Original Research Article

Cut-off surface irrigation as an effective way of water saving for teosinte forage crop in clay soils

ABSTRACT

The present study was carried out at Sakha Agricultural Research Station (clay soils) middle north of Nile Delta area during summer seasons 2021 and 2022 in randomized complete block design with three replications. Three irrigation levels were executed; 100% i.e., full irrigation, 90% cut-off irrigation and 80% cut-off irrigation. The mean performances of plant height, fresh and dry forage yields in the two seasons and combined are significantly affected by irrigation levels applied, whereas normal or control treatment with100% irrigation i.e., no cut-off (Trt. A) has the tallest height. On the other hand, the low irrigation level with 80% cut-off (Trt. C) has the shortest plants at the three cuts. Also, traits reduced with the decrease of irrigation water level at the three cuts. Both fresh and dry forage yields are severely decreased when plants irrigated by 80% cut-off. Decreasing the irrigation water level than the commonly controlled of 100% without cut-off (Trt.A) markedly reduced all studied growth characters at the three cuts. The inhibiting effect of the water deficit stress on the studied parameters notably appeared more pronounced under the 80% cut-off than that of 90% .The obtained results may refer to that decreasing the irrigation water lowered the soil moisture content which restricted the mobility of nutrients to plant that would reduce the efficiency of physiological and metabolic processes needed for plant growth. Regarding water relations, irrigation with 90% cut-off resulted in several advantages; almost same yield as obtained under full irrigation, 10% water saving as well as the highest values of crop-water functions of water productivity (WP) and productivity of irrigation water (PIW). The mean values of fresh forage yield of 100% irrigation levels recorded 610 and 685 Kg/strip with compared to 585 and 655kg/strip for 90 %irrigation treatment at first and second cuts ,respectively in the first season. The objective of this research was to find out the response of yield, water saving and some water functions for teosinte forage crop to cut-off surface irrigation owing to produce **" more per less".**

Keywords: Cut-off irrigation, Teosinte [*Zea* *Mexicana*] forage crop, WP, PIW, fresh and dry forage yields.

INTRODUCTION

Teosinte [*Zea Mexicana*] is very popular summer forage for dairy farming in tropical regions in Egypt. Teosinte is one of the important fodder group grown with sorghum and pearl millet, Also, it can grow rapidly after cutting. In Egypt, the area of summer forage crops is very limited, which may be related to the sever competition with the main summer crops such as maize, rice, grain sorghum, cotton and soybean. The forage sorghum, millet, cowpea, teosinte and maize as silage or fresh forage (darawa) are used in the summer season as fresh green fodder. Breeders and agronomists concerned with forage crops always doing their best to improve the quality and quantity of forage yield. The need to green feed for livestock has been increased vigorously in summer season especially during the period from Jun to November. Teosinte was introduced to Egypt last century and is grown in the Delta. Teosinte could provide an answer to overcome the shortage in production of summer fodder feed for farm animals. Recently, few authors presented information related to the nature of forage yield components **AbdEl-Maksoud *et al*.,(1998)[1].**studies are not enough to decide the way to improve teosinte as a new summer forage crop in Egypt. The maize plant like grass, and belongs to *Zea mexicana* Schrad, is named "teosinte" (USA and Australia)**,**"Makchari"(India) **Bogdan, (1977) [2]**and "Rayyana" Egypt. Teosinte can give three cuts from April to November comparing with only one cut obtained from fodder maize.During the last two decades, information about teosinte has been given by several investigators among them **Smith *et al*, (1984)[3], Abdel-Twab and Rashed (1985)[4], Aulicino and Magoja (1991) [5]**but the available information has contributed to the relationships among teosinte genotypes and between teosinte and maize. The increasing scarcity of water in dry areas is now a well-recognized problem. According to the World Commission Environment and Development, approximately 80 countries with 40 percent of the world population already suffer from serious water shortage **(Hamdy *et al.* 2002)[6]**.

Egypt is the solely country worldwide that its agricultural production is irrigated agriculture due to the prevailing aridity conditions. River Nile is the main water resource for Egypt with its inlets outside the boundaries of the country. Annual water capita share 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. This situation is due to the high increasing population rate and the limited water supply. At this prospecting water status, it is difficult to make progress in any national economic sector.

