Yield Response of Mung Bean to Deficit Irrigation in North Wollo

Sisay Ambachew[a] *(sisayambachew@yahoo.com) and Tena Alamirew*[b]
[a]*Gondar Agricultural Research Center, P.O. Box 1337, Gondar, Ethiopia*
[b]*Ethiopian Institute of Water Resources, Addis Ababa, Ethiopia*

Abstract
Deficit irrigation is becoming an important strategy to optimize agricultural water use in arid and semiarid regions. The regulated deficit irrigation experiment was conducted on mung bean, one of the newly introduced and promising crops to the mandate area at Lalibella, North Wello in 2010/2011 irrigation season. Furrow irrigation method was used to apply water. There were eight treatments: independent application of 25% ET_c *at first, second, third and forth crop growth stages (that is one period stresses); application of 25%* ET_c*, 50%* ET_c*, 75%* ET_c *and 100%* ET_c *throughout the growth stages. The treatments were arranged in Randomized Complete Block Design. It was found that application of 25%* ET_c*, irrigation water independently a first, second and forth crop growth stages and 75%* ET_c *throughout the growth stages were statistically non significant in terms of yield compared to full irrigation application (100%* ET_c*). While application of 25%* ET_c *at third growth stage provided significant yield difference compared to 100%* ET_c *application. The lowest (492 kg* ha^{-1}*) and the highest (1366 kg* ha^{-1}*) grain yield were obtained by applying 25%* ET_c *and 100%* ET_c *irrigation application throughout the growth stages, respectively. Water use efficiency was improved by 6-23% using deficit irrigation application. The lowest and the highest water use efficiency was found at deficit irrigation application of 25%* ET_c *in the third growth stage and 50%* ET_c *throughout the growth stages, respectively. The result indicated that crop productivity can be optimized through application of deficit irrigation considering the different growth stages of the crop. Therefore, farmers who are cultivating mung bean under irrigation condition are advised to practice irrigation application of 25%* ET_c *(75% deficit) either at initial, development and late growth stages in one period stress or 75% ETc (25% deficit) throughout the growth stages.*

Key words: Growth stage, Deficit irrigation, Water use efficiency, Mung bean, Ethiopia

Introduction

Increasing global demand for food and other agricultural products call for urgent measure to increase agricultural production. As the pressure on land increases, more and more marginal areas are being used for agriculture. And much of this land is located in arid and semi-arid belts where rainfall is erratic. Irrigated agriculture makes a major contribution to this pressure on land and drought risk. Increasing water productivity through effective development (adaptation) of genotypes and development of new water management technologies in arid and semi-arid regions for better utilization of the limited water resource have paramount importance (Montazar, 2009). One of the option regulated deficit irrigation is relatively inexpensive and easy to implement (Webber *et al*., 2006). Under conditions of water scarcity, deficit irrigation can lead greater water use efficiency by maximizing yield per unit of water used. The improvement of on farm irrigation systems and the introduction of low cost, water saving irrigation technologies are identified as key and attainable components for reducing agriculture's water demand (Horst *et al*., 2005).

According to Geerts and Raes (2009), review of selected research works around the world confirms that deficit irrigation successfully increased water productivity for various crops. For instance, Zwart and Bastiaanssen (2004) reviewed measured crop water productivity for several crops around the world and concluded that the crop water productivity could be significantly increased if irrigation was reduced and crop water deficit was intentionally induced. Oweis and Hachum (2001) demonstrated that, the higher level of crop cycle control and the lower sensitivity to climate resulting from deficit irrigation, sowing dates can be staggered, thus reducing peak supply by 20%. In this way, irrigation level water productivity is increased through managing planting date.

Mung bean is one of the most important short season grain legumes in the conventional farming system of tropical and temperate regions. The crop is known to perform well under condition of low soil moisture and have short life cycle to be used for crop intensification, and it is widely practiced for maximizing water use efficiency (Sadeghipour, 2008). According to Webber *et al*. (2008), regulated deficit irrigation reduced the crop consumptive water use for mung bean. Mung bean had shown greater potential to reduce its water use and maintain yield levels and increase water use efficiency. In mung bean cultivation post flowering and pod filling stages are most sensitive to water stress (Uperty and Bhatia, 1989). Thus, irrigation is critical during pod filling and flowering stages for mung.

