Original Research Article

Influence Of Irrigation Water Deficit On Forage Yield, and Water Utilization Efficiency For Sorghum and Cowpea Forage Crops

ABSTRACT

The present study was carried out at Sakha Agricultural Research Station (clayey soils) during 2018 and 2019 to find out the role of water deficit on yield and some water relations for sorghum and cowpea summer forage crops. Three irrigation levels were executed; 100% (full irrigation), 90% (10% deficit) and 80% (20% deficit). Results showed that increasing water deficit, markedly led to decreasing fresh, dry yield and plant height at the three cuts in the two seasons. Regarding water relations, irrigation level with 90% (10% deficit) resulted in several advantages; almost same yield as recorded under full irrigation, 10% water saving as well as the highest values of water productivity (WP) and productivity of irrigation water (PIW). The mean values of fresh sorghum forage yield can be arranged in descending order as; 2917.0 > 2857.5 > 2561.0 kgplot^{-1}, while the corresponding values of the dry weight were; 381.6> 367.8> 319.6 kgplot^{-1}. Plant height for cowpea slightly affected with different irrigation treatments. On the contrary, both fresh and dry yields were significantly affected with water level or deficit irrigation. Moreover, the effect was highly significant in connection with the combined analysis. In this regard, mean values of fresh yield descending arranged as; 1502.5> 1447.0> 1321.5 kgplot^{-1} for treatments A(control), B (90%) and C (80%), respectively. The corresponding values regarding dry yield are 253.5, 241.0 and 215.4 kgplot^{-1}. Comparing the deficit treatments with the control irrigation (Trt. A), overall mean decrease in fresh yield was 3.7% for treatment B (90%) and 12% for treatment C (80%). While, the corresponding decrease in dry yield were 4.9% and 15.0%.We can concluded that forage yield of sorghum and cowepea not affect by water irrigation deficit about 10% at Middle North Delta area.

Keywords: Forage crops, sorghum, cowpea, water deficit, water productivity, productivity of irrigation water.

INTRODUCTION

Egypt has unique features regarding its water status, it is the solely country worldwide that its agricultural production is mainly under irrigation i.e., irrigated agriculture due to the prevailing aridity conditions. Nile River is the main water resource for Egypt with its inlets outside the boundaries of the country. Capita share from water per annum becomes less than the water

poverty edge of 1000 m^3 and it decreasing rapidly towards the scarcity line of less than 500 m^3 in the few coming decades. At this situation, it is difficult to make progress in any national economic sector.

In addition, Egypt is facing a pronounced water shortage, particularly for irrigating summer crops. In other words, irrigation is the main critical factor in agricultural production. Agricultural irrigation is the main sector in water consumption with more than 80% from the annual national water supply. Therefore, water productivity becomes one of the main targets under the umbrella of **"effective on-farm irrigation management"**. Meaningfully, **more crop per drop**.

In this regard, irrigation management under water deficit status becomes a must.

Crop productivity and its water functions under the prevailing water shortage are among the first priorities of many researches in the world such as; **Abu-Zeid, M., and A. Hamdy 2002, Seckler et al. 1998, Hamdy and Lacirignola 1999, Cosgrove and Rijsberman 2000, IWMI-International water management institute 2000.**

Steduto et. al. (2012) demonstrated that the consumptive use (ET) of 110 to 130-day sorghum crops range between 450 and 750 mm, depending on evaporative demand. Seasonal water use is higher for late maturing genotypes because of longer growing periods. They also stated that surface irrigation methods of furrow, border, basin or corrugation are commonly practiced. Water deficit and drought are the most limiting factors affecting plant growth; reduce crop production and threating food security in the world **(Water in a changing world, 2009)**

On the other hand, sorghum and cowpea are among other summer crops for animal feeding stuff. Summer forage crops are essential to provide the necessary such animal feeding. Animal feeding stuff is lack in summer due to the less cultivated area in comparison to that cultivated with the winter principal forage crop of Egyptian clover.

Sorghum *Sorghum bicolor L. Moench* is among the most important forage crops in summer season. A successful forage sorghum breeding program to develop hybrid sorghum, which had more tolerant for unsuitable environment and more productivity **(Duvick, 1999).**

Cowpea *Vigna unguiculata L.* is an important source of protein in human diet **(Karigoudar and Angadi, 2005)** and is equally important as nutritious fodder for livestock **(Singh et al., 2003)**. As a legume fodder, it provides high quality forage rich in protein with

14-24% **(Heuze et al., 2013)**. It has ability to tolerate drought and can withstand heat and can utilize soil moisture efficiently as it has a well-developed root system **(Turk and Hall, 1980b), (Hamdy et al., 2002)**and **(Sambo et al., 2013)**.So, the aim of this work was to find out the

response of yield and some water functions for sorghum and cowpea forage crops to water deficit irrigation owing to produce " more per less".