Comment [A1]: Citation

Agriculture sector is by far the largest user of water in the world, 80 to 90% of all the water are consumed in agriculture. Irrigation water is the most limiting factor in agricultural production especially in arid and semi- arid regions. Therefore, practicing irrigation is very important to attain more implemented irrigation management. Water deficit and drought are the most limiting factors affecting plant growth which decrease crop production and threating food security in the world as mentioned by **Hall *et al*. 1979 [7], water in changing world 2009[8]**. Water deficit and drought are the most limiting factors affecting plant growth; decrease crop production and threating food security in the world **(Water in a changing world, 2009)[8].** Egypt is facing a pronounced water shortage, particularly for irrigating summer crops, Irrigation is the main input factor in agricultural production. Agricultural Irrigation is the main sector in water consumption with more than 80% from the annual national water supply. Hence, water productivity becomes one of the main targets under the umbrella of **"effective on-farm irrigation management"**. Meaningfully, **more crop per drop**.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[9], Seckler *et al.* 1998[10], Hamdy and Lacirignola 1999[11], Corgrove and Rijsberman 2000[12], IWMI-International water management institute 2000[13].**

In this regard, irrigation management under water deficit status becomes a must. In Egypt forage crops area in summer season are very limited compared with that in winter season. In Egypt summer forage crops are grown such as sorghum, millet, cowpea, teosinte and maize as silage or fresh forage crops. Teosinte is grown in summer season as a multi-cut and it is promising forage crop as stated by **Eagles *et al*. 1999 [14]**and **Tarrad *et al.* 2010[15]. Steduto *et al.* 2012 [16] and Doorenbos and Kassam (1979) [17]** 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 some genotypes because of longer growing periods. They also stated that surface irrigation methods of furrow, border, basin or corrugation are commonly practiced.

Creamer and Baldwin, 1999 [18],The rising of temperature causes a pronounced reduction in the amount of available water especially during the summer and resulted in a higher occurrence of drought. Many aspects of climate change and associated impacts will continue for centuries. On the other hand, teosinte or so-called rayan is 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 with that cultivated in winter season. **Duvick 1999 [19]** assumed that teosinte originated from natural hybridization.

Therefore, the objective of this research was to find out the response of yield, water saving and some water functions for teosinte forage crop to cut-off surface irrigation owing to produce **" more per less".**

MATERIALS AND METHODS

A field experiment was carried out during the two successive summer seasons 2021 and 2022 at the research farm of Sakha Agricultural Research Station. The site is located in middle North of Nile Delta area with 30°-57ʺ N latitude, 31-07°E longitude with an elevation of about 6 meters above mean sea level. Climatic elements of the site during the two field trial seasons are presented in **Table 1**.

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

Month	1st season, 2021				2nd season, 2022			
	T, C°	RH, %	μ_2 m.sec-1	EP, mmd^{-1}	T, C°	RH, %	μ_2 m.sec-1	EP, mmd^{-1}
May	28.2	58.3	1.17	8.94	25.9	60.6	1.25	6.5
June	28.8	65.2	1.33	8.92	29.4	67.4	1.03	7.6
July	31.5	67.7	1.15	8.60	28.8	69.8	1.22	7.9
Aug.	32.5	66.9	1.00	7.79	30.1	72.8	1.25	7.7
Sept.	28.8	66.8	1.16	7.56	29.5	69.4	1.04	6.52
Oct.	25.5	68.9	0.98	4.84	24.8	75.8	1.02	3.24
Mean	**29.1**	**65.6**	**1.13**	**7.78**	**28.1**	**69.3**	**1.14**	**6.58**

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)[20]** as well as soil bulk density (Db). Particle size distribution were also identified according to **Klute (1986)[21].** 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)[22].** Sulphate (So_4^{--}) was computed by the difference between soluble cations and anions, both in meqL^{-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	18.6	28.4	53.0	Clay	47.40	25.76	21.64	1.13
15 – 30	19.4	28.4	52.2	Clay	41.39	22.49	18.90	1.19
30 – 45	23.8	26.8	49.4	Clay	38.50	20.93	17.57	1.22
45 - 60	24.5	27.8	47.7	Clay	35.90	19.51	16.39	1.31
Mean	**21.6**	**27.9**	**50.6**	**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= soil bulk density, Mg/m^{-3}.