Understanding the yield response factor of mung bean with deficit irrigation at different growth stages and throughout the growing season is important for optimal scheduling of the limited water supply and for better crop management practice related to soil moisture. The objective of the study was thus to identify optimum irrigation water management strategies using deficit irrigation and identify the yield reductions of mung bean under different water stress regimes at different stages and throughout the growth stages.

Materials and Methods

Descriptions of the Study Areas

The field experiment was conducted at Lalibela in North Wello, one of the experimental sites of Sekota Dry land Agricultural Research Center during 2010/11 dry season, where an irrigation scheme was available. The site is located at 12°13 O! boe! 4: °14 F! boe, 2050 m.a.s.l. The mean annual rainfall of the area is 635 mm but very erratic and mean annual reference evapotranspiration of approximately 1481 mm. The mean annual minimum and maximum temperature vary between 11.4 °C to 13.7 °C and 23.8 °C to 25 °C, respectively. The soil is well drained, dark brown in color, and very shallow in depth and clay loam in texture. The soil field capacity and permanent wilting point is 24.32% and 13.86% by volume which gives a soil water holding capacity of 104.2 mm with 1.39 gcm^{-1} bulk density.

Experimental setup

The field experiment was set on a field plot where regulated flow of water is possible. Every experimental unit had a metal sheet at the head for dividing water equally to every (eight) furrows of experimental plot. The irrigation water was pumped from a canal supplied from Medagie River and stored in barrel of known volume and then measured amount of water was applied to the experimental plots (through furrows) using watering cans.

The experiment was made in a randomly complete block design with four replications. A spacing of 1.5 m and 1 m was used between blocks and between plots respectively. Within each block, eight deficit irrigation applications (Table 1) were randomly distributed. Then each experimental unit was prepared in such a way that each of them consisted of eight furrows and seven ridges with furrow length of 5 m. Mung bean (N_{26}

variety) was planted at 10 cm spacing between plants and 30 cm spacing between rows on a 2.4 m x 5 m plots. DAP fertilizer was applied at the rate of 100 kg/ at planting. Frequent weeding was done manually when there was an invasion of weeds.

Table 1. Description of irrigation treatments setup used for deficit irrigation of Mung bean at Lalibela during 2010/2011

No.	Treatments.	Growth Stage				
		P1	P2	P3	P4	
1.	T1 (1111)	1	1	1	1	Normal irrigation
2.	T2 (0000)	0	0	0	0	All stress
	One period stress					
3.	T3 (0111)	0	1	1	1	Stress at P1
4.	T4 (1011)	1	0	1	1	Stress at P2
5.	T5 (1101)	1	1	0	1	Stress at P3
6.	T6 (1110)	1	1	1	0	Stress at P4
	Partial stress throughout the growing season					
7.	T7 (50%)	50 %	50 %	50 %	50 %	
8.	T8 (25%)	25 %	25 %	25 %	25 %	

Note: 1= Normal watering- watering 100 % of ETc, 0= Stress (75% deficit) indicates stressed - watering only 25% of ETc , 50 % = 50% Deficit - watering 50% of ETc, 25% = 25% Deficit - watering 75% of ETc, and P1, P2, P3 and P4 are initial, developmental, mid and late season growth stages.

The depth of water applied for eight treatments and its irrigation period is presented in Table 3. The depth of total irrigation water applied was the sum of pre irrigation (25 mm) and all subsequent scheduled amount of irrigation calculated from the CROPWAT model. The purpose of pre irrigation was to encourage a full and even plant stands.

