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A practical Approach for water Use Efficiency in Arid Areas

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مدخل عملي لكفاءة استخدام الماء في المناطق القاحلة

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استخدم مدخل عملي لكفاءة استخدام الماء يصلح للمناطق الجافة ويعتمد على كمية الماء المضافة للنبات وقد تم تطبيقه على بعض المحاصيل في المعادلة النظرية التي وضعت لهذا الغرض، وقد تمت تجربة هذا المدخل على محاصيل الدخن والذرة الرفيعة والشعير في مدينة توسان بولاية اريزونا الأمريكية ومدينة العين بدولة الإمارات العربية المتحدة وبمحطة بحوث الرميس بسلطنة عُمان على التوالي. وتم استخدام المعادلات النظرية لحساب كفاءة استخدام الماء لهذه المحاصيل لانتاج البذور والاعلاف. وقد اعتمد في الحالات الثلاثة استعمال نظام الري بالرش المتدرج لخلق وضعاً يشابه الوضع بهذه المناطق القاحلة.

أوضحت النتائج وجود اختلافات بين المحاصيل في استجابتها وكذا بين اصناف المحصول الواحد. فقد قلت كفاءة استخدام الماء مع النقص في المياه لمحصولي الدخن والذرة وذلك بسبب نقص الانتاجية إلا أن محصول الشعير اظهر كفاءة أعلى في استخدام الماء لانتاج البذور في معدلات ري منخفضة ونسبة لتأثير انتاجية المحاصيل بنقص المياه في المناطق الجافة فيمكن حساب كفاءة استخدام الماء بكمية الماء المضافة حتى تكون الصورة حقيقة.. وكتوجه عام في المناطق الجافة فإنه يجب التركيز على أعلى انتاجية اقتصادية مقارنة مع كمية الماء المضاف بدلا من الانتاجية المطلقة.

Key-Words : Arid areas, Applied water, Efficiency, Production, Yield.

ABSTRACT

A practical approach for water use efficiency (WUE) relying on the actual amount of applied water was examined from both theoretical and practical stand points. Pearlmillet (***Pennisetum americanum*** (L.) K. Schum), sorghum (***Sorghum biclor*** L. Moench) and barley (***Hordeum vulgare*** L.) were planted under sprinkler irrigation gradient at Tucson, Arizona, U.S.A; Al-Ain, United Arab Emirates and Rumais, Sultanate of Oman, respectively. Equations were developed for WUE for both yield and forage production.

Water use efficiency of sorghum and millet genotypes decreased with decreasing level of water due to the reduction in total yield. However, barley(winter crop) showed a different trend as WUE for grains was higher for low water level. Because of the effect of decreasing water level on yield, WUE was calculated by the actual amount of water applied. Whenever water is the main limiting factor to production, the emphasis should be geared toward maximum economic production per unit of applied water rather than maximum yield.

INTRODUCTION

Water management in arid areas is the most important factor that determines productivity. With the increase of the irrigated area and the onset of the drought cycle, water resources become limiting and endangered by salinity. Rainfall is very scanty and erratic in arid areas with annual total ranges between less than 100 and 400 mm (1). Water use efficiency (WUE) is a useful relative term in drought selection. Under stress conditions, the main concern is the production per unit of applied water rather than absolute production (2,3,4,5,6,7and8).Stewart et al.,(9) calculated WUE of sorghum on the basis of kg grain m^{-3} evapotranspiration (ET).

Utilization of the limited water resources necessiates the estimation of crop water requirement for efficient use of water. Trivedi et al.(10), found that sorghum varieties had relatively low values for consumptive use and higher values of WUE by grain and stover. Most of the estimation of WUE depends on consumptive use of water (CU) and evapotranspiration (ET). The moisture is needed for the production of the harvestable part (grain or fodder). Trivedi et al.,(10) estimated an average of 56.8 mm of moisture for the production of one ton grain of sorghum.

Water use efficiency has been increased by 25 to 30% when modern irrigation system was used (1). The line source sprinkler procedure described earlier(11,12,13) has been very useful for applying various levels of irrigation water to experiments. It has been used successfully to screen a large number of genotypes of millet and sorghum (14and 15). Many techniques have been used to determine WUE in crops, but few have been evaluated under arid areas or low water levels. The objective of this study is to examine the possibility of using the total amount of water as a practical method that can be used for selection under the sprinkler gradient system.

