Determination of Optimal Irrigation Scheduling for Mung Bean at Kobo Irrigation Scheme, Kobo Ethiopia.

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Abstract

Appropriate supply of the right amount of irrigation water at the right time and growth of early maturing cash crops is the alternative options for sustainable utilization of water resources. The study aims for determining the optimal crop water requirement and irrigation scheduling on yield and water use efficiency of mung bean. The experiment consisted of nine treatments constructed from a combination of three crop water levels (75% ETc (30 mm), 100% ETc (40 mm), and 125% ETc (50 mm)) with three irrigation intervals (10, 14 and 18 days) and was laid out in factorial RCBD *with three replications. The analysis was carried out using Genstat 15.0 software and the mean separation was performed using LSD test at a 5 % probability level. The analysis of variance showed that the* grain yield and water use efficiency *were significantly affected* ($p<0.05$) *by the main effects of irrigation interval and crop water levels, and their interaction.* Mung bean grain yield decreased when the crop water level declined and the irrigation interval increased; while the crop water use efficiency increased. The maximum mean grain yield *(1721.8 kgha-1)* was recorded from100% ETc applied in 10 days interval, while the minimum *(752.6 kgha-1) was recorded from 75% ETc applied in 14 days interval*. The highest crop water use efficiency *(1.2 kg/m^3) was noted from 75% ETc applied in 18 days interval; while it was statistically at par with treatments 75% ETc in 10 days interval (0.83 kg/m^3), 100% ETc applied in 10 days and 18 days irrigation interval as 0.82 kg/m^3 and 0.87 kg/m^3 respectively. Whereas* the lowest crop water use efficiency *(0.56 kg/m^3)* was obtained *from 75% ETc applied in 14 days interval*. The present study concludes that, the maximum grain yield and crop water use efficiency were obtained by applying 100% ETc (40 mm) in 10 days interval.

Keywords*: Crop water level, irrigation interval, grain yield, crop water use efficiency.*

Introduction

Mung bean (*Vigna radiata* L.) is one of the short-season grain legume families characterized by low water requirement, fast growth under warm conditions, and enhancement nitrogen fixation for excellent soil fertility (Yagoob 2014). The special features of the crop include early maturity; high yield, good nutritive value for protein and lysine-rich grain, reasonable cost of production, and drought-resistant (Itefa, 2016). It is utilized in many ways; sprouts, seeds, and young pods are all consumed to provide a rich source of vitamins, amino acids, and minerals (Somta and Srinives, 2007). Among pulse crops, it is known by high nutritive value, digestibility and contains 60.4% carbohydrates, 28% protein, 1.3% fat, and essential micronutrients and vitamins (Anwar *et a*l., 2007 and Hussain *et al*., 2011).

Mung bean is an important pulse crop in developing countries of Asia, Africa, and Latin America where it is produced in tropical and sub-tropical environments without impounding of irrigation or rainwater (Karuppanapandian *et al*., 2006). In Ethiopia, mung bean is the most grown pulse crop by smallholder farmers and ranked as 13th among the -producing countries (FAO, 2015). The total national mung bean production area, average yield, and productivity were estimated at about 27,085.92 hectares, 271,58.98 tone, and 1003 kgha-1 respectively (CSA, 2016). Mostly it is produced in the drier marginal environments of Ethiopia particularly in the Amhara regional states of North Shewa and South Wollo area in both rain-fed and irrigation seasons (Asfaw *et al*., 2012).

Due to its high profitability per unit area, the increases in irrigation development and early maturing characteristics the area under mung bean production in the country is increasing from time to time in the crop rotation system (Rehman *et al*., 2009 and Asfaw *et al*., 2012). Currently, it is becoming a widely cultivated cash crop in the Raya Kobo valley irrigation schemes for improving the potential of crop patterns. Furthermore, by a symbiotic relationship with bacteria and soil, mung bean roots can fix atmospheric nitrogen to improve soil fertility (Nabizade *et al*., 2011).

In many areas of the world, irrigation water is becoming the main limiting factor to agriculture. It has a vital role in plant growth, development, and productivity. More than any other environmental factors, the permanent and temporary water shortage can limit the growth, distribution, and vegetation performance of the cultivated plants (Tuberosa and Salvi, 2006; Shao *et al*., 2009 and Ashraf, 2010). In the Raya valley, the rainfall occurs in early secession, uneven distribution and erratic nature lead to recurrent drought and crop faller for chronic food shortage. Therefore, crop production mainly depends on irrigation in a place where there is a good potential for surface and groundwater resources (Getahun, 2014). Sustainable utilization of the present water resources through adaptation of genotypes and development of new water management technologies is a critical issue. Application of the right amount of irrigation water at the right time helps to produce a high crop yield and ultimately increases water productivity through adequately saving irrigation water (Montazar, 2009). Therefore, the objectives of the study were to determine optimal crop water requirement and irrigation interval on yield and water use efficiency of mung bean in Raya Kobo valley irrigation scheme.