Table 2. Reference evapotranspiration, crop and irrigation water requirement of mung bean at seven days irrigation interval for Lalibela during 2010/2011

Date	ET_o (mm/peroid)	Crop Kc	CWR (ET_c) (mm/peroid)	Net Irr. Req. (mm/peroid)
15 Novmber	3.83	0.50	13.6	13.6
21 Novmber	22.98	0.50	16.7	16.7
28 Novmber	26.81	0.50	19.3	19.3
5 December	26.32	0.63	21.6	21.6
12 December	26.11	0.79	24.2	24.2
19 December	26.11	1.00	28.0	28.0
26 December	26.11	1.05	29.7	29.7
2 January	26.53	1.05	27.4	27.4
9 January	27.58	1.05	27.9	27.9
16 January	27.58	1.05	28.3	28.3
23 January	27.58	1.05	28.0	28.0
30 January	27.58	0.81	27.3	27.3
6 Febrauary	31.92	0.56	21.2	21.2
17 Febrauary	31.92	0.35	17.5	17.5
Total	358.96		330.7	330.7

ET_o = Reference evapotranspiration, K_c = Crop coffiecient , CWR = Crop water requirment

Determination of Crop and Irrigation Water Requirement

The FAO Penman Monteith equation (Allen *et al*., 1998) was used to calculate the reference evapotranspiration ET_o using the CROPWAT Program (Table 2). Crop water requirement (ET_c) over the growing season was determined from ET_o using crop coefficient Kc according to the following equation:

ETc = $K_c \times ET_o$ (1)

Where ET_c is the crop water requirement, K_c is the crop coefficient and ET_o is the reference evapotranspiration. Since there was no rainfall during the experimental period, net irrigation requirement was taken to be equal to ET_c. Irrigation water use efficiency (IWUE) was calculated as:

IWUE= $\frac{Y}{IW}$ (Ibragimov *et al*., 2007) (2)

Where Y is the crop yield (kg/ha) and IW is total irrigation water applied (m^3ha^{-1}).

The yield response factor for deficit irrigation application was determined following Doorenbos and Kassam (1979) equation.

$$1-\frac{Y_a}{Y_m}=K_y(1-\frac{ET_a}{ET_m}) \quad (3)$$

Where: Y_a and Y_m are actual and maximum crop yields, corresponding to and actual (ET_a) and maximum (ET_m) evapotranspiration, respectively; Ky is yield response factor.

Table 3. Total water depth applied for the eight treatments (mm) at Lalibela 2010/2011

Date	Interval (days)	Treatments							
		T1	T2	T3	T4	T5	T6	T7	T8
13 Novmber	**	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
15 Novmber	0	11.6	2.9	2.9	11.6	11.6	11.6	5.8	8.7
21 Novmber	6	15.6	3.9	3.9	15.6	15.6	15.6	7.8	11.7
28 Novmber	7	18.2	4.6	4.6	18.2	18.2	18.2	9.1	13.7
5 December	7	20.7	5.2	20.7	5.2	20.7	20.7	10.4	15.5
12 December	7	23.2	5.8	23.2	6.8	23.2	23.2	11.6	17.4
19 December	7	27.1	6.8	27.1	7.3	27.1	27.1	13.6	20.3
26 December	7	29.2	7.3	29.2	14.0	7.3	29.2	14.6	21.9
2 January	7	27.4	6.9	27.4	27.4	6.9	27.4	13.7	20.6
9 January	7	27.9	7.0	27.9	27.9	7.0	27.9	14.0	20.9
16 January	7	28.3	7.1	28.3	28.3	7.1	28.3	14.2	21.2
23 January	7	28.0	7.0	28.0	28.0	28.0	7.0	14.0	21.0
30 January	7	27.3	6.8	27.3	27.3	27.3	6.8	13.7	20.5
6 Febrauary	7	21.2	5.3	21.2	21.2	21.2	5.3	10.6	15.9
Total	95	330.7	101.6	296.7	263.8	246.2	273.3	178.1	254.3

*Note: ** = pre-irrigation two days before planting*

The agronomic data were collected from the middle 5 rows of each plot. Plant phenological stages such as days to flowering and maturity, thousand seed weight (g) and grain yield (kg/ha) were recorded on plot bases. Parameters such as number of seeds per pod and number of pods per plant were recorded on plant bases.