Materials and Methods

A Sprinkler gradient line was set up at different locations (Tucson, Arizona, 1983/1984; Al-Ain, United Arab Emirates, 1991/1992 and Rumais Research station, Sultanate of Oman, 1995-96) to evaluate the response of different crops at different water levels. Pearlmillet, (81-1014 Female , Senegal - bulk Male and their hybrid) , sorghum (Feterita , Dabar , Um Benin , Gadam el hamam , Honey drip , Pioneer , Sudax and FS. SX - 17) and barley (Duraqui) were examined in a sandy loam soil at the three locations respectively. The experiments were split plot in a systematic complete block strip plots which consisted of 14 rows each side and parallel to the source line and 4. 5 m wide with water levels as subplots. Subplots were taken as high irrigation level for the first two rows from the line source, intermediate irrigation level for the seventh and eighth rows and low irrigation level for the last two rows away from the line source. . Data for grain yield, biological yield and total amount of applied water were collected and subjected to statistical analysis with the aid of MSTAT Computer programme.

Theoretical

Water Use Efficiency (WUE) can be calculated using the total amount of applied water for grain and dry matter as follows :

$$WUE = \frac{Y_G}{W_T} \quad \ldots\ldots\ldots\ldots \quad 1$$

$$WUE = \frac{Y_{DM}}{W_T} \quad \ldots\ldots\ldots\ldots \quad 2$$

Where :

WUE = Water use efficiency (kg/ha. cm)

Y_G = Grain yield (kg/ha)

Y_{DM} = Dry matter yield (kg/ha)

W_T = total water applied (cm)

Equations 1 and 2 were used to convert the actual data for millet, sorghum and barley for the subsequent results in tabular forms.

RESULTS

Water use efficiency (WUE) for grain and dry matter could be found for high, medium and low water levels. Selection is for genotypes with high efficiency under low water levels (equations 1 and 2) and for genotypes with a decreasing amount of water use under stress. When the stress is severe the production will be very low and that will affect the total efficiency (Table 1).

Water use efficiency for total dry matter and grain yield of millet was decreased with stress for all entries (Table 1). WUE at low water level was higher for the hybrid for both yield and dry matter in 1983. Under stress, the hybrid used more water in both seasons, but it was only able to express that in terms of production in 1983 (Table 1) when the stress was more pronounced.

Water use efficiency (WUE) of sorghum, for grain yield and dry matter, decreased with water stress in all genotypes (Table 2). There was a significant difference in WUE for grain between high and low water levels for all genotypes in 1991. In 1992, where water stress was more pronounced, there was a significant diference in WUE for grain between high and low water levels for grain sorghum genotypes (Table 2), while there was no difference for forage sorghum genotypes. Feterita was the most efficient genotype in water use for grain production at low water level in 1991, while Umbenin was the best in 1992. The most efficient genotype for fodder production at low water level was Feterita in 1991 and Pioneer in 1992.

The results of the data in barley (Table 3) over two locations indicated that water levels had a significant effect only with respect to total water applied while the location effect was significant for WUE for grain. The interaction effect between water level and location, however, was interestingly evident for both grain and biological yields. WUE's computed on both grain and biological yields were of higher magnitude at LRC because of its favourable enviroment as compared to ARC. Table 3 also showed that Duraqui genotype responds favourably with marginal loss of efficiency to increased water level with respect to grain yield while it tends to gain WUE to produce high biological yields.

DISCUSSION

Water use efficiency (WUE) is a useful relative term in arid areas. Under such conditions, the main concern is the production per unit of applied water rather than absolute production. The practicality of the equations defined in this paper depends on the responses of the crop genotypes to dry conditions and particularly when used under the sprinkler gradient. Selection with this approach needs a large number of genotypes. Lines (genotypes) that grow well under such conditions would be expected to have a high efficiency in water use as they will increase the proportion of the harvestable part due to less amount of water applied.