Materials and Methods

A field experiment was carried out during the two successive summer for sorghum and forage cowpea at the Research Farm of Sakha Agricultural Research Station2018 and 2019 seasons forage. The site is located in middle North of Nile Delta area with 30°-57 N latitude, 31°-07E longitude with an elevation of about 6 meters above mean sea level. Table 1 represents the climatic elements of the area during the two field trial seasons. The soil of the site is clayey in texture as shown in Table 2.

Table (1). Climatic elements of; air temperature (T, C°), relative humidity (RH, %), wind speed (U_2, $m.sec^{-1}$) and evaporation pan (Ep, $mm.d^{-1}$).

A.1st season, 2018							b-2nd season, 2019						
Month	T, C°			RH, %	U_2, $m.sec^{-1}$	Ep, $mm.day^{-1}$	Month	T, C°			RH, %	U_2, $m.sec^{-1}$	Ep, mm. day^{-1}
	max	min	Mean			m		max	min	Mean			mm
May-18	31.2	23.8	27.5	60	1.1	6.3	May-19	31.9	25.4	28.3	57.2	0.79	6.8
June "	32.6	25.3	28.9	62	1.14	7.8	June "	33	27	30	65.7	1.19	8.5
July "	34.2	25.4	29.8	67	1.03	7.4	July "	33.5	28.4	30.9	70.5	0.97	9.4
Aug. "	33.9	25.3	29.6	67	0.88	6.4	Aug. "	34.2	29.1	31.7	70.8	0.8	6.8
Sept. "	32.8	23,5	28.2	66	0.8	5	Sept. "	32.4	27.9	30.2	68.2	0.89	5.9
Oct. "	29.5	20.6	25.1	66	0.67	3.2	Oct. "	30.2	26.7	28.5	70.8	0.66	3.8
Mean	32.4	24	28.2	65	0.94	6	Mean	32.5	27.4	29.9	67.2	0.88	6.9

Physical and chemical characteristics of the studied site.

Soil samples were collected from different depths: 0-15, 15-30, 30-45 and 45-60 cm to determine soil-water constants of field capacity (F.C) and permanent wilting point (PWP) according to **James (1988)** as well as soil bulk density (Db). Physical properties of particle size distribution were determined according to **Klute (1986).** The obtained analysis indicated that the soil is clayey in texture as shown in Table 2. Chemical properties of total soluble salts, soil reaction (pH), both soluble cations and anions were also determined according to **Jackson (1973).** Sulphate (So_4^{--}) was computed by the difference between soluble cations and anions, both in meq L^{-1} as tabulated in Table 3.

Table (2):Particle Size distribution and soil-water constants of the studied experimental site.

Soil depth, cm.	Particle size distribution			Texture class	F.C, %	W.P, %	AW, %	Db, Mg/m^{-3}
	Sand, %	Silt, %	Clay, %					
0 – 15	19.5	27.6	52.9	Clay	46.40	25.21	21.19	1.14
15 – 30	20.4	27.4	52.2	Clay	41.38	22.49	18.89	1.18
30 – 45	24.9	25.7	49.4	Clay	38.50	20.92	17.58	1.22
45 – 60	25.6	26.8	47.6	Clay	36.90	20.05	16.85	1.30
Mean	22.6	26.9	50.5	Clay	40.80.	22.17	18.63	1.21

Where: F.C, % = soil field capacity, W.P, % = wilting point, AW, % = available soil water and Db, $Mg.m^{-3}$ = soil bulk density.

Table (3): Chemical properties of the experimental site:

Soil depth, cm	Ec, dsm^{-}	PH (1: 2.5) soil water suspension	Soluble ions, $meqL^{-1}$							
			Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0-15	1.78	8.30	6.20	3.20	8.20	0.27	0.00	5.20	8.10	4.57
15-30	2.40	8.15	9.63	4.70	9.54	0.22	0.00	4.76	7.94	11.38
30-45	2.56	8.20	9.20	5.95	10.34	0.20	0.00	4.53	7.38	13.78
45-60	2.94	8.01	10.70	6.70	11.86	0.19	0.00	3.78	7.56	18.11
Mean	2.42		8.93	5.14	9.99	0.22	0.00	3.57	7.75	11.96

Agronomic practices:

The cultivated summer forage crops were sorghum (*Sorghum bicolor L. Moench* cv. piper black) and cowpea (*Vigna unguiculata* cv. Baladi), from Forage Corps Res. Dept, grown in a randomized complete block design (R.C.B.D) with three replications for each crop. Each crop grown in nine plots, every plot area was $140m^2$ **[**(25 m long x 5.6 m width (8 ridges, 0.7m wide)**]**.

Sowing date (S) in the two growing seasons were 20^{th} and 24^{th} of May in the two seasons, receptively. Seeding rates were 20 kg/fad for sorghum and 30 kg /fed for cowpea. Twenty unit of nitrogen in the form of urea applied in the three times for each crop, at the second irrigation and after the first and the second cut. Harvesting date (H) in the two seasons at three cuts were taken for every crop, the first, second and third cuttings were taken after 55,100 and 140 days from sowing in the two seasons, respectively.