Statistical Analysis

Analysis of variance and treatment mean comparisons for the different measured parameters were carried out using SAS(R) software window 9.0. Mean separation for the recorded plant parameters were made using Least Significance Difference Test (at 0.05siginificance level). Model efficiency developed by Nash and Sutcliffe (1970) was used to evaluate the performance of models. It was calculated as:

$$ME = \frac{\sum_{i=1}^{n}(Ym - Ya)^2 - \sum_{i=1}^{n}(Yp - Ym)^2}{\sum_{i=1}^{n}(Ym - Ya)^2}$$

(4)

Where: ME is model efficiency (%), Y_m measured value of yield reduction (%), Yp is CROPWAT predicted value of yield reduction (%) and Ya is the average value of measured yield reduction (%) and n is 8th number of treatments tested.

Results and Discussion

Crop and Irrigation Water Requirement

Reference evapotranspiration (ET_o) and crop evapotranspiration of mung bean, as estimated by the FAO Penman Monteith equation, is presented in Table 2. Crop water requirements were calculated by multiplying the reference evapotranspiration values with the mung bean crop coefficients given by Allen *et al*. (1998), 0.5 for the initial stage, 0.5 < K_c < 1.05 for the development stage, 1.05 for the mid-season stage and 0.35 < K_c < 1.05 for the late season stage. Based on the calculation the reference evaporation, crop water requirement and irrigation requirement is for mung bean in Lalibela area 359 mm, 330.7 mm and 330.7 mm respectively.

Yield Components of Mung bean

The phonological stages and yield component results such as number of days from planting to 50% flowering and days to maturity are presented in Table 4. Mung bean supplied with only 25% ET_c, (75% deficit water from the full) application throughout the growth stages gave shorter number of days to reach flowering while full irrigation application gave longest days to flowering from planting. Flowering was shortened by about a week with an application of 75% deficit water as compared to full irrigation water application. This finding is in line with those obtained by Ahmed *et al*. (2008), flowering and maturity for faba bean; plants try to escape from unfavorable stress conditions by ending their life few days earlier than those under normal soil moisture conditions.

Table 4. Phenological stages and yield components of mung bean as influenced by different deficit irrigation applications at Lalibela during 2010/2011

Treatments	Days to flowering **	Days to maturity **	Number of pods per plant**	Number of seeds per pod**	1000 Seed Weight (g) *
T1(1111)	51.75^{a}	89.75^{a}	12.01^{a}	12.26^{a}	53.88^{a}
T2 (0000)	44.50^{e}	81.75^{d}	5.88^{e}	7.70^{d}	46.38^{c}
T3 (0111)	49.50^{bcd}	88.75^{ab}	11.76^{ab}	11.99^{a}	51.88^{ab}
T4 (1011)	49.25^{dc}	86.75^{b}	11.04^{bc}	11.23^{b}	51.50^{ab}
T5 (1101)	50.00^{bc}	88.75^{ab}	10.65^{c}	10.18^{c}	51.38^{ab}
T6 (1110)	51.00^{ab}	89.50^{a}	11.29^{abc}	10.32^{c}	50.63^{ab}
T7 (50%)	48.00^{d}	84.50^{c}	9.20^{d}	9.93^{c}	48.50^{bc}
T8 (25%)	50.50^{ab}	88.25^{ab}	11.56^{abc}	12.05^{a}	52.75^{a}
Grand Mean	49.31	87.25	10.42	10.71	50.86
LSD (0.05)	1.52	2.11	0.966	0.459	3.816
CV (%)	2.09	1.64	6.30	2.92	5.10

*LSD- Least Significant Difference and CV- Coefficient of Variation **Means followed by different superscripts are statistically different*

The result for average number of pods per plant, seeds per pod and thousand seed weight for each irrigation application revealed that these parameters were influenced by variations in levels of irrigation water application. The number of pods per plant and seeds per pod have shown highly significant difference among the deficit irrigation applications ($p<0.01$). There was no significance difference in number of pods per plant among deficit irrigations 75% ET_c at first and last growth stages 25% deficit at all stages and the full application. Whereas the number of pods per plant obtained at 75%

at all stages, 75% deficit application at second and third stages and 50% deficit application deficit at all stages were significantly different with the full application. This indicate that the development and mid season growth stages are more sensitive to water stress than other growth stages. This is in line with research findings of Sadeghipour (2008) which reported that moisture stress at flowering and pod formation stage resulted in minimum number of pods per plant, number of seeds per pod and 1000 seed weight of mung bean. Simsek *et al*. (2011) also reported that water stress during reproductive stage in common bean increased the number of aborted flowers and reduced the number of pods per plant.