Materials and Methods

Description of the Study Area: The study was conducted in 2016 and 2017 at the Kobo research station of Amhara National Regional State, Ethiopia. Geographically, it is situated between 12.03 -12.08° N latitudes and 39.28°- *39.42°* E longitudes with an altitude of 1470 meters above sea level (m.a.s.l.) and it is placed 570 km away from Addis Ababa in the North direction. The area is identified as the most drought-prone district with the mean monthly minimum and maximum temperatures, mean annual rainfall are 8.1 °C, 36.7 °C, and 602.4 mm respectively.

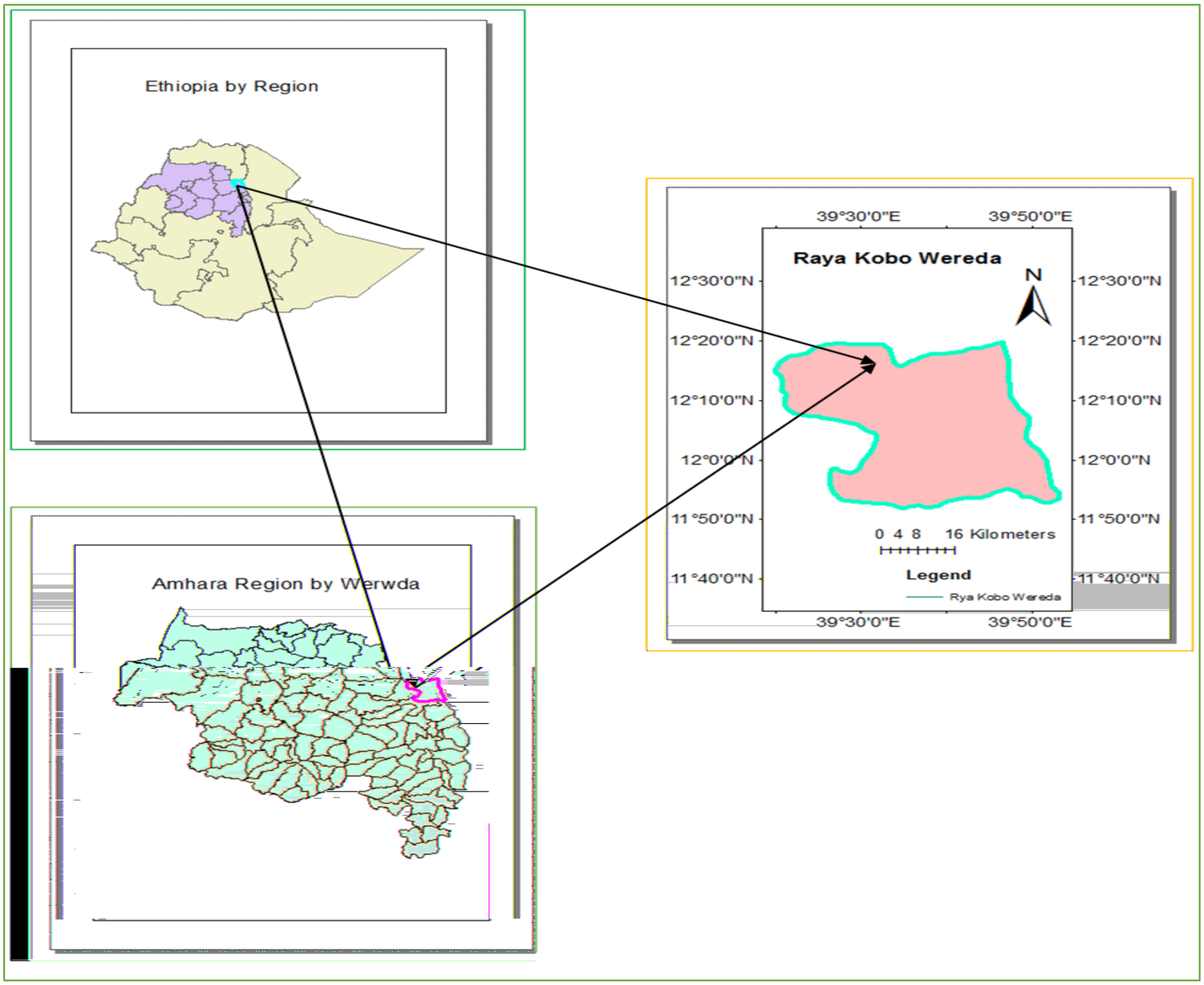

Figure 1: Map of the study area

Determination of Irrigation Scheduling

Determination of Reference Evapotranspiration (Eto): Based on the ten years weathered data as indicated in Table 1, the physically-based reference evapotranspiration (ETo) calculation methods, such as the Penman-Monteith method was applied using the aid of CROPWAT 8.0 model (Allen *et al*., 1998) to provide accurate estimations of ETo (Yang *et al*., 2016; Mahmoud and Gan, 2019).