Data recorded for each crop in the three cuts in the two seasons at the middle plot (4 ridges with 5 m long which mean 2.8 x 5 m for fresh forage yield and dry forage yield/kg ($14m^2$)and converted to kg/plot ($140m^2$),as well as plant height cm.

Statistically analysis:

The recorded data were statistically analyzed according to **Steel and Torrie (1980).** Treatment means were compared by the least significant difference test using **MSTAT –C, 1986.** Homogeneity of experiments variances were computed according to **Bartlett(1937).**

Irrigation treatments:

Three irrigation treatments based on water deficit levels were assigned as follows:

A- Irrigation with 100% of crop water requirements (control).

B- Irrigation with 90% of control A (10% deficit).

C- Irrigation with 80% of control A (20% deficit).

Data collection:

a. Water parameters:

- **Irrigation water (IW)**

Irrigation water was controlled and measured by irrigation pump with a discharge of 18 L per second. Control irrigation treatment A was irrigated till the end of the assigned cultivated plot.

- **Consumptive use (CU)**

Actual consumptive use (CU) or so-called crop evapotranspiration (ET) was computed based on soil moisture depletion (SMD) in the effective root zone of 60 cm as follows **(Hansen et al., 1979)**:

$$\mathrm{Cu} = \frac{FC - \Theta}{100} * \frac{Db}{Dw} * d$$

Where:

CU = consumptive use or actual crop- water consumed, cm.

FC = percent soil moisture content on weight basis at field capacity

Θ = percent soil moisture content on weight basis before irrigation as well as at harvesting.

Db = soil bulk density, $Mg.m^{-3}$

Dw = density of water = 1

d = effective root zone of 60 cm.

- **Crop-water functions**

i. Water productivity (WP):

Water productivity as defined by **Bos,1980** is the parameter of crop-water functions which reflects the capability of water consumed by growing crop in producing marketable yield as follows:

$$WP = Y/CU$$

Where:

WP = productivity of crop- water consumed

Y = marketable yield, and

CU = consumption use.

ii. Productivity of irrigation water (PIW):

This parameter of PIW refers to the capability of applied irrigation water in producing marketable yield as defined by **Bos,1980.**

$$\mathbf{PIW = Y/ IW}$$

Where:
PIW = productivity of applied irrigation water,
Y = marketable yield, and
IW = applied irrigation water.

3. RESULTS AND DICUSSION

3-a. Mean squares:

Analysis of variance of two years and their combined for fresh and dry forage yield and plant height for each summer forage crop were presented in Tables (4) and (5). Data revealed that differences among irrigation levels were highly significant and significant effects for most fresh and dry forage yield as well as plant height at the three

cuts and total yield for the two forage crops in the two seasons and combined analysis were detected similar results obtained by **Blum (2009), Hall *et al* (1997) and Ludlow and Muchow (1990).**

Table (4) Analysis of variance for two years and combined analysis for yield and plant height of forage Sorghum under water deficit.

2018 season													
S.of.V.		Fresh forage yield				Dry forage yield				Plant height cm			
	df	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
Replication	2	75	8.33*	1.33*	46.3	0.053**	1.5	0.343*	4.33*	4.11	14.3	28	3.81
Irrigation	2	7275.0*	10675**	5772.00**	69937**	217.56**	372.4 **	400.33* *	2915.29**	352.44**	523.0*	241.33**	363.15**
Error	4	637.5	508	131.33	111	8.42	17	7.87	95.8	5.77	32.3	6.33	6.53
Total	8	-	-	-	-	-	-	-	-	-	-	-	-
2019 season													
S.of.V.		Fresh forage yield				Dry forage yield				Plant height cm			
	df	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
Replication	2	36.33	22.33*	6.33*	144.0*	0.260*	0.040**	0.04	0.823*	2.778*	5.78	7.11	3.02
Irrigation	2	13129.0**	18157.0**	4501.0**	100069.0**	378.02**	627.19**	216.19**	3501.31**	287.44*	560.77**	214.77*	338.01**
Error	4	578.8	515	231.33	3822	10.2	12	5.52	80.6	20.8	20.9	18.1	17.2
Total	8	-	-	-	-	-	-	-	-	-	-	-	-
combined													
S.of.V.		Fresh forage yield				Dry forage yield				Plant height cm			
	df	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
Replication	2	8.167	24.5	1.5	35.2	0.23	1	0.25	3.85	6.50*	9.06	20.2	2.53
(Y)Year	1	1002152**	125000.0**	19404.5**	285012.50**	522.29**	926.651**	477.405**	990.125**	206.722**	2403.55**	600.88**	168.05*
Error	2	103.2	6.17	6.167	155	0.08	0.6	0.14	1.31	0.39	11.5	14.9	4.3
Irrigation(I)	2	19974.5**	28333.5**	10233.5**	168655.5**	584.44**	983.138**	602.105**	6402.88**	630.167**	1078.22**	455.72**	698.087**
(Y)x(I)	2	429.5*	499*	39.5*	1350.50**	11.1	17	14.4	13.7	9.72	5.56	0.389*	3.08