Yield and Water Use Efficiency of Mung bean

The mean grain yield and irrigation water use efficiency results are presented in Table 5. A significant difference in grain yield among the deficit irrigation application was observed. Water stress at third growth stage (mid season) that is at flowering and reproductive stage had produced lower yield (24.94% yield reduction) as compared to full irrigation. Deficit application of 75% during initial, development and late season stages resulted in respective yield reduction of 4.54%, 7.80% and 5.93% as compared to the full irrigation application. Through imposing deficit at early growth stages the crop gets enough time to recover from the stress during the rest of the growing seasons to produce reasonable yield. Comparable grain yield reduction (non significance difference) was obtained by applying 75% deficit water at first, second and last growth stages.

This finding provides an indication of the growth stage when it is worth to save water with little or optimal yield reduction. Stress during mid season stage has more severe impact on yield. This is in line with other findings which indicate that water stress that occurs at reproductive stage specially flowering and pod formation stages, affected grain yield more severely (De Costaa et *al*., 1999; Simsek *et al.*, 2011).

Table 5. Effects of deficit irrigation levels on grain yield, irrigation water use efficiency and the amount of saved water at Lalibela during 2010/2011

Treatment	Average yield (kg/ha)**	IWUE (kg/m^3)*	Water saved(m^3/ha)
T1(1111)	1366.25[a]	0.248[c]	-
T2 (0000)	492.00[c]	0.290[ab]	2291
T3 (0111)	1304.25[a]	0.264[bc]	340
T4 (1011)	1259.75[a]	0.287[abc]	669
T5 (1101)	1025.50[b]	0.250[c]	845
T6 (1110)	1285.25[a]	0.282[abc]	574
T7 (50%)	902.50[b]	0.304[a]	1526
T8 (25%)	1271.75[a]	0.300[ab]	764
Grand Mean	1113.41	0.278	-
LSD (0.05)	149.72	0.040	-
CV (%)	9.14	9.65	-

*Where: IWUE- irrigation water use efficiency LSD- Least Significant Difference and CV- Coefficient of Variation *, **=significant at 5 and 1% level. Means followed by different superscripts are statistically different*

The irrigation water use efficiency of mung bean varied from 0.248 kg m^{-3} to 0.304 kg m^{-3}. The probable reason why water use efficiency decreased under optimal irrigation water application may attribute to water loss through evaporation reduced in deficit irrigation treatments than full irrigation application. Maximum mean IWUE was obtained when 50% of the crop water requirement was applied throughout the growth stages. Plots which received three-fourth of the full irrigation water throughout the growth stages resulted in the second largest IWUE. This result is suported with the findings of Onder *et al.* (2009). Webber *et al*. (2008) which reported that mung bean had greater potential to increase water use efficiency under deficit irrigation. According to Geerts and Raes (2009), in their selected research review works around the world confirm that deficit irrigation increase water productivity for various crops.

The second lowest mean value of IWUE (0.250 kg m^{-3}) was found when 75% deficit was imposed at mid season stage. Thomas *et al*. (2004) reported that the grain yield of mung bean is severely affected by soil moisture stress at flowering and pod filling stages and then ultimately the water use efficiency. Therefore, application of adequate water during flowering and pod development was the most significant factor in bean irrigation (Simsek *et al*., 2011). This has important economical implications because it means that under water limited conditions, mung bean fully irrigated around flowering and pod filling stages can produce more yields per unit of irrigation water applied.

Figure 1 shows that there is a linear relationship between the amount of water applied and the grain yield. The coefficient of determination (R^2) indicates that more than 92.6% of the yield variation is coming from the variability in irrigation water application.