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

Soil depth, cm.	EC, Ds m^{-1}	PH (1 : 25) Soil water Suspension	Soluble ions, $megl^{-1}$							
			Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{-}	$HCO3^{-}$	CL^{-}	$So4^{-}$
0-15	1.75	8.27	6.18	3.15	8.15	0.28	0.00	5.15	8.15	4.46
15-30	2.30	8.10	9.60	4.60	9.50	0.23	0.00	4.70	7.90	11.33
30-45	2.36	8.15	9.15	5.90	10.30	0.22	0.00	5.40	7.35	12.82
45-60	2.74	7.97	10.60	6.60	11.79	0.20	0.00	4.60	7.50	17.09
Mean	**2.29**		**8.88**	**5.06**	**9.94**	**0.23**	**0.00**	**4.96**	**4.46**	11.43

The experimental lay out was arranged in strips and the irrigation treatments were arranged in a randomized complete block design ,with three replication .Strip area was (140m^2 =1/30 fed.) Under each irrigation treatment, three strips, each with 25 m long x 5.6 m width. The width was 8 ridges with 0.7m wide. The crop plant used for all area was teosinte [*Zea Mexicana*] local variety cv. Baladi. Means were compared at 0.05 level of significance by least significant different (L.S.D) test using **MSTAT-C 1986[23].**The recorded data were statically analyzed according to **Steel and Torrie 1980[24]**. Homogeneity of experiments variances was computed according to **Bartelett 1937[25]**.

Seeds were hand drilled in ridges between hill and other 12.5 cm apart, at seeding rate of 20 $kg.fed^{-1}$, fertilizer was applied at the form of urea 46.5%N with three equal doses of 20 unit ,the first dose was after first irrigation and the second and third doses were after second and third cuts ,respectively. Three cuts were taken from each summer season. The first, second and third cuts were taken after 60,105 and 145 days from sowing, respectively. The rest of other culture practice were applied to the recommendations of the Agricultural Research Center(ARC) from Forage Corps Res. Dept. Observation and measurements recorded from the three cuts of the two successive season were taken from 4 guarded ridges with 5 meter long [4 ridges x 0.7^{m} wide x 5 meter long=$14m^2$] to determine fresh forge yield (kg/plot).Also, dry matter yield was determined from size sample of green forage from each cut ,dried 70^0c till constant weight then the dry matter yield were calculated . Plant height (cm),was measured from the base of the plant to the flag leaf.

Irrigation treatments:

Three irrigation treatments based on water deficit levels via cut-off surface irrigation. Investigated irrigation treatments were as follows:

A- Irrigation with 100% of crop water needs (control) i.e. water front reach the end of the cultivated strip.

B- Irrigation under 90% cut-off i.e. water front reach 90% of the cultivated strip.

C- Irrigation under 80% cut-off i.e. water front reach 80% of the cultivated strip.

The stated treatments were arranged in a randomized complete block design (RCBD) with three replicates.

Data collection:

Water parameters:

Irrigation water (IW)

Irrigation water was controlled and measured by irrigation pump with a discharge of 18 L per second.

Consumptive use (CU)

Actual consumptive use (CU) or so-called crop evapotranspiration (ET_c) was computed based on soil moisture depletion (SMD) in the effective root zone of 60 cm as follows **(Hansen et al. 1979)[26].**

Where:

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

Comment [A2]: write the equation in the manuscript

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, Mgm^{-3}

Dw = density of water = 1

d = effective root zone of 60 cm.

Crop-water functions:

Water productivity (WP):

Water productivity as defined by **Bos,1980[27]** 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,

CU = consumption use.

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[27].**

PIW = Y/IW

Where:

PIW = productivity of applied irrigation water, ,

Y = marketable yield,

IW = applied irrigation water.

RESULTS AND DISCUSSION

Analysis of variance of the two successive study seasons 2021-2022 and the combined for fresh and dry forage yield in addition to plant height are presented in

Table 4,5 and 6. Data revealed that irrigation levels have highly significant effects on the investigated parameters at the three cuts of teosinte forage crop. These results are in the same line with that obtained by **Blum 2009[28] , Ludlow and Muchow 1990[29] and El-Gaafarey *et al*. 2022[30].**

Table (4) Analyses of variance for the two seasons and combined data for fresh forage yield of **teosinte** under cut-off irrigation.

