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Effect of Irrigation Regime on Growth and Development of Two Wheat Cultivars (*Triticum aestivum* L.) in the Nigerian Savanna

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Abstract
Field trials were conducted at irrigation research stations of the Institute for Agricultural Research, Kadawa (11° 39'N, 08° 27'E, 500m asl). The objective was to study the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Siete cerros and Pavon 76). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m^2 and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the highest water use efficiency of 4.0-4.8kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Keywords: irrigation regime, wheat growth, wheat yield,available soil moisture, Pavon 76, Siete cerros, Nigeria, savanna

1 Introduction

Plant response to varying degrees of water regime has been a subject of considerable study and review (Slayter, 1967; Kajdi, 1993; Khehr *et al.*, 1996). Yet the question of how water regime interacts with other cultural practices to affect growth, yield and quality of crops remain one of the important problems in crop agriculture. Conclusive explanations of these interactions have not been achieved. Current emphasis however appear to be on understanding the plastic responses of crop genotypes to soil water status and the determination of climate, plant and soil relationships (Benbi, 1994) that would improve appropriate scheduling of irrigation. Wheat cultivars respond differently to irrigation treatments. Studies by Kumar and Yayock (1980), Falaki (1994) and by Abubakar (1999) have shown considerable variations in yields between cultivars in Nigeria. Their reports and that of Negedu (1994) also show seasonal variations in yields of individual cultivars. The differences in yields among cultivars, and between seasons

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are commonly associated with differences in growth and yield attributes (NEGEDU, 1994; FALAKI, 1994; ABUBAKAR, 1999) and to genetic differences (RAJARAM and VAN GIMKEL, 1996).

Several workers have observed that the yield of wheat was enhanced if irrigation was sustained at 50% or higher available soil moisture levels (ERIE, 1962; BAPNA and KHUSPE, 1980; SINGH *et al.*, 1980). These results implicate the need for determination of the response of newly developed wheat varieties under different moisture regimes.

In the light of the above this study was initiated among other things to:

> Evaluate the effect of three irrigation regimes on water use, water use efficiency, growth and yield of two newly introduced wheat cultivars.

2 Materials and Methods

Field Experiments were conducted for three seasons, 1995/96, 1996/97 and 1997/98 dry seasons at the Institute for Agriculture (IAR/ABU) Irrigation Research Station at Kadawa (11° 39'N 08° 15'E and 500m above sea level) in the Sudan Savanna of Nigeria.

The soil was sandy loam, pH > 7.2-8.0, CEC (meq/100) of 5.89–6.21, exchangeable Na^{++} of 0.152–0.182, K^{+} of 0.202–0.268, Ca^{++} of 2.16–2.93, total N of 0.041–0.048, and total P (ppm) 29.4–33.4. The water table depths of the sites used in the study determined by the method described by NWA (1982) on the 20^{th} of each month of the study averaged 77 cm in 1995/96, over 100 cm in 1996/97 and 92 cm in 1997/98. Table 1 shows the trend of evaporation, maximum–minimum temperature and relative humidity that prevailed during the experiment. Rain did not fall throughout the period of the experiment.

Three irrigation levels (60%, 75% and 90% ASM) and two spring semi-dwarf wheat varieties (*Triticum aestivum* L.) viz, Siete cerros (maturing in about 110-115 days) and Pavon 76 (maturing in about 90 - 102 days) were evaluated in three replicates laid out in a randomized complete block design. Moisture levels were determined using a Toxler neutron probe in each plot. The experimental land was irrigated, ploughed and harrowed three times to obtain a fine tilt. Basins were constructed manually and its raised borders (70 cm height) were carefully compacted to minimize seepage. The internal basin dimensions were 4 × 3m. The seeds were treated with Apron plus 50DS at the rate of 10 g/kg of seed before sowing. Seeding rate adopted was 120 kg/ha. Corresponding quantity of seed for each plot was weighed and used completed. Planting was conducted based on the sowing date treatments. Seeds were sown in rows of 20 cm rows by drilling. The first and the third rows each side were treated as border rows while the second row was used for destructive sampling. Also along the length of the plot, 0.25 m was treated as border area. Therefore the net plot size was $7m^2$. The first dose of 60 kg each of N, $P_2 0_5$ and $K_2 0$/ha was applied basally at planting. Compound fertilizer was used to supply the nutrient. A second dose of 60 kg N/ha was applied six weeks after sowing (WAS) using Urea (46% N) as source of nitrogen. The same fertilizer regime was adopted throughout the study. Weeds were controlled manually by hoe weeding at 3, 5 and 7 WAS. The crop was harvested at physiological maturity stage