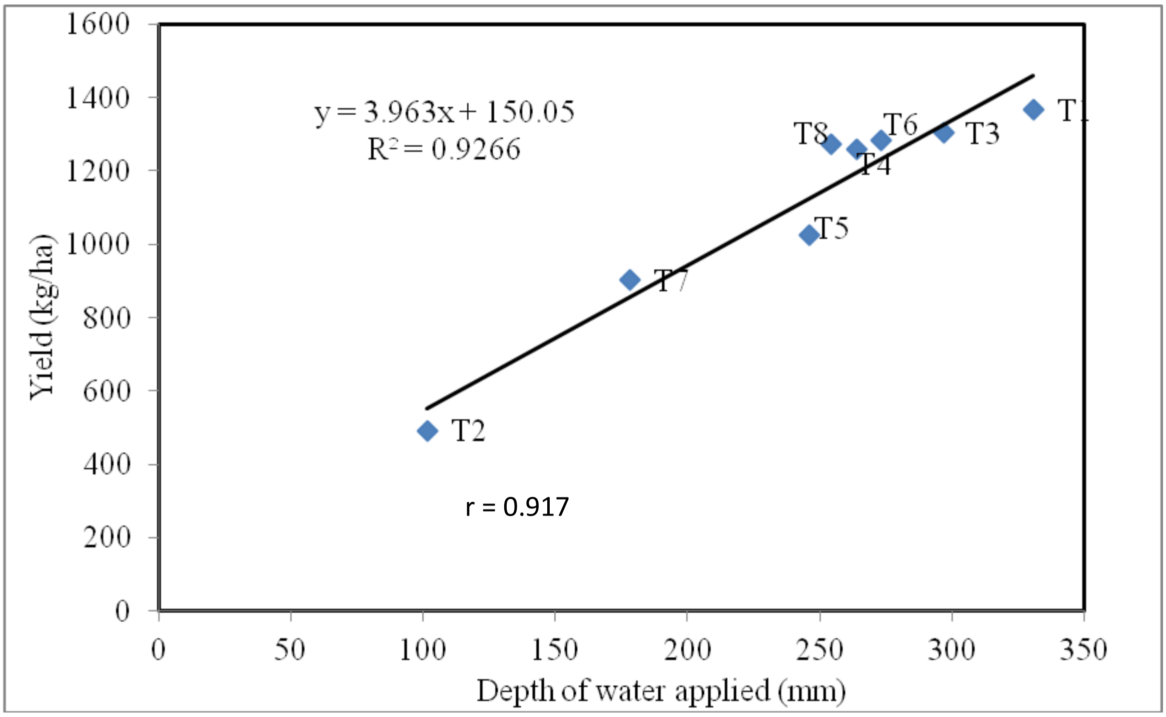

Figure 1. Yield - water relationships of mung bean at Lalibela during 2010/2011 G.C.

The relationship can be expressed by linear equation as: Grain yield (kg/ha) = 3.96(depth of irrigation (mm)) + 150

Sadeghipour (2008) also reported that water stress reduced mung bean yield and yield component regardless of whether the stress had imposed when the plant was in vegetative or reproductive stage. The slope of the regression line which indicates the increment of grain yield for a unit increment of irrigation water was near to four fold. Similarly the calculated Modeling efficiency is 93.2% which implies the model was satisfactorily predicting the yield reduction as a result of stress imposition. The yield reductions calculated by CROPWAT model were comparable with the measured yield reduction at field conditions.

From Figure 2, the yield response factor for each of the growth stages was less than unity which implies the relative yield reduction was less than the relative evapotranspiration deficit. The highest K_y value (0.98) was obtained in the mid season stage. Thus, irrigation was critical during mid season stage for mung bean. This shows that trying to improve crop water production by adopting deficit irrigation without due consideration of its timing might not be beneficial. The overall production of mung bean will be increased by extending the area under irrigation without meeting full water requirement. Mung bean had shown greater potential to reduce its water use and maintained yield levels and increased water use efficiency under soil moisture deficit (Sadeghipour, 2008).