Table 1: Climatic data (2002 - 2015) used by the model for determining ETo

Month	Max Temp °C	Min Temp °C	WS (m/s)	RH (%)	SS (hours)
Jan	30.1	8.4	1.6	58.41	9.2
Feb	31.9	10.4	1.87	51.95	9.8
Mar	32.7	10.8	1.93	48.36	10.3
Apr	33.8	13.3	1.76	49.65	10.2

Source: *Kobo metrological station. Where WS (wind speed), RH (relative humidity), and SS (sunshine hour).*

Determination of Actual Evapotranspiration (Etc) and Irrigation Interval:

Crop Data: The crop data is one of the main driver parameters (Table 2) for irrigation scheduling by taking into account the length of each growth stage (SARC, 2008), rooting depth, crop coefficient factor, and depletion level (Allen *et al*., 1998).

Table 2: Mung bean crop parameters adopted from FAO irrigation and drainage Paper No. 56 used in CROPWAT model.

Growth stage	Initial	Development	Mid	Late	Total
Stage lengths (days)	15	20	20	15	70
Crop coefficient (Kc)	0.4	>>	1.05	0.35	
Rooting depth (m)	0.1	>>	0.6	0.6	
Depletion levels (P)	0.45	0.45	0.45	0.45	
Max. Crop Height in cm (optional)			0.4		

Source: Allen et al. (1998).

Note: “>>” indicates the value is found between the right and the left column

Soil data: Soil characteristics such as texture, organic matter content, bulk density, soil moisture content at field capacity and permanent wilting point parameters can affect soil water distribution and root water absorption (Ross *et al.,* 1997). Therefore, five representative soil samples from 0-20, 20-40 and 40-60 cm depths were collected up to the maximum rooting depth of mung bean (60 cm) (Allen *et al*., 1998), and composited independently depth-wise. The field capacity and permanent wilting point of the soil were determined using pressure plate apparatus. The soil texture was determined using Bouyoucos hydrometer method as pointed out by Sahlemedhin and Taye, (2000) and the soil bulk density was obtained from the derived parameters using the equation (Blake and Hertge, 1986);

$$— \qquad (1)$$

Where = soil bulk-density (gm/ cm^3)

= weight of dry soil (gm)

= volume of core (cm^3)

For describing the characteristics of the experimental site, *electrical conductivity (EC) and soil reaction (pH) were determined from saturated paste extract using digital pH-meter and conductivity meter respectively followed the methods as stated by USSLS, (1954) and FAO, (1999).*

Finally, using the climatic (ETo), crop and soil data as, the crop water requirement and irrigation interval which intended to satisfy the fraction of actual evapotranspiration (ETc) was determined by CROPWAT 8.0 model. Therefore, the full irrigation scheduling (100 % ETc and irrigation interval) simulated by the model was 40 mm crop water depth with 14 days irrigation interval.

Determination of Net Irrigation Requirement and Effective Rainfall

The average long-term expected rainfall which is considered by the CROPWAT 8.0 model (Table 1) for generating 100 % ETc and irrigation interval occurs in a certain probability level. Therefore at each irrigation event, the net irrigation requirement has computed by monitoring the actual daily rainfall (Table 5 and 6). It was calculated by the equation;

rain formula as follows:

$$(1)$$

Where, Net irrigation requirement (mm),

= Crop water requirement (mm) and

= Effective rainfall (mm).

Effective rainfall is a part of rainfall that entered into the soil and made available for crop production. It is determined by using AGLAW or dependable rain formula as follows: -

If P <— (2)

— If P >— (3)

Where, = precipitation (mm/month)

Monthly decades of effective rainfall (mm).

Experimental Setup: The three water levels by adding and subtracting 25 % from the simulated value as 75 % (30 mm), 100 % (40 mm) and 125 % (50 mm) of the ETc with 10, 14, and 18 days irrigation interval were tested in factorial randomized complete block design with three replications. Totally nine treatments were studied at each experimental plot with the sizes of (3m * 3 m = 9 m^2) and the distance between plots and blocks were 1 and 2 m respectively. The mung bean seed was sown on the experimental plots with plant and row spacing were 10cm and 40cm respectively. Two days prior to sowing the experimental plots received an equal amount of irrigation water up to field capacity (Table 4) for initiating seed germination. The irrigation scheduling was started at 4 days after sowing with the existing soil moisture content of 38 mm depth before irrigation. Treatment combinations constructed as:

Table 3: Combination of crop water level and irrigation interval

Factor 1 (Crop water levels in mm)	Factor 2 (Irrigation intervals in day)		
75% ETc (30 mm depth)	10	14	18
100% ETc (40 mm depth)	10	14	18
125% ETc (50 mm depth)	10	14	18

Data Collection: The grain yield, yield-related agronomic parameters (plant height, number of pods per plant and number of seed per pod) and crop water use efficiency were collected from each experimental unit for statistical analysis. The crop water use efficiency was determined by the equation;

$$\frac{}{} \quad (4)$$

The volume of water applied to each experimental plot was calculated by multiplying the depth of the water with the area of the plot (Yenus, 2013) as:

(5)

Statistical Analysis: The statistical analysis was carried out using Genstat 15.0 software by following the procedures outlined by Gomez and Gomez, (1984). The mean separation was performed using the least significant difference (LSD) test at a 5 % probability level.