Fresh forage yield					
		2021 season			
S.of.V.	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	174.3	16.33*	30.3	499.0
Irrigation	2	11683.0*	6975.0**	4597.0**	6724.0**
Error	4	727.8	376.3	219.3	3705.5
Total	8	-	-	-	-
2022 season					
S.of.V.	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	52.3	14.33*	6.33*	180.3*
Irrigation	2	30517**	23668.0**	5329.0**	161101.0**
Error	4	494.3	475.3	311.3	3790.3
Total	8	-	-	-	-
combined					
S.of.V.	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	205.16	30.16*	30.5	638.2
(Y)Year	1	1359600.5**	1150644.5**	1012.5**	5155260.5**
Error	2	21.5	0.5	6.2	41.2
Irrigation(I)	2	39970.50**	2816.5**	9906.50**	218188.5**
(Y)x(I)	2	2229.5	2481.5	19.5	10161.5
Error	8	611.08	425.83	265.33	3747.917
Total	17	-	-	-	-

*, ** P ≤ 0.05 and 0.01 respectively

Table (5) Analyses of variance for the two seasons and combined analysis for dry yield of **teosinte** under cut-off irrigation.

	Dry forage yield				
	2021 season				
S.of.V.	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	0.160*	0.565*	0.163*	2.303*

Irrigation	2	278.68**	249.69**	170.59**	2073.8**
Error	4	15.44	13.4	14.2	129.03
Total	8	-	-	-	-
S.of.V.	2022 season				
	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	1.8*	0.52	1.013	8.2*
Irrigation	2	782.8**	666.8**	182.4**	4525.9**
Error	4	58.1	34.8	13.41	293.7
Total	8	-	-	-	-
	Combined				
S.of.V.	df	Cut 1	Cut 2	Cut 3	Total
Replication	2	1.416	1.066*	0.915	9.591
(Y)Year	1	15254.2**	17015.8**	2.9	65365.2**
Error	2	0.509	0.019	0.262	0.904
Irrigation(I)	2	997.74**	866.25**	352.74**	6363.4**
(Y)x(I)	2	63.68	50.199	0.29*	236.27
Error	8	36.75	24.11	13.80	211.36
Total	17	-	-	-	-

*, ** P ≤ 0.05 and 0.01 respectively

Table (6) Analyses of variance for the two seasons and combined analysis for plant height of **teosinte** under cut-off irrigation

	Plant height cm				
S.of.V.	2021 season				
	df	Cut 1	Cut 2	Cut 3	Average
Replication	2	6.77	14.77	6.33	5.73
Irrigation	2	514.11**	612.11*	257.00**	429.82 **
Error	4	21.61	28.27	22.83	13.35
Total	8	-	-	-	-
	2022 season				
S.of.V.	df	Cut 1	Cut 2	Cut 3	Average
Replication	2	6.333	16.77	8.11*	0.274*
Irrigation	2	330.33*	257.44 **	448.11*	340.48**
Error	4	94.66	48.44	9.94	36.619
Total	8	-	-	-	-
	Combined				
S.of.V.	df	Cut 1	Cut 2	Cut 3	Average

Replication	2	1.55	0.67*	14.38**	1.76
(Y)Year	1	440.05*	953.38*	373.55**	564.48**
Error	2	11.55	30.88	0.056	4.25
Irrigation(I)	2	830.722**	759.50**	672.38**	745.644**
(Y)x(I)	2	13.722	110.05	22.72*	24.67
Error	8	58.14	38.36	16.38	24.99
Total	17	-	-	-	-

*, ** P ≤ 0.05 and 0.01 respectively

Forage production and plant height :

A- Fresh forage (kg/strip).