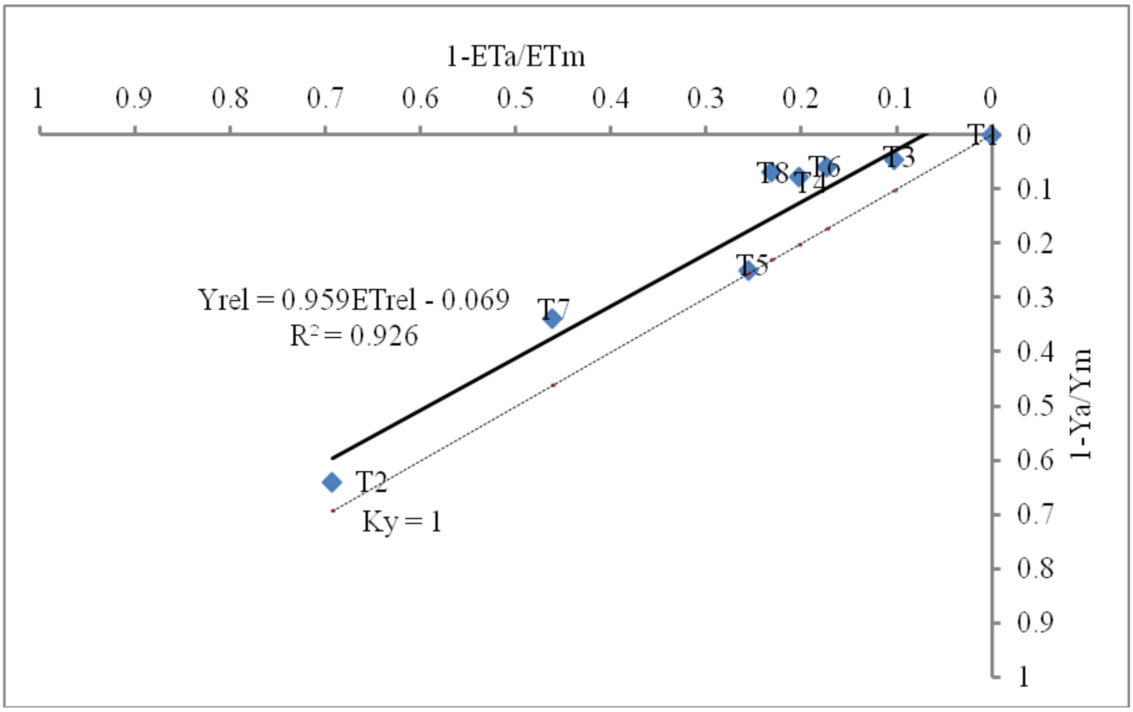

Figure 2. The relationship between relative yield reduction and relative seasonal water deficit for mung bean at Lalibela during 2010/2011 G.C where: Yrel is relative yield reduction and ETrel is relative evapotranspiration deficit.

Conclusion and Recommendations

The field experiment has revealed that when water stress is imposed at initial, development or late season growth stages high yield of mung bean could be easily sustained provided that adequate watering conditions take place during the rest of the growing season. Then more positive results could be obtained from deficit irrigation by imposing 75% deficit either at the initial, development or late season growth stages or the 25% deficit could be distributed at all growth stages. The most critical period for mung bean irrigation is the mid season growth stage. Imposing water stress during the mid season growth stage is found to produce lower yield indicating the severe effect of water stress during flowering and pod filling stage on grain yield. This shows that trying to improve crop water productivity by adopting deficit irrigation without due consideration of its timing might not be beneficial. Water use efficiency increased with decreasing the amount of water applied. However, water stress inversely affect water use efficiency when the deficit was imposed at mid season growth stage via severely affecting the grain yield. As finding of this research suggest, farmers are advised to practice full irrigation water application when water is not a limiting factor. However, when irrigation water is a limiting factor farmers are advised to practice 75% deficit irrigation either at the initial, development, late season stages or 25% deficit application throughout the growth stages.

References

Ahmed, A.K., K.M. Tawfik and Z.A. Abd El-Gawad, 2008. Tolerance of seven faba bean varieties to drought and salt stresses. *Res. J of Agric. & Biol Sci*. 4(2): 175-186.