Results and Discussion

Preliminary Study of Physicochemical Characteristics of Kobo Irrigation Research Experimental Site

The textural classes of the Kobo irrigation research station vary from clay loam to silty clay loam for 0-20 and 40-60 cm soil layer respectively *(Table 4). Based on USDA soil textural classification, the experimental site was classified as "silty clay loam" soil.* The organic matter content of the experimental site ranged from 3.1 to 2.76 % and pHe from 6.75 to 6.79 for 0-20 to 40-60 cm depths respectively (Table 4). Based on *Takalign et al., (1991) rating criteria, the soil has* *The* EC *values in the three respective soil layers found within the* ranged of 0.53 and 0.58 dS m^{-1} for 0-20 and 40- very little chance of injury for all plants (USSLS, 1954; Lamond and Whitney, 1992). The total available water within the maximum rooting zones of mung bean (60 m) was 83.02 mm with average field capacity and permanent wilting point were 33.71and 19.87 mm respectively.

Table 4: Selected physicochemical properties for Kobo irrigation research experimental site

SD	TC	Bd (gm cm^{-3})	OM (%)	pH	EC	FC	PWP	TAW
0-20	CL	1.14	3.1	6.75	0.53	32.58	20.53	24.1
20-40	SCL	1.21	2.89	6.81	0.62	33.33	19.5	27.66
40-60	SCL	1.28	2.76	6.79	0.58	35.21	19.58	31.26
					Average	33.71	19.87	Sum=83.02

*SD- soil depth; TC- textural class; Bd- bulk density; CL- clay loam; SCL- silty clay loam; SL silty loam; OM organic matter content; EC- electrical conductivity and TAW- total available water.

Total and Effective Precipitation throughout the Growing Period: From Table 5, the total and effective precipitation throughout the delta periods were 53.5 and 27.1 mm for 2016, and 91.5 and 66.9 mm for 2017 respectively. It implies that the high precipitation was occurred in 2016 and 2017 (as compared to the expected mean rainfall (Table 5). In comparing the two years independently, relatively high rainfall (84.7 mm) above the expected mean precipitation has occurred in 2017.

Table 5: Total and effective precipitation during 2016 and 2017 experimental period

Year	Month	Ex. m P (2002-2015)	Oc. P (2016)	Oc. P above the ex. Value	P_{eff}	Remark
2016	Jan	5.7	2.8			Pd (Jan, 25)
	Feb	4.5	38.8	34.3	27.1	
	Mar	27.6	9			Sche (Apr, 1)
	Apr	37	2.9			Hd (Apr, 8)
	Total	78.4	53.5	34.3	27.1	
2017	February	4.5	91.5	84.7	66.9	Pd (Feb, 12)
	March	27.6	0			Sche (Apr, 7)
	April	37				Hd (Apr,15) and
	Total	69.1	91.5	84.7	66.9	

* *P- Precipitation;* Ex. m P- *Expected mean precipitation;* Oc. P- Actually occurred *precipitation and P_{eff}- Effective precipitation, Sche.- Irrigation scheduling ended, Pd- planting date and Hd-.harvesting date.*

The delta periods which indicate from the beginning of irrigation scheduling up to the last irrigation application dates (Table 5) were 63 and 50 days for 2016 and 2017 respectively. The total growing periods were 74 and 62 days for 2016 and 2017 respectively. In 2017, the simultaneously frequent occurrences of relatively high precipitation and temperature at the establishment (initial) stage resulted in a quick vegetative response to reach a short growing period. At lower altitudes, the crops have a shorter growing period, due to higher temperature coupled with frequent rainfall in a small quantity (Shah, 2021).

Effects of Crop Water Levels and Irrigation Frequency on Yield Related Parameters

The obtained result showed that the mean plant height was significantly affected ($P<0.05$) by the interaction effect of crop water application depth and irrigation interval in 2016 and the combination of two years, whereas crop water levels and irrigation interval as the main effect had no significant effect (Table 6). The interaction effect of crop water levels and irrigation interval indicated that plants treated by 100% ETc with 10 days and 125% ETc with 14 days interval had the tallest mean plant heights of 25.5 and 25.6 cm respectively, whereas plants treated by 75% ETc with 14 and 18 days interval had the shortest plant heights of 20.1 and 20.38 cm respectively (Table 6). The minimal plant height through the decreased crop water level (75% ETc) and increased irrigation interval might be since under relatively soil moisture stress the plant photosynthesis, cell division and elongations are slowing down for ultimately decrease plant height. A similar experience had been reported by Sisay *et al*., (2014) who reported that mung bean plants that received the full amount of irrigation water throughout the growing season had higher plant height than those under water stress. Moreover, Merkebu, (2014) pointed out that the plant height of soybean relatively decreased as the crop water levels decreased.

The analysis of the result revealed that the number of pods per plant was significantly ($p<0.05$) influenced by interaction effects of variable crop water levels and irrigation interval in each year and combined over years (Table 6). The highest mean combined number of pods (9) per plant was recorded by the application of 125% ETc with 14 days intervals, while 75 and 100% ETc with 18 days intervals (T6 and T7) had the least number of pods (6) per plant. The application of lower crop water level with a wider irrigation interval, the mung bean plant becoming susceptible to moisture stress resulted in abortion and abscission of flowers and pods for a reduction in the number of pods per plant. This finding is in line with Sadeghipour, (2008) and Sisay *et al*., (2014) reported that the optimal irrigation scheduling gave a higher number of pods per plant, while the number of pods per plant became decreased with decreased crop water levels. The analysis of the result from Table 7 showed that the crop water levels and irrigation interval in single and their interaction has not a significant effect *(P >0.05)* on the number of seeds per plant in each year (2016 and 2017) and combined over years.