Table 1: Mean maximum temperatures (℃), relative humidity (%) and pan evaporation at 10-day interval during 1995/96 dry season at Kadawa

Month	*Temperature (℃)*						*Relative Humidity (%)*			*Pan Evaporation (mm/day)*		
	1995/96		*1996/97*		*1997/98*							
	Max	*Min*	*Max*	*Min*	*Max*	*Min*	*95/96*	*96/97*	*97/98*	*95/96*	*96/97*	*97/98*
December												
1-10	34	11	32	12	38	13	65	59	32	6	5	6
11-20	33	14	33	11	34	12	57	73	35	6	5	5
21-31	30	12	33	11	38	13	61	59	39	6	6	5
January												
1-10	31	12	33	11	32	17	51	56	39	7	14	11
11-20	33	12	34	11	30	10	63	61	27	6	13	12
21-31	28	13	33	11	37	13	65	46	41	6	6	12
February												
1-10	34	13	32	10	41	16	67	39	37	7	8	12
11-20	33	12	33	11	37	16	63	30	30	6	15	12
21-31	33	13	34	12	35	15	65	28	24	6	8	10
March												
1-10	36	17	34	12	35	16	57	35	29	7	7	12
11-20	37	21	41	12	30	18	61	35	39	6	6	15
21-31	35	18	43	21	40	20	42	41	28	8	8	11

Source: IAR meteorological unit

11.4 on Feekes scale illustrated by Large (1954). Harvesting was conducted by cutting the crops with a sharp sickle as close as possible to the ground level. The harvested net plots were bundled into sheaves, dried on the field, weighed, threshed and winnowed. Dry matter per square meter was determined at 3, 6, 9 and 12 WAS. The plants in 0.5 m linear row were carefully uprooted and the roots washed. The samples were then oven dried at 60℃ until they attained constant weight. A balance (Metler 310) was used to weigh the samples. Leaf area index was determined by the method described by Bell and Fischer (1994). The numbers of tillers and spikes per m^2, were recorded from the plants uprooted from a 0.5 m linear row at 6 WAS. Plant height was determined from the main shoot of three tagged plants in each plot from ground level to the tip of the spike excluding the awns. Plant height was measured at maturity. Length of the spike, the weight and number of grains per spike were determined from 5-tagged plants in each plot. Measurement of grain yield was conducted from yield samples from each plot. Three samples of 250 g each were carefully weighed and the 1000-grain mass determined. Grain yield was determined by weighing after threshing and winnowing from the $7m^2$ net plot. The grain yields per net plot were extrapolated to per hectare. Water use efficiency was derived from the ratio of grain yield from a plot to the total irrigation water applied to the same plot.

All data collected were subjected to analysis of variance described by SNEDECOR and COCKRAN (1967). Growth and yield component data were compared using Duncan multiple range test (DMRT) (DUNCAN, 1955).

3 Results

3.1 Growth

The varieties had no effect on the dry matter accumulation (Table 2). The effect of irrigation regime on dry matter accumulation was not significant. Pavon 76 produced higher LAI than Siete cerros only at 6 and 9 WAS (Table 3). The effect of irrigation on LAI manifested late as from 9 and 12 WAS at which irrigation level of 90% ASM produced higher LAI than the less irrigated treatments.

Pavon 76 produced more tillers than Siete cerros in the three seasons (Table 3). The effect of irrigation regime on tiller number was not significant throughout the experiment. All the interactions were not significant throughout the three seasons.

Siete cerros took longer time to mature than Pavon 76 in the three years. Increase of available soil moisture from 60 to 75% significantly increased the number of days to maturity (Table 4). The difference between 75 and 90% ASM was however not significant. When each of the varieties was examined across the irrigation levels (Table 5), it was found that the duration to maturity of both varieties at 60% was lower than at 75 and 90% ASM that were at par. When the two varieties were compared at each moisture level, it was observed that Pavon 76 matured earlier at all the levels than Siete cerros in the three years.