Allen, R., L.A. Pereira, D. Raes and M. Smith, 1998. Crop Evapotranspiration. Irrigation and Drainage Paper No. 56. FAO. Rome, Italy.

De Costaa, W.A.J.M., K.N. Shanmugathasan and K.D.S.M. Joseph, 1999. Physiology of yield determination of mung bean (*V. radiata* (L.). Under Various Irrigation Regimes in the Dry and Intermediate Zones of Sri Lanka. Peradeniya, Sri Lanka. *Field Crops Research*. 61: 1-12.

Fereres, E. and M.A. Soriano, 2007. Deficit irrigation for reducing agricultural water use. Special jttvf! po! 'Jouf hsbufe! bqqspbdi ft! up! tvtubjo! boe! jn qspwf! qrbou qspevdujpo! voefs! espvhi u tusftt /! *Journal of Experimental botany*. 58: 147 159.

Fitsum, H., G. Makombe, R. E. Namara, S. B. Awulachew, 2009. Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. International Water Management Institute (IWMI Research Report 128). Colombo, Sri Lanka.

Geerts, S. and D. Raes, 2009. Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. *Agricultural Water Management* 96:1275 1284.

Horst, M. G., S. S. Shamutalov, L. S. Pereira, and J. M. Gonçalves, 2005. Field assessment of the water saving potential with furrow irrigation in Fergana, Aral Sea basin. *Agricultural Water Management.* 77:210-231.

Ibragimov, N., Evett, R., Yusupbek, Esanbekov,, Bakhtiyor, S,. Kamilov, Lutfullo Mirzaev and John, P.A., 2007. Water use Efficiency of Irrigated Cotton in Uzbekistanunder Drip and Furrow Irrigation. Elsevier B.V. 90:112-120.

Montazar, A., 2009. Assessing the global water productivity of some irrigation command areas in Iran. *World Academy of Science, Engineering and Technology*. 150: 18-29.

Nash, J.E. and V. Sutcliffe, 1970. River flow forecasting through conceptual methods. A discussion of principles. *Journal of hydrology. 10: 280-292*

Onder, D., Y. Akiscan, S. Onder and M. Mert, 2009. Effect of different irrigation water level on cotton yield and yield components. *African Journal of Biotechnology*. 8 (8):1536-1544.

Oweis, T. and A. Hachum, 2001. Reducing peak supplemental irrigation demand by extending sowing dates. *Agricultural water Water Management*. 50:109 123.

Sadeghipour, O., 2008. Effect of Withholding irrigation at different growth stages on yield and component of mung bean (*Vagna radiata*) Varieties. *Journal of Agriculture and Environmental science.* 4 (5):590-594.

Simsek, M., N., Comlekcioglu and I. Ozturk, 2011. The effects of the regulated deficit irrigation on yield and some yield components of common bean (*Phaseolus vulgaris* L.) under semi-arid conditions. *African Journal of Biotechnology*. 10(20): 4057- 4064.

Thomas, R., M.J. S. Fukai and M.B. Peoples, 2004. the effect of timing and severity of water deficit on growth, development, yield accumulation and nitrogen fixation of mung bean. *Field Crops Research*, 86: 67-80.

Uperty D.C. and A.Bhatia, 1989. Effect of water stress on the photosynthesis, productivity and water status of Mung bean (*Vigna radiate* (L) Wilczek). *Journal of Agronomy and Crop Science*. 163:115-123

Webber, H.A, C.A, Madramootoo, M. Bourgault, M.G. Horst, G. Stulina and D.L. Smith, 2006. Water use efficiency of common bean and green gram grown using alternate furrow and deficit irrigation. *Agricultural Water Management.* 86: 259-268.

Webber, H.A, C.A, Madramootoo, M. Bourgault, M.G. Horst, G. Stulina, D.L. Smith, 2008. Plant and Soil Water Dynamics of Alternate Furrow and Regulated Deficit Irrigation for Two Legume Crops. *American Society of Agricultural and Biological*. 51(5): 1341-1350.

Zwart, S. J., and W. G. M. Bastiaanssen, 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton,and maize. *Agricultural Water Management* 69(2): 115-133.