The mean performances of fresh forage in the two seasons and combined data are presented in **Table 7.**Also, highest mean values for

Fresh forage yield of teosinte were attributed to cut two by cut one and the lowest was the cut three. These is the natural behavior of teosinte.Insipte of irrigation levels 100% had the highest mean values of total fresh yield through three successive cuts and their total cuts but there were no significant differences notice between the two irrigation treatments 100% and 90% in first and second cuts in the first summer season 2021 and in the three successive cuts in the second summer season 2022 .The mean values of fresh forage yield of 100% irrigation levels recorded 610 and 685 Kg/strip with compared to 585 and 655kg/strip for 90 %irrigation treatment at first and second cuts ,respectively in the first season. Whereas, the second season 2022 ,100% irrigation level resulted in 775,868 and 420 kg/strip with compared to 90% irrigation level which recorded 740,868 and 420 kg/strip for first ,second and third cuts, respectively .The decreasing of irrigation level from 100% to 90% lead to reduction of total fresh forage production by 4.65 and 4.99% for first and second seasons ,respectively, fresh yields are severely decreased when plants irrigated by 80% cut-off. These results are in the same line with those obtained by **Assaeed 1994 [31], Ghasemi *et al.* 2012[32], Wricke 1962[33]** and **Heisey and Edmeades 1999[34]**. On the contrast, decreasing water irrigation level from 100% to 80% resulted in a sharp decline percentage in total fresh forage yield by 16.58 and 17.20 of first and second season, respectively. With concern to combined analysis over two seasons .Results showed the same trend of irrigation treatment's on fresh forage production.

Table (7) Effect of irrigation levels in the two seasons and combined data for fresh forage of **teosinte** under cut-off irrigation

Fresh forage yield				
Treatments	2021 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	610	685	490	1785
90%	585	655	462	1702
80%	515	570	404	1489
Significant	*	**	**	**
LSD0.05	57.24	51.11	25.98	23.92
Treatments	2022 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	775	868	420	2063
90%	740	825	395	1960
80%	647	717	344	1708
Significant	**	**	**	**
LSD0.05	54.54	51.46	34.45	46.7
Treatments	combined			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	692.5	776.5	455	1924
90%	662.5	740	428.5	1831
80%	581	643.5	374	1598.5
Significant	**	**	**	**
LSD0.05	32.83	30.12	17.93	59.04

B- Dry forage (kg/strip).

Data in **Table 8** reveals significant effect of irrigation level on dry forage yield of teosinte at first and second seasons and their combined .The highest mean values of total dry yield was belonged to treatments received 100% irrigation level (262.8 ,279.9 and 271.35 kg/strip)for first, second and combined analysis ,respectively followed by 90% irrigation level which had (242,258 and 250 kg/strip)for first, second and combined analysis ,respectively. From the same table, results showed no significant differences between 100 and 90 % irrigation level treatments on dry forage yield in in first and second cutting of the first season with reduction reached to 6.21 and 6. 99%, respectively.The inhibiting effect of the water deficit stress on the studied parameters notably appeared more pronounced under the 80% cut-off than that of 90% as stated by **Blum 2009[28], Hall *et al.* 1979**[7] **, Ludlow and**

Muchow 1990[29] and Geries *et al.* 2021[35].The obtained results may refer to that decreasing the irrigation water lowered the soil moisture content which restricted the mobility of nutrients to plant that would reduce the efficiency of physiological and metabolic processes needed for plant growth. Meanwhile, significant differences were recorded among all treatments except at the first cut between 100 and 90%irrigation treatment. The lowest values of total dry yield (201.5, 212 and 207.2 kg/strip) were found among treatment applied with 80 irrigation level at first, second seasons and their combined analysis, respectively Our results are in accordance with those obtained by **Dewet *et al.*1971[36], Carrow 1996[37], Mariola staniak and Anna kocon 2015[38], El-Shamarka *et al.* 2012[39] and Ghasemi *et al.* 2012[32]**.

Table (8) Effect of irrigation levels in the two seasons and combined data for dry yield of **teosinte** under cut-off irrigation

Dry forage yield				
Treatments	2021 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	80.5	100.02	82.3	262.8
90%	75.5	93.03	73.5	242
80%	63.9	78.2	59.4	201.5
Significant	**	**	**	**
LSD0.05	6.58	9.27	6.36	22.19
Treatments	2022 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	93.82	117.2	68.9	279.9
90%	86.6	108.2	63.2	258
80%	71.8	88.9	52.2	212
Significant	**	**	**	**
LSD0.05	7.23	7.77	5. 32	20.35
Treatments	combined			
Irrigation levels	Cut 1	Cut 2	Cut 3	Total
100%	87.16	108.61	75.6	271.35
90%	81.05	100.61	68.35	250
80%	67.85	83.55	55.8	207.2
Significant	**	**	**	**

LSD0.05	4.06	5.02	3.44	12.5

C- Plant height (cm).