Error	**8**	**608.2**	**512**	**181.33**	**1967**	**9.31**	**14**	**6.7**	**88.2**	**13.3**	**26.6**	**12.2**	**11.9**
Total	**17**	-	-	-	-	-	-	-	-	-	-	-	-

***, ** P ≤ 0.05 and 0.01 respectively**

Table (5) Analysis of variance of two years and combined analysis for yield and plant height of forage Cowpea under water deficit.

2018 season													
S.of.V.		**Fresh forage yield**				**Dry forage yield**				**Plant height cm**			
	df	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Average**
Replication	**2**	**4**	**16**	**6.333***	**72.33***	**0.173***	**0.013****	**0.1**	**0.360****	**0.190***	**0.163***	**0.653***	**0.298***
Irrigation	**2**	**1351**	**2496.0***	**2547.00***	**18811.0***	**53.3**	**112.00***	**139.08***	**880.36***	**13.9**	**49.6**	**43.3**	**33.04**
Error	**4**	**256**	**224**	**174**	**1944**	**12.4**	**9.1**	**9.2**	**91**	**18.5**	**9.96**	**15.1**	**14.24**
Total	**8**	-	-	-	-	-	-	-	-	-	-	-	-
2019 season													
S.of.V.		**Fresh forage yield**				**Dry forage yield**				**Plant height cm**			
	df	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Average**
Replication	**2**	**52**	**9.00***	**4.00***	**147**	**0.154****	**1.377***	**0.493***	**4.960***	**0.97**	**0.33**	**0.39**	**0.493**
Irrigation	**2**	**3411.0***	**6247.00****	**2179.00****	**39361.0***	**136**	**248.58***	**104.160***	**1414.359****	**30.8**	**39**	**128.170***	**58.96**
Error	**4**	**460**	**155**	**98**	**1911**	**23.2**	**34**	**13**	**204**	**23.8**	**10.8**	**16.5**	**16.55**
Total	**8**	-	-	-	-	-	-	-	-	-	-	-	-
combined													
SOV		**Fresh forage yield**				**Dry forage yield**				**Plant height cm**			
	df	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Average**
Replication	**2**	**42**	**24.50***	**10.167***	**211.167***	**0.3**	**0.6**	**0.5**	**4**	**1.01**	**0.43**	**1.022***	**0.776**

(Year(Y	**1**	**214512.50****	**186050.00****	**8580.500****	**642978.00****	**3397.902****	**4418.940****	**364.50****	**11160.178****	**121.680****	**345.845****	**5070.245****	**448.002 ****
Error	**2**	**14**	**0.5**	**0.17**	**8.2**	**0.03**	**0.8**	**0.1**	**1.3**	**0.16**	**0.07**	**0.02**	**0.016**
Irrigation(I)	**2**	**4524.50 NS**	**8319.500****	**4718.00****	**51591.50****	**179.507****	**347.113****	**241.980****	**2263.219****	**43**	**88.265***	**160.235****	**90.141***
(Y)x(I)	**2**	**238**	**424**	**8**	**1112**	**9.54**	**13**	**1.3**	**32**	**1.68**	**0.37**	**11.255***	**1.871**
Error	**8**	**358**	**189**	**136**	**1928**	**17.8**	**22**	**11**	**148**	**21.1**	**10.4**	**15.8**	**15.4**
Total	**17**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

***, ** P ≤ 0.05 and 0.01 respectively** **NS; not significantly different**

3.b. Mean Performance:

3.b.1.Forage Sorghum

The obtained results (Table 6) revealed that yield of forage sorghum crop is significantly affected with water deficit irrigation comparing to the full irrigation control treatment A. Mean performance of plant height, fresh and dry forage yield for sorghum is presented in Table 6. Data showed that plant height were affected by irrigation levels as reported by **Assaeed, 1994** and **Bakheit, 1990.** The 80% water irrigation (deficit 20%) the lowest applied water has the shortest plant height at the three cuts in the two experiments seasons and combined analysis as well. Plant height as affected with the levels of applied irrigation water which resulted from the tested water deficit treatments can be arranged in descending order as; no deficit (control) > 10% deficit > 20% deficit. The corresponding mean combined values are; 196.0, 187.6 and 173.9 cm.

For fresh and dry sorghum forage yields, the highest mean values were obtained from the control normal watering. On the other hand, the low-level irrigation which associated with deficit treatments caused the low mean values at the three cuts in the two seasons and their combined data. The mean values of fresh sorghum forage yield can be arranged in descending order as; 2917.0 > 2857.5 > 2561.0 kgplot^{-1}, while the corresponding values of the dry weight are; 381.6> 367.8> 319.6 kgplot^{-1} (area of plot = 140m^2 = 0.033fed = 0.014 ha). The stated values for treatments A (100% no deficit), B (90% of A) and C (80% of A), respectively.