Table 6: Effects of crop water levels and irrigation frequency on the grain yield of groundnut

Trs.*	Plant height (cm)			NPPP			NSPP		
	2016	2017	Comb.	2016	2017	Comb,	2016	2017	Comb.
100% ETc-14	20.27^{ab}	22.27^{b}	21.27^{cd}	6^{ab}	7^{cd}	7^{ab}	10	10	10
75% ETc-14	20.07^{ab}	20.13^{b}	20.10^{d}	7^{a}	6^{d}	7^{ab}	9	10	10
125% ETc-14	21.4^{ab}	29.73^{a}	25.60^{a}	6^{ab}	11^{a}	9^{a}	10	11	11
100% ETc-10	21.93^{ab}	29^{a}	25.50^{a}	5^{ab}	9^{ab}	7^{ab}	10	10	10
75% ETc-10	21^{ab}	25.13^{a}	23.07^{abc}	5^{ab}	8^{abcd}	7^{ab}	9	11	10
125% ETc-10	22.73^{a}	27.53^{a}	25.13^{ab}	6^{ab}	9^{abc}	8^{ab}	10	11	11
100% ETc-18	20.13^{ab}	24.8^{a}	22.47^{bcd}	5^{ab}	7^{bcd}	6^{b}	9	10	10
75% ETc-18	19.5^{ab}	21.26^{b}	20.38^{cd}	5^{ab}	7^{abcd}	6^{b}	9	10	10
125% ETc-18	20.93^{ab}	26.87^{a}	23.9^{abc}	5^{ab}	9^{abc}	7^{ab}	9	11	10
CV (%)	7.89	9.52	9.88	15.82	16.49	20.88	10.73	13.76	11.37
LSD (5 %)	Ns	4.27	2.7	1.00	2.00	2	ns	ns	ns
T × Y	-	-	Ns	-	-	ns	-	-	ns

**Trs: treatments, NPPP: number of pod per plant, NSPP: number of seed per pod, Comb: combined over years, ns: non-significant difference, CV (%): coefficient of variation in percent, LSD: list significant difference at 5 % probability level, T × Y: treatment by year.*

Effects of Crop Water Levels and Irrigation Frequency on Mungbean Grain Yield

The analysis of variance revealed that crop water levels and irrigation interval had significant interaction effects ($p<0.05$) on mung bean grain yield. Based on the combined result the maximum grain yield (1721.8 kgha-1) was recorded from 100% ETc applied in

10 irrigation interval, whereas the lowest (752.6 kgha-1) was obtained from 75% ETc applied in 14 days irrigation interval followed by 18 days interval (Table 7). The yield obtained during irrigation gave 721.5 kgha-1 (72%) over the rain-fed system (CSA, 2016). The yield attained from 100% ETc with 10 days irrigation interval was greater than by 56.3% compared with 75% ETc with14 days interval applied treatment. This finding agreed with the finding of Sisay *et al.*, (2014) who reported that 34% yield reduction at 50% deficit irrigation throughout the growing season compared with the yield under optimum irrigation. Similar experiences were reported by Malik *et al.*, (2006) and Robertson *et al.*, (2004) stated that plant growth and yield of mung bean tend reduced due to the reduction of crop water level and the increment of irrigation interval.

Table 7: Effects of crop water application depth and irrigation frequency on grain yield

	Grain yield (kgha-1)		
Treatments	2016	2017	Combined over years
T1: 100% ETc-14	1155.3^{bcd}	1055.6^{b}	1105.5^{cd}
T2: 75% ETc-14	894.3^{d}	611.1^{c}	752.6^{e}
T3: 125% ETc-14	1122.3^{bcd}	2162^{a}	1642^{ab}
T4: 100% ETc-10	1554.7^{a}	1888.9^{a}	1721.8^{a}
T5: 75% ETc-10	1428^{abc}	1277.8^{b}	1352.9^{bc}
T6: 125% ETc-10	1456^{ab}	1828.7^{a}	1642.4^{ab}
T7: 100% ETc-18	1083^{cd}	1277.8^{b}	1180.4^{cd}
T8: 75% ETc-18	927^{d}	1193.5^{b}	1060.3^{de}
T9: 125% ETc-18	1033^{d}	1444.4^{b}	1238.7^{bcd}
CV (%)*	15.55	17	21.27
LSD (5 %)	352.5	452.18	327.1
T × Y	-	-	Ns

** CV (%): coefficient of variation in percent, LSD: list significant difference at 5 % probability level, T × Y: treatment by year and ns: non-significant difference.*