Application of 100%irrigation level resulted in significant enhancement in plant height (cm) followed by 90% and 80%irrigation level. Comparing among all treatments ,no significant differences were recorded between 100 and 90%irrigation levels on plant height for second and third cuts of the first season and all cuts and their main average of second season **Table 9** .The shortage of plant height from 100% irrigation level to 90%ranged from (4-6%) and (1.8-4.1%) for first and second season ,respectively Such findings are closed by that found by **Assaeed 1994 [31]and Hall *et al.* 1979[7]**. On the other hand the lowest values of plant height were belonged to 80% irrigation treatment and the decreasing of plant height with compared to 100%irrigation treatment for first and second cut, respectively.

Table (9) Effect of irrigation levels in the two seasons and combined data for plant height of **teosinte** under cut-off irrigation.

	Plant height cm			
Treatments	2021 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Average
100%	126	139	117.33	127.66
90%	118.6	130.66	112.66	120.66
80%	104.6	113.66	100	106.1
Significant	**	*	**	**
LSD0.05	5.44	12.89	5.7	5.79
Treatments	2022 season			
Irrigation levels	Cut 1	Cut 2	Cut 3	Average
100%	130	161.66	105.33	132.33
90%	127.66	156	101	128.2
80%	112	135.66	89	112.23
Significant	*	**	*	**
LSD0.05	10.33	10.37	9.65	9.41
Treatments	combined			

Irrigation levels	Cut 1	Cut 2	Cut 3	Average
100%	128	150.66	111.33	130
90%	123.16	143.33	106.83	124.43
80%	108.33	124.66	94.5	109.16
Significant	**	**	**	**
LSD0.05	7.28	6.87	4.65	4.59

Decreasing percent of teosinte forage crop in 2021 and 2022 seasons and combined analysis are presented in **Table 10**. Water stress of 80% cut-off irrigation reduced total fresh forage yield production of teosinte were 16.6% , 17.2 and 16.9% for first ,second seasons and combined data ,respectively. Also, for total dry yield were 27.8%, 24.2% and 23.6% for two seasons and combined data respectively. Recent of decrease of average plant height of water stress of 80% cut-off irrigation for two seasons and their combined data were 16.9% and 15.2% and 16.0%, respectively. Same results were confined by **Casler and Hovin 1984[40]**. Water stress of 90% cut-off irrigation less than water stress of 80% for effect reduced of yield.

Table (10) Percent of decrease of Teosinte summer forage.

	2021season											
	Fresh forage yield				**Dry forage yield**				**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%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
90%	**4.1**	**4.4**	**5.7**	**4.6**	**6.2**	**7.0**	**10.7**	**7.9**	**5.9**	**6.0**	**4.0**	**5.5**
80%	**15.6**	**16.8**	**17.6**	**16.6**	**20.6**	**21.8**	**27.8**	**23.3**	**17.0**	**18.2**	**14.8**	**16.9**
	2022season											
	Fresh forage yield				**Dry forage yield**				**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%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
90%	**4.5**	**5.0**	**6.0**	**5.0**	**7.7**	**7.7**	**8.3**	**7.8**	**1.8**	**3.5**	**4.1**	**3.1**
80%	**16.5**	**17.4**	**18.1**	**17.2**	**23.5**	**24.1**	**24.2**	**24.3**	**13.8**	**16.1**	**15.5**	**15.2**
	combined											
	Fresh forage yield				**Dry forage yield**				**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%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
90%	**4.3**	**4.7**	**5.8**	**4.8**	**7.0**	**7.4**	**9.6**	**7.9**	**3.8**	**4.9**	**4.0**	**4.3**

80%	**16.1**	**17.1**	**17.8**	**16.9**	**22.2**	**23.1**	**26.2**	**23.6**	**15.4**	**17.3**	**15.1**	**16.0**

Water relations:

Applied irrigation water (IW).