Comparing with treatment A, 98% and 88% were obtained under deficit treatments B and C, respectively. Regarding dry weight, the corresponding percentages are 96% and 84%.

Therefore, by implementing10% water deficit irrigation (Trt. B), only 2 and 4% (Table 11)decreasing in fresh and dry yield of sorghum were recorded comparing to the traditional irrigation and the decrease were insignificant ,as combined data. While C treatment were recorded 12 and 16% decreased in fresh and dry yield compared to control A treatment and highly significant decreased ,(Table 11)it can be concluded that 10% water deficit irrigation on forage sorghum not affect on fresh and dry yield. General mean of total and dry yield is very high in the second season for two forage crops, it is due to may be climatic elements (Table 1) The obtained results are nearly as obtained by **Carrow 1996, Abdel-Fattah, 2011, Mariole staniak and Anna Kocon 2015, El-Shamarka et al. 2012 and Ghasemi et al. 2012.**

Table (6) Effect of irrigation levels in two years and combined data for fresh and dry forage yield and plant height of forage Sorghum under water deficit.

2018 season												
	Fresh forage yield kg/plot				Dry forage yield kg/plot				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
100%	1045.0	750.0	554.0	2349.0	125.4	101.3	89.7	316.4	261.6	185.0	164.0	203.5
90%	1032.0	735.0	542.0	2309.0	121.8	97.0	86.7	305.5	251.3	165.0	157.0	191.1
80%	931.0	660.0	481.0	2072.0	107.2	83.8	75.4	266.4	235.6	157.3	146.0	179.6
Grand Mean	1002.6	715.0	525.6	2243.33	118.1	94.0	83.9	296.1	249.5	169.1	155.6	191.4
Significance	*	**	**	**	*	**	*	*	**	*	**	**
LSD0.05	61.1	43.9	33.5	138.0	8.9	8.3	8.53	25.75	10.5	12.0	10.8	8.2
LSD0.01	-	72.9	55.6	228.8	-	13.7	-	-	17.4	19.9	-	13.7
2019season												
	Fresh forage yield kg/plot				Dry forage yield kg/plot				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
100%	1624.0	1288.0	573.0	3485.0	188.4	167.4	91.0	446.8	248.3	161.3	155.6	188.4
90%	1596.0	1254.0	556.0	3406.0	182.6	160.4	87.2	430.2	242.6	158.3	151.3	184.1
80%	1437.0	1120.0	493.0	3050.0	158.0	126.7	76.0	372.8	228.0	144.0	132.6	168.2
Grand Mean	1552.3	1220.6	540.6	3313.6	176.3	138.8	84.7	416.6	239.6	154.5	146.5	180.2

Significance	**	**	*	**	*	**	*	*	*	**	*	**
LSD0.05	50.4	49.4	40.0	139.6	17.2	13.3	8.3	38.8	-	-	7.1	13.7
LSD0.01	83.5	81.9	-	231.4	-	22.1	-	-	-	-	11.8	-
Combined												
	Fresh forage yield kg/plot				**Dry forage yield kg/plot**				**Plant height cm**			
Irrigation levels	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Average**
100%	1334.5	1019.0	563.5	2917.0	156.9	134.3	90.3	381.6	255.0	173.1	159.8	196.0
90%	1314.0	994.5	549.0	2857.5	152.2	128.7	86.9	367.8	247.0	161.6	154.1	187.6
80%	1184.0	890.0	487.0	2561.0	132.6	111.3	75.7	319.6	231.8	150.6	139.3	173.9
Grand Mean	1277.5	967.8	533.1	2778.5	147.2	124.7	84.3	356.3	244.6	161.8	151.1	185.8
Significance	**	**	**	**	**	**	**	**	**	**	**	**
LSD0.05	46.5	38.8	30.6	115.3	11.4	9.2	6.9	27.3	10.1	8.2	5.3	6.6
LSD0.01	67.7	56.5	44.6	167.7	16.6	13.4	10.1	39.8	14.7	12.0	7.8	9.6