WUE for total dry matter and grain for most genotypes in the study decreased with a decrease in water (Tables 1,2,3). The results agreed with Singh and Kanemasu (16) who found reduced WUE for grain yield under no irrigation. Gerrity et al.(17) found a strong negative trend in WUE with water stress. The decrease in dry matter agreed with Chaudhuri and Kanemasu (18) finding that increasing the watering level increased WUE for total dry matter. This has also been observed in the investigations conducted in Mexican high lands endowed with 93% dry land agriculture where barley showed the higher values of WUE in terms of both grain and biological yields (19).

However, Ibrahim et al. (2) found an increase in WUE for total dry matter with stress, but when calculated on the basis of grain yield there was a decrease in WUE. This could be explained by the findings of Owonubi and Kanemasu (20) that tall sorghum plants had high evapotranspiration and high water use efficiency for dry matter while dwarf plants were water efficient for grain production. Pandey et al., (21) added that increased leaf senescence will result in less water use. The same trend could be observed in table 2 where there was a significant difference between high and low water for grain sorghum genotypes while no significant differences between forage sorghum genotypes.

Research programmes, in arid areas, should concentrate on the effect of production factors, acting singly and as a package, under severe enviromental conditions that is aggravated by high evaportanspiration load. Intensive inputs are used to increase production per unit area, especially when modern irrigation methods are used. The study suggested that whenever water is a limiting factor for production, the emphasis should be geared towards maximum economic production per unit of applied water rather than the maximum yield. This approach could be very useful in defining selection critiria for water use efficiency. The method could be used for different crops if supported by different visual,physiological and morphological techniques and good understanding of WUE of such crops. The use of a sprinkler gradient line is a valuable technique in such studies as it enables the evaluation of a large number of genotypes.

Teble 1. Perfomance of pearlmillet genotypes under different water levels 1983/1984 at Tucson, Arizona, U.S.A.

Name of genotype	Water level	1983					1984				
		Total water applied (cm)	Grain yield $plant^{-1}$ (g)	Dry matter $plant^{-1}$ (g)	WUE ($kg\ ha^{-1}\ -cm^{-1}$)		Total water applied (cm)	Grain yield $plant^{-1}$ (g)	Dry matter $plant^{-1}$ (g)	WUE ($kg\ ha^{-1}\ -cm^{-1}$)	
					Grain	Fodder				Grain	Fodder
Famale	high	61,3	3.6b	113.4b	17.7b	359.9b	67.3	36.6a	174.0a	79.7a	591.3b
81- 1014	medium	26.4	1.2e	99.4d	3.4e	299.3d	29.0	6.2e	107.5c	12.5c	246.5d
	low	6.4	0.01g	32.9h	0.03g	104.4i	15.6	1.2d	81.0d	2.4e	156.0g
Male	high	61,4	25.4a	1055e	80.8a	330.1c	67.8	35.5a	172.7a	89.2a	586.6b
Sengal	medium	26.2	2.4d	69.0f	6.1d	227.2f	29.6	5.0c	96.6d	9.8d	213.3e
Bulk	low	9.5	0.08f	48.1g	0.3f	152.8h	15.2	0.6a	92.8d	1.3e	174.5f
Hydrid	high	60.9	27.1a	124.8e	86.0a	435.2a	66.9	33.6a	178.6a	88.1a	604.3a
18 - 1014x	modium	26.4	4.3c	84.9e	13.7c	287.4e	29.1	8.3b	131.5b	15.7b	361.7c
Sengel Bulk	low	9.5	1.1e	62.9f	3.5e	199.6g	15.3	0.6e	90.3d	1.2e	174.4f

Means followed by the same letter within each column are not significanthy different each year at the 5% level according to the SNK Method

Table 2. Perfomance of Sorghum genotypes under different water levles 1991/1992 at Al-Ain, U.A.E.