Seasonal values of applied irrigation water (IW) for teosinte during the two growing seasons of study are tabulated in **Table 11**. It is cleared from the presented data that the control irrigation water (Trt. A) has the highest values compared with cut-off irrigation treatments B and C. In this regard, mean values of I.W. for teosinte could be arranged in descending order as 83.1 > 74.1> 68.9 cm. for treatments A (100%), B (90%cut-off) and C (80%cut-off), respectively.

Therefore, by comparing I.W. for cut-off irrigation treatments with the control (Trt. A, 100%), mean water saving for teosinte counted by nearly 10 and 17% under 90 and 80% cut-off treatments, respectively.

It should be notified that choosing the suitable level of surface cut-off irrigation to be executed in the clayey soils should be linked with the decreasing in crop yield. In other words, two factors should be taken into consideration; water saving and crop productivity. The obtained findings are in the same direction with that reported by **Doorenbos and Kassam, 1979[17], Abdel-Fattah 2011[41]** and **Steduto *et al*., 2012[16].**

Consumptive use (CU)

Seasonal values of crop consumed water (CU) for different irrigation treatments in the two growing seasons are tabulated in **Table 11**. Data show that control treatment A (100%) has the highest values of seasonal CU, while the lowest ones are for 80% cut-off irrigation (Trt. C).

In this regard, mean values of seasonal CU for teosinte forage crop can be arranged in descending order as 64.8> 60.8> 58.6cm. for treatments A (100%) control, 90% and 80% cut-off treatments, respectively. These finding are owing to the less applied irrigation water under cut-off 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[17], Abdel-Fattah 2011[41], Kassab *et al*. 2012[42]**and **Steduto *et al.*, 2012[16].**

Table 11: Seasonal applied irrigation water (IW, cm) and Consumptive Use (Cu, CM.) FOR Teosinte as affected with different irrigation treatments.

Irrigation Treatment	IW				CU			
	2021,cm.	2022,cm.	Mean		2021,cm.	2022,cm.	Mean	
			Cm.	M^3 fed^{-1}			Cm.	M^3 fed^{-1}
A=100% control	83.7	82.4	83.1	3438.1	67.0	62.6	64.8	2721.6
B=90% Cut - off	76.7	71.5	74.1	3111.5	62.9	58.6	60.8	2555.0
C=80% Cut - off	71.1	66.6	68.9	2893.1	60.5	56.7	58.6	2466.2

Crop-water functions:

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

Water productivity (WP).

The obtained data of WP in kgm^{-3} consumed water for different treatments are tabulated in **Table 12** . It is cleared that the 90% cut-off irrigation of treatment B has the highest values of WP and vice versa for the non-cut-off 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 of treatment A. In other words, there is a reverse relation between CU and WP.

Productivity of Irrigation water (PIW)

It is cleared that PIW in kgm^{-3} irrigation water took the same trend of WP **Table 12**. 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 line with that reported by **Lazaridou and Koutroubas 2004[43], Ali and Talukder 2008[44], Abdulaziz *et al.* 2009[45], Ouda *et al.* 2012[46], Abdel-Fattah 2011 [41], Kassab *et al.* 2012[42] and Bondok *et al.* 2022[47].**

Table 12: Mean Seasonal Values of Fresh, Dry Yield, Consumptive Use (CU), Irrigation Water (IW), Crop Water Productivity (WP) and Productivity of Irrigation Water (PIW) for teosinte as affected with different irrigation treatments.

Irrigation Treatment	Yield, Kg fed^{-1}		C**µ**, m^{3}fed^{-1}	IW, m^{3}fed^{-1}	Productivity, Kgm^{-3}			
					WP		PIW	
	Fresh	Dry			Fresh	Dry	Fresh	Dry
A=100% control	57720.0	8140.0	2721.6	3438.1	21.21	2.94	16.79	2.36
B=90% Cut - off	54930.0	7500.0	2551.5	3111.5	21.52	2.99	17.65	2.41
C=80% Cut - off	47955.0	6204.0	2460.2	2893.1	19.49	2.52	16.58	2.14

Maximizing productivity of water unit

As mentioned before, the 90% cut-off irrigation treatment B produced nearly the highest yield as full irrigation (Trt. A,100%) with slight decrease in fresh and dry yield with4 .83 and 7.89% for teosinte forage crop **Table 12.**

In that regard, mean values of WP and PIW under treatment B of 90% cut-off irrigation for fresh and dry yield of teosinte is the highest as presented in **Table 12.**