***, ** P ≤ 0.05 and 0.01 respectively NS; not significantly different**

3.b.2. Cowpea

The mean performance of plant height, fresh and dry cowpea forage yield in the two seasons as well as the combined data are tabulated in Table 7. Plant height slightly affected with different irrigation treatments. On the contrary, both fresh and dry yields were significantly affected with water level or deficit irrigation. Moreover, the effect was highly significant in connection with the combined analysis. In this regard, mean values of fresh yield descending arranged as; 1502.5> 1447.0> 1321.5 kg plot^{-1} for treatments A(control), B (90%) and C (80%)from A, respectively. The corresponding values regarding dry yield are 253.5, 241.0 and 215.4 kg plot^{-1}. Comparing the deficit treatments with the control irrigation (Trt. A), overall mean decrease in fresh yield was 3.7% for treatment B (90%) and 12% for treatment C (80%). While, the corresponding decreases in dry yield were 4.9% and 15.0%**, Hayatu and Mukhtar 2010.** The decreasing in treatment B (deficit 10%)were insignificant effect of fresh and dry forage yield as combined data ,while treatment c(20% deficit) irrigation were highly significant effect fresh and dry forage yield. This finding could be attributed to the less applied irrigation water under 80% level comparing with 90%**.** The obtained results emphasized the results that reported by **Mullen 1999, IITA 1989 and Madamba et al. 2006** Obtained data also showed that average plant height of cowpea forage crop is not affected with irrigation level in the two seasons of study Combined analysis showed that the highest plant height was resulted with control irrigation i.e., no deficit and vice versa for deficit irrigation treatments. The average combined values arranged in descending order as 67.8> 65.6> 60.2 cm. for treatments A, B and C, respectively.

In general, increasing water deficit stress notably affected the physiological processes and nutrient uptake by fodder cowpea crop. Therefore, growth, development and yield are negatively affected (Z**einab et al 2015)**.

Table (7) Effect of irrigation levels in two years and combined data for fresh and dry forge yield and plant height of forage Cowpea under water deficit.

2018												
	Fresh forage yield kg/plot				Dry forage yield kg/plot				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
100%	470.0	424.0	407.0	1301.0	73.8	74.6	78.2	226.6	67.0	63.0	57.0	62.3
90%	459.0	408.0	389.0	1256.0	71.4	70.6	73.6	215.6	65.7	61.1	54.8	60.5
80%	429.0	368.0	350.0	1147.0	65.6	62.6	64.8	193.0	62.8	55.2	49.6	55.9
Grand Mean	452.6	400	382.0	1234.6	70.8	69.2	72.2	211.7	65.1	59.7	53.8	59.5
Significance	NS	*	*	*	NS	*	*	*	NS	NS	NS	NS
LSD0.05	-	33.9	29.8	99.9	-	6.8	6.8	21.6	-	-	-	-
LSD0.01	-	-	-	-	-	-	-	-	-	-	-	-
2019												
	Fresh forage yield kg/plot				Dry forage yield kg/plot				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Cut 3	Average
100%	700.0	642.0	362.0	1704.0	103.6	108.4	68.4	280.4	73.0	54.0	93.0	73.3
90%	679.0	615.0	344.0	1638.0	99.2	102.8	64.4	266.4	71.3	52.0	88.9	70.7

80%	**634.0**	**553.0**	**309.0**	**1496.0**	**90.4**	**90.6**	**56.8**	**237.8**	**66.8**	**47.0**	**80.2**	**64.6**
Grand Mean	**671.0**	**603.3**	**338.3**	**1612.6**	**97.7**	**100.6**	**63.2**	**261.5**	**70.3**	**51.0**	**87.3**	**69.5**
Significance	*	*	**	*	NS	*	*	*	NS	NS	*	NS
LSD0.05	**48.5**	**28.1**	**22.4**	**99.1**	-	**13.2**	**8.2**	**32.4**	-	-	**9.2**	-
LSD0.01	-	-	**37.2**	-	-	-	-	-	-	-	-	-
Combined												
	Fresh forage yield kg/plot				**Dry forage yield kg/plot**				**Plant height cm**			
Irrigation levels	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Total**	**Cut 1**	**Cut 2**	**Cut 3**	**Average**
100%	**585.0**	**533.0**	**384.5**	**1502.5**	**88.8**	**91.5**	**73.3**	**253.5**	**70.0**	**58.5**	**75.0**	**67.8**
90%	**569.0**	**511.5**	**366.5**	**1447.0**	**85.3**	**86.0**	**69.0**	**241.0**	**68.5**	**56.5**	**71.8**	**65.6**
80%	**531.5**	**460.5**	**329.5**	**1321.5**	**78.0**	**76.6**	**60.8**	**215.4**	**64.5**	**51.1**	**64.9**	**60.2**
Grand Mean	**561.8**	**501.6**	**360.1**	**1423.6**	**84.0**	**84.9**	**67.7**	**236.6**	**67.7**	**55.3**	**70.5**	**64.5**
Significant	NS	**	**	**	**	**	**	**	NS	*	**	*
LSD0.05	**35.6**	**25.9**	**21.95**	**82.6**	**7.7**	**8.7**	**8.7**	**22.9**	-	**6.07**	**7.48**	**7.38**
LSD0.01	**51.8**	**37.6**	**31.94**	**120.3**	**11.5**	**12.7**	**12.7**	**33.3**	-	-	**10.8**	-

***, ** P ≤ 0.05 and 0.01 respectively NS; not significantly different**

3.c. Water relations

3.c.1. Applied irrigation water (IW).

