture stress.

From our result, it can be concluded that semi-arid areas like Kobo Girrana Valley which have problems of rainfall distribution and occurrence (late onset and early offset) and having an access to irrigation can increase the yield advantage above 1t ha^{-1} with supplementary irrigation starting from crop development stages at none fixed interval following moisture deficiency indicators like crop physiological appearance and soil moisture stress with amount of 330mm seasonal irrigation water requirement for improved variety of sorghum (Teshale) from combined analysis of the two years the range of yield advantage over the control reaches up to 2.90 t ha^{-1}.

As an alternative if sorghum didn't have moisture stress at development stage (early) and water is the limiting factor in the growing season, only by supplementing at development stage about 226.5mm at eight days interval can give a reasonable good grain, biomass yield and water productivity. However, this research finding highly recommended that supplementing rain fed for sorghum production starting from development stage (20 days after sowing) is better during development and mid season stage at 8 days interval. Although in rain fed areas, irrigation comes at a cost. Therefore, economic studies are highly recommended in order to evaluate its feasibility and to identify any constraints that might affect its implementation.

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