Since treatment B of 90% cut-off irrigation has the highest values of both WP and PIW, therefore as sketched in Figure 1, one m^3 consumed water produced 21.52and/or2.94 kg as fresh and dry yield for teosinte. Meanwhile, Figure 2 shows that one m^3 of applied irrigation water produced 17.65 and/or 2 .41 kg as fresh and dry yield of teosinte forage crop, respectively. In other words, to produce 1 kg fresh teosinte it consumed 46.46 liter and 34.43 liter for dry yield. Meanwhile, to produce 1kg fresh teosinte, it needs56.66 litre as applied irrigation water, while it is 41.40 liter for dry yield.

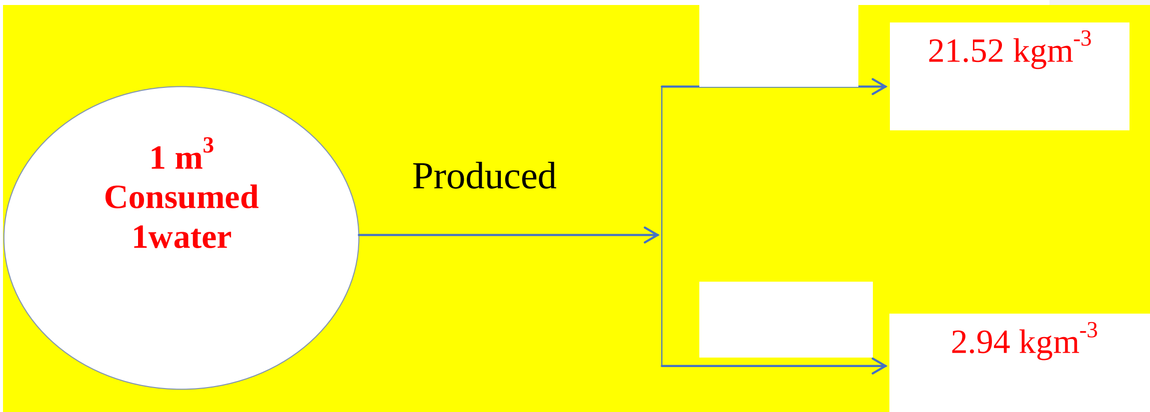

Fig.1. crop water productivity (WP) for fresh and dry teosinte under 90% cut-off irrigation.

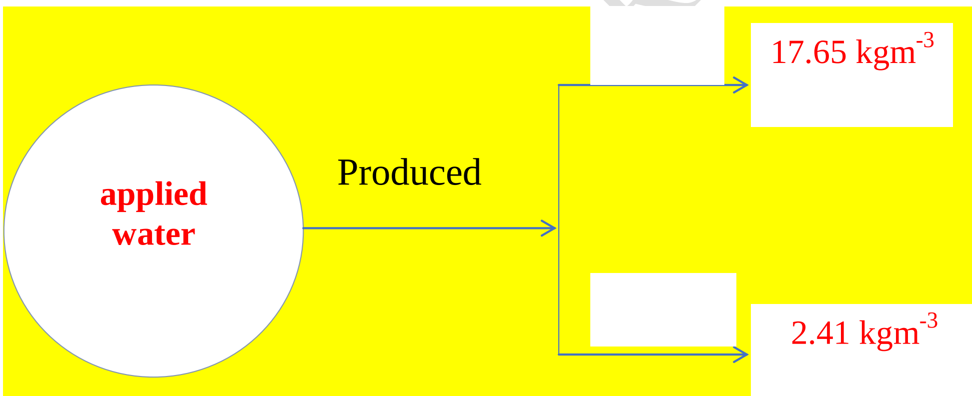

Fig.2. Productivity of irrigation water (PIW) for fresh and dry teosinte under 90% cut-off irrigation.

Comment [3A]: Put it in a table

CONCLUSIONS

Comment [4A]: Change the way conclusions are presented and provide more content

- Executing 90% cut-off irrigation for teosinte forage crop, several advantages could be gained such as; nearly highest yield, 10% water saving as well as higher productivity of each unit of consumed and/or irrigation water.
- More investigations are needed regarding the performance of crops and their water relations particularly under the prevailing water shortage that facing Egypt.

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