Seasonal values of applied irrigation water for forage sorghum and cowpea during the two growing seasons of the study are tabulated in Table 8. It is clear from the presented data that the control water (Trt. A) has the highest values compared to water deficit treatments B and C. In this regard, mean values of I.W. for sorghum could be arranged in descending order as 83.44> 75.25> 69.47 cm. for treatments A (100%), B (90%) and C (80%), while the corresponding values for cowpea are 78.51> 72.93> 68.30 cm.

Therefore, by comparing I.W. for water deficit treatments with the control (Trt. A), mean water saving for sorghum counted with 9.8 and 16.7% under 90 and 80% water deficit, respectively. For cowpea crop, the corresponding values are 7.1 and 13.0%.

It should be notified that choosing the suitable level of water deficit to be executed under surface irrigation in the clayey soils should be linked with the decreasing in crop yield. In other words, factors should be taken into consideration; water saving and crop productivity as well as net return per m3 of water.

The obtained findings are in the same direction with that reported by **Doorenbos and Kassam, 1979, Abdel-Fattah 2011** and **Steduto et al., 2012.**

Table 8. Seasonal irrigation water (IW, cm) for Sorghum and Cowpea as affected with different irrigation treatments.

Treatment	Crop	1st season cm.	2nd season cm.	Mean	
				Cm	m^3/fed
A (100%)	Sorghum	84.75	82.13	83.44	3504.5
	Cowpea	82.63	74.38	78.51	3297.4
B (90%)	Sorghum	78.29	72.20	75.25	3160.3
	Cowpea	75.12	70.73	72.93	3062.9
C (80%)	Sorghum	71.65	67.29	69.47	2917.7
	Cowpea	70.59	66.00	68.30	2868.6

3.c.2. Consumptive use (CU)

Seasonal values of crop consumed water (CU) for different treatments in the two growing seasons are tabulated in Table9. Data show that control treatment A (100%) has the highest values of seasonal CU, while the lowest ones are for 80% water deficit (Trt. C).

In this regard, mean values of seasonal CU for sorghum crop are arranged in descending order as 66.8> 61.7> 59.1cm, while the corresponding ones for cowpea are 62.8> 59.8> 58.1cm for treatments A, B and C, respectively.

This finding is owing to the less applied irrigation water to water deficit irrigation treatments which caused a decreasing in consumed water by the growing plants.

The obtained results are in a good agreement with that obtained by **Doorenbos and Kassam, 1979, Abdel-Fattah 2011, Kassab et al 2012**and **Steduto et al., 2012.**

Table 9. Seasonal consumptive use (CU, cm) for Sorghum and Cowpea as affected with different irrigation treatments.

Treatment	Crop	1st season cm.	2nd season cm.	Mean	
				Cm	m^3/fed
A (100%)	Sorghum	67.80	65.70	66.75	2803.5
	Cowpea	66.10	59.50	62.80	2637.6
B (90%)	Sorghum	64.20	59.20	61.70	2591.4
	Cowpea	61.60	58.00	59.80	2511.6
C (80%)	Sorghum	60.90	57.20	59.05	2480.1
	Cowpea	60.00	56.10	58.05	2438.1

3.c.3. Crop-water functions

Crop- water functions reflect the capability of consumed and/or irrigation water in water productivity, herewith:

3.c.3.1. Water productivity (WP)

The obtained data of WP in kg/m3consumed water for different treatments are tabulated in Table 10. It is clear that the 90% water level (10%deficit) of treatment B has the highest values and vice versa for the non-deficit irrigation treatment A of full watering. This could be attributed to that CU as the dominator of crop-water function is the highest for full irrigation. In other words, there is a reverse relation between CU and WP.

3.c.3.2. Productivity of Irrigation water (PIW)

It is clear that PIW in kg/m3 irrigation water took the same trend of WP (Table 8). The highest applied irrigation water, the lowest PIW taking into consideration the obtained yield.

Therefore, the obtained results of WP and PIW are in the same trend with that reported by **Lazaridou and Koutroubas 2004, Ali and Talukder 2008, Abdulaziz et al. 2009, Ouda et al. 2010, Abdel-Fattah 2011 and Kassab et al 2012.**

3.c.3.4. Maximizing productivity of water unit

As mentioned before, the water level of 90% (Trt. B) produced nearly the highest yield as full irrigation (Trt. A,100%) with slight decrease in fresh and dry yield with 2.0 and 4.0% for sorghum and 3.7 and 4.9%, for cowpea (Tables 6&7).

In that regard, mean values of WP and PIW under treatment B with 10% deficit for fresh and dry yield of sorghum and cowpea are the highest as presented in Table 10.

Table 10. Mean values of fresh, dry yield, consumptive use (CU), irrigation water (IW), water productivity (WP) and productivity of irrigation water (PIW) for sorghum and cowpea under different treatment.