The result showed that application of crop water levels as the main effect has significant ($p<0.05$) effect on mung bean grain yield in 2017 and combined over years, while there was no significant ($p > 0.05$) effect in 2016 (Table 8). The maximum mean grain yield (1507.8

kgha-1) was recorded from 125 % ETc applied treatment. But, there was no statistically significant difference compared with 100% ETc (1336 kgha-1). The lowest grain yield (1100.9 kgha-1) was obtained from 75% ETc. The reduction of mung bean grain yield with reduced crop water level could be due to the strong association of water with photosynthesis and metabolic activities resulted in abortion and abscission of flowers and pods a grain yield reduction. The finding agreed with many authors who pointed out that plant growth and yield of mung bean tends reduced due to reduction of crop water level (Robertson *et al.*, 2004; Malik *et al.*, 2006; Sadeghipour, 2008; Sisay *et al.*, 2014). Moreover, Raza *et al.*, (2012) reported that the decreased crop water level significantly affected seed yield.

Table 8. Effects of crop water levels on grain yield

	Grain yield (Kgha-1)		
Water levels	2016	2017	Combined
75% ETc	1181.4[a]	1020.4[c]	1100.9[b]
100% ETc	1264.5[a]	1407.4[b]	1336.0[ab]
125% ETc	1203.8[a]	1811.7[a]	1507.8[a]
CV (%)	15.5	17	21.27
LSD (0.05)	Ns	282	197.0
T × Y	-	-	Ns*

** ns: non-significant difference, CV: coefficient of variation, LSD: least significant difference at 5 % probability level.*

Irrigation frequencies as the main effect had a significant ($p<0.05$) effect on the mung bean grain yield combined over years (Table 9). Application of irrigation water with 10 days interval gave significantly ($p<0.05$) higher mean grain yields (1549.3 kgha-1) of mungbean. From the combined result, when the interval between two consecutive irrigation events increased from 10 to 14 and 18 days, the grain yield decreased by 24.7 and 22.2 % correspondingly. This might be attributed to the fact that during the application of irrigation water with relaxed frequency, the soil moisture could be tightly held by soil particles and it is not easily available for plants. Therefore, the plant becomes susceptible to moisture stress gives lower grain yield.

Table 9: Effects of irrigation interval on grain yield

	Grain yield (Kg)		
Irrigation intervals (days)	2016	2017	Combined over years
10	1479.3[a]	1665.1[a]	1549.3[a]
14	1057.3[b]	1276.2[b]	1166.8[b]
18	1113[b]	1298.2[b]	1205.6[b]
CV (%)*	15.5	17	21.27
LSD	203.5	282	195
T × Y	-	-	Ns

** CV: coefficient of variation, LSD: least significant difference at 5 % probability level and ns: non-significant difference.*

The crop water levels and irrigation interval had significant interaction effect ($p<0.05$) on crop water use efficiency in each year and combined over years (Table 10). The maximum crop water use efficiency (1.2 kg/m^3) combined over years was recorded from 75% ETc applied in 18 days interval (T8), while the minimum crop water use efficiency (0.56 kg/m^3) was noted from 75% ETc applied in 14 days interval. The crop water use efficiency is inversely related with the amount of water consumed by the crop and positively correlated with the obtained grain yield. In addition, reducing irrigation water amount and increasing irrigation interval reduced water loss by evaporation and increased water use efficiency. Similar results were reported by Sisay *et al.,* (2014) who stated that the maximum water use efficiency of mung bean was noted by the decreased crop water requirement throughout the entire seasons. Moreover, Onder *et al.,* (2009) also explained that the relatively low water levels attained maximum water use efficiency of cotton.

Table 10: Effects of crop water level and irrigation frequency on crop water use efficiency

	Volume of water			Water use efficiency (Kg/m^3)		
Treatments	2016	2017	Combined	2016	2017	Combined
T1: 100% ETc-14	2000	1600	1800	0.58^{bcd}	0.66^{cd}	0.62^{b}
T2: 75% ETc-14	1500	1200	1350	0.6^{cd}	0.51^{d}	0.56^{bc}
T3: 125% ETc-14	2500	2000	2250	0.45^{d}	1.09^{ab}	0.77^{b}
T4: 100% ETc-10	2400	2000	2200	0.70^{bc}	0.94^{abc}	0.82^{ab}
T5: 75% ETc-10	1800	1500	1650	0.7967^{b}	0.85^{bc}	0.83^{ab}
T6: 125% ETc-10	3000	2500	2750	0.48^{d}	0.74^{bcd}	0.61^{b}
T7: 100% ETc-18	1600	1200	1400	0.68^{bc}	1.06^{ab}	0.87^{ab}
T8: 75% ETc-18	1200	900	1050	1.02^{a}	1.31^{a}	1.2^{a}
T9: 125% ETc-18	2000	1500	1750	0.52^{cd}	0.96^{abc}	0.74^{b}
CV (%)*				17.5	19.5	22.77
LSD (5 %)				0.19	0.31	0.19
T × Y				-	-	ns

** ns: non-significant difference, CV: coefficient of variation, LSD: least significant difference at 5 % probability level.*

The analysis of the result from Table 11 revealed that irrigation interval as the main effect has a significant effect ($P<0.05$) on crop water use efficiency in each year and combined over years, but the single effect of crop water levels had no significant effect ($P>0.05$). The maximum crop water use efficiency (0.9 kg/m^3) combined over years was recorded from the application of irrigation water in 18 days irrigation interval.