Name of genotype	Water level	1991					1992				
		Total water applied (cm)	Grain yield plant^{-1} (g)	Dry matter yield plant^{-1} (g)	WUE (kg ha^{-1} -cm^{-1})		Total water applied (cm)	Grain yield plant^{-1} (g)	Dry matter yield plant^{-1} (g)	WUE (kg ha^{-1} -cm^{-1})	
					Grain	Fodder				Grain	Fodder
Feterita	high	63.5	4.5	22.3	70.7	351.2	55.6	2.9	16.9	52.2	304.0
	medium	44.9	2.9	14.4	64.6	276.2	41.7	1.8	12.2	43.2	292.6
	low	26.3	1.1	4.6	41.8	174.9	21.3	1.0	3.8	37.7	179.2
Dabar	high	63.5	3.9	22.1	61.4	348.0	55.0	2.8	16.8	51.5	305.5
	medium	45.0	1.8	11.8	40.0	262.2	41.0	1.9	11.8	46.5	287.8
	low	26.3	0.8	3.1	30.4	117.8	21.0	0.8	2.8	38.3	134.0
Hney Drip	high	63.5	3.2	21.8	50.4	343.3	55.0	2.5	20.2	45.5	357.9
	modium	44.9	6.1	11.4	35.6	253.9	41.3	1.5	14.1	36.3	341.4
	low	26.3	0.5	2.2	19.0	83.7	20.9	0.7	6.8	33.5	325.4
Pioneer	high	63.5	3.3	22.3	52.0	351.2	54.5	2.3	22.1	42.2	405.5
	medium	44.9	2.2	11.0	49.0	245.0	40.0	1.6	15.0	40.1	375.0
	low	26.3	0.6	2.8	22.8	106.5	21.2	0.8	7.1	37.7	334.9
Sudex	high	63.9	3.6	20.2	56.7	318.6	55.0	2.5	21.0	45.5	381.8
	medium	44.9	1.8	12.1	40.1	269.5	41.2	1.8	14.8	43.7	359.2
	low	26.5	0.6	2.6	22.8	98.9	21.1	0.7	6.9	3.2	327.0
Um Benin	high	63.5	3.2	20.8	50.4	327.6	55.1	3.4	17.1	61.7	310.3
	modium	44.9	1.6	11.2	35.6	249.4	40.9	2.1	12.1	51.3	295.8
	low	26.3	0.8	2.8	30.4	106.5	22.1	1.0	4.1	45.2	185.5
Gadamel Hamam	high	63.5	3.1	19.8	48.8	311.8	54.8	3.2	18.2	85.4	332.1
	medium	44.9	1.5	10.6	3.4	236.1	41.2	2.0	11.8	48.5	286.4
	low	26.3	0.8	2.9	30.4	110.3	20.9	0.9	3.9	43.1	186.6
FS-SX-17	high	63.5	2.8	18.4	44.1	289.9	55.0	2.6	20.4	47.3	370.9
	medium	44.9	1.4	10.4	37.2	231.6	40.6	1.9	14.2	46.5	347.2
	low	26.3	0.5	1.8	19.0	68.4	20.9	0.8	5.4	38.3	258.4
Cd		-	1.2	5.4	18.4	60.5	-	1.4	6.2	12.5	58.4

Table 3. Performance of rainfed Omani barley "Duraqui" under three water levels, in two enviroments during winter, 1995/1996

Location	Water level	Total water applied (cm)	Grain Yield (kg/ha)	Dry matter yield (kg/ha)	Water use efficiency (WUE) (kg/ha/cm)	
					Grain	Fodder
Livestock	high	35.6	1803.0	7550.0	50.7	211.7
Research	medium	28.4	1267.0	4550.0	44.6	161.0
Center	low	19.1	1043.0	3663.0	54.9	192.4
(LRC)	F-Test	**	**	*	NS	NS
.	Sem +/-	0.456	3.162	15.630	2.433	12.450
Agriculturral	high	34.3	680.0	3773.0	19.7	110.3
Research	medium	29.5	580.0	4437.0	19.7	150.3
Center	low	20.3	417.0	2993.0	20.7	147.7
(ARC)	F-Test	**	NS	NS	*	NS
.	Sem +/-	0.354	6.532	16.12	0.707	1.592
pooled Analysis	Water level	**	NS	NS	NS	NS
over the	Location	NS	*	NS	**	NS
locations	water level x location	NS	**	**	NS	NS
.	Sem +/-	1.300	5.130	15.920	1.789	8.870

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