Treatment	Crop	Yield, Kg/fed		CU, m^3/fed	IW, m^3/fed	Productivity, Kg/m^3 water			
		Fresh	Dry			WP		PIW	
						Fresh	Dry	Fresh	Dry
A (100%)	Sorghum	88385.1	11562.5	2803.5	3504.5	31.5	4.1	25.2	3.3
	Cowpea	45525.8	7681.1	2637.6	3297.4	17.3	2.9	13.8	2.3
B (90%)	Sorghum	86582.3	11144.3	2591.4	3160.3	33.4	4.3	27.4	3.5
	Cowpea	43844.1	7302.3	2511.6	3062.9	17.5	2.9	14.3	2.4
C (80%)	Sorghum	77598.3	9683.9	2480.1	2917.7	31.3	3.9	26.6	3.3
	Cowpea	40041.5	6526.6	2438.1	2868.6	16.4	2.7	14.0	2.3

Therefore, one m^3 consumed water produced 33.4and/or 4.3 kg as fresh and dry yield for sorghum, and 17.5 and/or 2.9 kg for cowpea. Meanwhile, that one m3 of applied irrigation water produced 27.4 and/or 3.5 kg as fresh and dry yield of sorghum and 14.3 and/or 2.4 kg for cowpea.

In other words, to produce 1 kg fresh and dry yield of sorghum it consumed 29.9 liter and 232.6 liter, respectively. For cowpea, the values were 57.1 and 344.8 liter, respectively.

Meanwhile, to produce 1kg fresh sorghum, it needs36.5 liter as irrigation water, while it is 285.7 liter for dry yield. For cowpea, the values were 69.9 and 416.7 liter for fresh and dry yield, respectively.

4- Percent of decrease:

Percent of decrease of sorghum and cowpea in 2018 and 2019 seasons and combined analysis are presented in Table (11).Water stress fewer than 80% irrigation, reduced total fresh and dry forage yield production for sorghum and cowpea **Mai-Kodomi et al (1999a), Hall et al (1997).** In this regard, **Wang et al, (2003)** found that drought stress led to reduced average yield for most major crops by more than 50%.Although, cowpea was tolerant to decreased water of irrigation **Hall (2004)** , **Dadson et al (2005), Ehlers and Hall (1997).**

Table (11) Percent of decrease of summer forage

Sorghum 2018 season												
	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	1.2	2.0	2.2	1.7	2.9	4.2	3.3	3.4	3.9	10.8	4.3	6.1
80%	9.8	10.2	11.3	10.3	12.0	13.6	13.0	12.8	6.2	4.7	7.0	6.0
Sorghum 2019 season												
	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	1.7	2.6	3.0	2.3	3.1	4.2	4.2	3.7	2.3	1.9	2.8	2.3
80%	10.0	10.7	11.3	10.5	13.5	21.0	12.8	13.3	6.0	9.0	12.4	8.6
Sorghum combined												
	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	1.5	2.4	2.6	2.0	3.0	4.2	3.8	3.6	3.1	6.6	3.6	4.3
80%	9.9	10.5	11.3	10.4	12.9	13.5	12.9	13.1	6.2	6.8	9.6	7.3
Cowpea 2018 season												

	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	2.3	3.8	4.4	3.5	3.3	5.4	5.9	4.9	1.9	3.0	3.9	2.9
80%	6.5	9.8	10.0	8.7	8.1	11.3	12.0	10.5	4.4	9.7	9.5	7.6
Cowpea 2019 season												
	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	3.0	4.2	5.0	3.9	4.2	5.2	5.8	5.0	2.3	3.7	4.4	3.5
80%	6.6	10.1	10.2	8.7	8.9	11.9	11.8	10.7	6.3	9.6	9.8	8.6
Cowpea combined												
	Fresh forage yield				Dry forage yield				Plant height cm			
Irrigation levels	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	$\bar{x}$	Cut 1	Cut 2	Cut 3	Average
100%	100	100	100	100	100	100	100	100	100	100	100	100
90%	2.7	4.0	4.7	3.7	3.9	6.0	5.9	4.9	2.1	3.4	4.3	3.2
80%	6.6	10.0	10.1	8.7	8.6	10.9	11.9	10.6	5.8	9.6	9.6	8.2

CONCLUSIONS

- Water productivity (WP) for m^3 of sorghum and cowpea yield (fresh and dry) under treatment B of 90% level (10% deficit) were 33.4, 4.3, 17.5and 2.9 kg, respectively.
- Productivity of irrigation water (PIW) for sorghum and cowpea yield (fresh and dry) under treatment B of 90% level (10% deficit) were 27.4 , 3.5 ;14.3, 2.4 kg , respectively
- By implementing irrigation of 90% water needs i.e., 10% deficit for sorghum and cowpea forage crops, several advantages could be achieved such as; nearly highest yield, 10% water saving, the highest productivity of each unit of either consumed or applied irrigation water.
- More research should be done regarding the performance of crops and their water relations under deficit irrigation with considering the net return per consumption of m3 of water term.

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