Table 11: Effects of irrigation interval on crop water use efficiency

Irrigation intervals (days)	Crop water use efficiency (Kg/m^3) 2016	2017	Combined
10	0.64^{ab}	0.85^{b}	0.73^{b}
14	0.54^{b}	0.75^{b}	065^{b}
18	0.74^{a}	1.1^{a}	0.90^{a}
CV(%)*	17.5	19.04	
LSD	0.10	0.19	0.16
T × Y	-	-	Ns

**ns: non-significant difference, CV: coefficient of variation, LSD: least significant difference at 5 % probability level.*

Pearson Correlations Analysis: From the analysis of the result, the grain yield of mung bean exhibits a relatively strong correlation with plant height (r=0.74) and the number of pods per plant (r=0.51), while it has a relatively weak positive correlation with the number of seeds per pod (0.34). Similarly, the crop water use efficiency has a relatively positively strongly correlated with grain yield (r=0.61), plant height (r=0.5), and the number of pods per plant (r=0.5), whereas it has a relatively weak positive correlation with the number of seeds per pod (Table 12).

Table 12: Pearson correlation of the combined data

	Grain yield	Plant height	NPP	NSPP	WUE
Grain yield	1				
Plant height	0.74	1			
NPP*	0.51	0.7768	1		
NSPP	0.34	0.4144	0.2248	1	
WUE	0.61	0.502	0.5	0.2085	1

* *NPP: number of pods per plant, NSPP: number of seed per pod, WUE: water use efficiency*

Conclusion and Recommendations

In Raya Kobo valley, there is a huge groundwater resource utilized for irrigation. However, utilization of this natural resource can be achieved by appropriately supplying the right amount of irrigation water at the right time. This study investigates the effects of crop water levels and irrigation intervals on the yield and water use efficiency of mung bean. *Crop water levels and irrigation intervals as the main effect and their interaction showed a significant effect (*$p<0.05$*) on mung bean plant height, grain yield and water use efficiency. Application of 100% (30 mm) ETc in 10 days irrigation interval gave simultaneously higher grain yield and water use efficiency and thus recommended for wider use for mung bean production.*

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References

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998. Crop evapotranspiration guidelines for computing crop water requirements. *FAO Irrigation and drainage paper* 56. *FAO, Rome*, 300(9), p. Do5109.

Anwar, F., Latif, S., Przybylski, R., Sultana, B. and Ashraf, M., 2007. Chemical composition and antioxidant activity of seeds of different cultivars of mungbean. *Journal of food science*, *72*(7), pp. S503-S510.

Asfaw, A., Gurum, F., Alemayehu, F. and Rezene, Y., 2012. Analysis of multi-environment grain yield trials in mung bean vigna radiate (L.) Wilczek based on GGE bipot in Southern Ethiopia.

Ashraf, M., 2010. Inducing drought tolerance in plants: recent advances. *Biotechnology advances*, *28*(1), pp.169-183.

Blake, G.R. and Hartge, K.H., 1986. Bulk density. *Methods of soil analysis: Part 1 Physical and mineralogical methods*, *5*, pp.363-375.

Shah, H., Siderius, C. and Hellegers, P., 2021. Limitations to adjusting growing periods in different agroecological zones of Pakistan. *Agricultural Systems*, *192*, p.103184.

Central Statistical Agency (CSA)., 2016. Agricultural sample survey area and production of major crops (Private peasant holdings, Meher season): Annual report. The Federal Democratic Republic of Ethiopia Central Statistical. Agency Addis Ababa, Ethiopia.

Food Agriculture Organization (FAO)., 2015. Analysis of price incentives for mung beans in Ethiopia for the time period 2005 -2012, United Nations

Food and Agricultural Organization (FAO)., 1999. *Soil salinity assessment: Methods and interpretation of electrical conductivity measurements*. FAO Irrigation and Drainage Paper 57, Rome, Italy.

Getahun Wendmkun., 2014. Groundwater modeling and optimization of irrigation water use efficiency to sustain irrigation in Kobo Valley, Ethiopia (*M.Sc. Thesis*, UNESCO-IHE).

Gomez, K.A. and Gomez, A.A., 1984. Statistical procedures for agricultural research. *John Wiley and Sons, second edition, New York*.

Hussain, F., Malik, A.U., Haji, M.A. and Malghani, A.L., 2011. Growth and yield response of two cultivars of mungbean (Vigna radiata L.) to different potassium levels. *J. Anim. Plant Sci*, *21*(3), pp.622-625.

Itefa, D., 2016. General characteristics and genetic improvement status of mungbean (Vigna radiata L.) in Ethiopia: Review article. *International Journal of Agriculture Innovations and Research*, *5*(2), pp.2319-1473.

Karuppanapandian, T., Karuppudurai, T., Sinha, P.B., Kamarul, H.A. and Manoharan, K., 2006. Genetic diversity in green gram [Vigna radiata (L.)] landraces analyzed by using random amplified polymorphic DNA (RAPD). *African Journal of Biotechnology*, *5*(13).

Lamond, R.E. and Whitney, D.A., 1992. Management of saline and sodic soils. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Retrieved 29.10. 2008.

Mahmoud, S.H. and Gan, T.Y., 2019. Irrigation water management in arid regions of Middle East: Assessing spatio-temporal variation of actual evapotranspiration through remote sensing techniques and meteorological data. *Agricultural Water Management*, *212*, pp.35-47.

Malik, A., Waheed, A., Qadir, G. and Asghar, R., 2006. Interactive effects of irrigation and phosphorus on green gram (Vigna radiata L.). *Pakistan Journal of Botany*, *38*(4), p.1119.

Merkebu Getachew., 2014. Influence of soil water deficit and phosphorus application on phosphorus uptake and yield of soybean (Glycine max L.) at Dejen, North-West Ethiopia. *American Journal of Plant Sciences*, *2014*.

Montazar, A., 2009. Assessing the global water productivity of some irrigation command areas in Iran. *World Academy of Science, Engineering and Technology*, *33*, pp.424-428.

Nabizade, M., Nejad, T.S. and Mojadam, M., 2011. Effect of irrigation on the yield of mungbean cultivars. *The Journal of American Science*, *7*(7), pp.86-90.

Onder, D., Akiscan, Y., Onder, S. and Mert, M., 2009. Effect of different irrigation water level on cotton yield and yield components. *African Journal of Biotechnology*, *8*(8).

Raza, M.H., Sadozai, G.U., Baloch, M.S., Khan, E.A., Din, I. and Wasim, K., 2012. Effect of irrigation levels on growth and yield of mungbean. *Pakistan Journal of Nutrition*, *11*(10), p.876.

Rehman, A., Khalil, S.K., Nigar, S., Rehman, S., Haq, I., Akhtar, S., Khan, A.Z. and Shah, S.R., 2009. Phenology, plant height and yield of mungbean varieties in response to planting date. *Sarhad J. Agric*, *25*(2), pp.147-151.

Robertson, M.J., Fukai, S. and Peoples, M.B., 2004. The effect of timing and severity of water deficit on growth, development, yield accumulation and nitrogen fixation of mungbean. *Field Crops Research*, *86*(1), pp.67-80.

Ross, A., Franks, S., Mason, H.D., Hardy, K. and Stark, J., 1997. Modelling the control of ovulation and polycystic ovary syndrome. *Journal of mathematical biology*, *36*(1), pp.95-118.

Sadeghipour, O., 2008. Effect of withholding irrigation at different growth stage on yield and yield components of mung bean (Vigna radiata L. Wilczek) varieties. American-Eurasian J. *Agric. & Environ. Sci*, *4*(5), pp.590-594.

Sahlemedhin Sertsu and Taye Bekele., 2000. Procedures for soil and plant analysis. Technical paper, *74, p.110.*

SARC (Sirinka Agricultural Research Center)., 2008. Recommended and released technologies. Sirinka Agricultural Research Center technical note.

Shao, H.B., Chu, L.Y., Jaleel, C.A., Manivannan, P., Panneerselvam, R. and Shao, M.A., 2009. Understanding water deficit stress-induced changes in the basic metabolism of higher plants biotechnologically and sustainably improving agriculture and the ecoenvironment in arid regions of the globe. *Critical reviews in biotechnology*, *29*(2), pp.131-151.

Sisay Ambachew, Tena Alamirew, Assefa Melese., 2014. Performance of mungbean under deficit irrigation application in the semi-arid highlands of Ethiopia. *Agricultural Water Management*, *136*, pp.68-74.

Somta, P. and Srinives, P., 2007. Genome research in mungbean (Vigna radiata (L.) Wilczek) and blackgram (V. mungo (L.) Hepper). *Science Asia*, *33*(Suppl 1), pp.69-74.

Tekalign Mamo, Haque, I., 1991. Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. Tropical Agriculture 68(1), pp. 2-8.

Tuberosa, R. and Salvi, S., 2006. Genomics-based approaches to improve drought tolerance of crops. *Trends in plant science, 11*(8), pp.405-412.

U.S. Salinity Laboratory Staff (Richards, L.A)., *1954.* Diagnosis and Improvement of Saline and Alkali Soils. *USDA Handbook No. 60, Pp.160.*

USDA-NRCS., 1997. Irrigation Guide, National Engineering Handbook; Washington, DC, USA.

Yagoob, H. and Yagoob, M., 2014. The effects of water deficit stress on protein yield of mung bean genotypes. *PJAS*, *2*, pp.30-35.

Yang, Y., Cui, Y., Luo, Y., Lyu, X., Traore, S., Khan, S. and Wang, W., 2016. Short-term forecasting of daily reference evapotranspiration using the Penman-Monteith model and public weather forecasts. *Agricultural Water Management*, *177*, pp.329-339.

Yenus Ousman., 2013. Effects of irrigation and nitrogen levels on bulb yield, nitrogen uptake and water use efficiency of shallot (Allium cepa var. ascalonicum Baker). *African Journal of Agricultural Research*, *8*(37), pp.4637-4643.