3.2 Grain Yield and Yield Components

The effect of variety on grain yield was significant only in 1996/97 season in which Pavon 76 produced a higher grain yield than Siete cerros (Table 6). The irrigation level had effect on grain yield only in 1997/98 season. Irrigation at 90% ASM resulted in a higher grain yield than irrigation at 60 and 75% ASM. Only in 1995/96 Pavon 76 produced more spikes/m^2 than Siete cerros (Table 4). Irrigation frequency did not affect the spike number /m^2 in the three seasons. All the interactions were not significant on this parameter in the three seasons.

Grain weight/spike of Siete cerros was higher than that of Pavon 76 in both 1996/97 and 1997/98 seasons (Table 6). The irrigation regime had no effect on the grain weight/spike.

Throughout the three seasons, Siete cerros consistently had higher number of grains per spike than Pavon 76. The irrigation levels evaluated in the study did not significantly affect the number of grains/spike. All the interactions were not significant.

Pavon 76 had heavier grains than Siete cerros in the three seasons (Table 6). Irrigation had no significant effect on the size of the grains in 1995/96 whereas in 1996/97 and 1997/98 seasons. Increase of irrigation regime from 60 to 90% ASM decreased the grain size.

The harvest index (HI) was only in 1996/97 slightly higher in Pavon 76 compared to Siete ceros (Table 5), whereas it was not affected by irrigation.

Table 2: Effect of variety and irrigation regime on wheat dry matter accumulation at 3, 6, 9 and 12 WAS in 1995/96-1997/98 dry seasons at Kadawa

Treatment	*Dry Matter Accumulation (g/cm^3)*											
	1995/96				*1996/97*				*1997/98*			
	3 WAS *	*6 WAS*	*9 WAS*	*12 WAS*	*3 WAS*	*6 WAS*	*9 WAS*	*12 WAS*	*3 WAS*	*6 WAS*	*9 WAS*	*12 WAS*
Variety												
Siete cerros	130.89^a	354.1^a	549.1^a	672.7^a	129.30^a	335.6^a	530.3^a	605.4^a	142.06^a	354.1^a	602.4^a	704.7^a
Pavon 76	130.56^a	355.3^a	553.5^a	675.0^a	130.41^a	324.6^a	530.7^a	610.1^a	140.92^b	356.76^b	604.3^a	708.9a
SE±	0.45	3.47	1.87	2.36	2.26	3.45	5.86	11.26	0 .177	2.62	4.74	9.20
Significance	NS	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS
Irrigation at												
60% ASM†	130.72^a	352.1^a	547.8^a	669.9^a	129.67^a	318.6^a	528.4^a	602.8^a	141.42^a	355.0^a	600.8^a	705.0^a
75% ASM	130.50^a	454.2^a	552.2^a	677.4^a	130.00^a	335.4^a	533.0^a	608.2^a	141.38^a	355.5^a	603.2^a	706.9a
90% ASM	130.74^a	357.84	554.0^a	678.2^a	129.89^a	336.3^a	530.1^a	612.4^a	141.67^a	355.6^a	606.1^a	708.5a
SE +	0.56	4.25	2.28	2.89	2.31	4.26	6.81	7.72	2.22	3.25	6.94	11.63
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
V.I	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	**

* WAS ≙ weeks after sowing; † ASM ≙ Available Soil Moisture
Means followed by the same letter within the same treatment group are statistically the same using DMRT.
NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

Table 3: Effect of variety and irrigation regime on leaf area index of wheat at 3, 6, 9 and 12 WAS in 1995/96- 1997/98 dry seasons at Kadawa

Treatment	*Leaf Area Index*											
	1995/96				*1996/97*				*1997/98*			
	3 WAS *	*6 WAS*	*9 WAS*	*12 WAS*	*3 WAS*	*6 WAS*	*9 WAS*	*12 WAS*	*3 WAS*	*6 WAS*	*9 WAS*	*12 WAS*
Variety												
Siete cerros	1.24a	2.36b	4.01b	3.83a	1.20a	2.54b	3.83b	3.60a	1.36a	2.92b	4.02b	3.92a
Pavon 76	1.24a	2.91a	4.03a	3.84a	1.22a	2.60a	3.85a	3.62a	1.35a	2.95a	3.06a	3.94a
SE±	0.004	0.004	.006	.007	0.004	0.015	0.003	0.003	0.004	0.002	0.008	0.008
Significance	NS	*	*	NS	NS	*	*	NS	NS	*	*	NS
Irrigation at												
60% ASM†	1.24a	2.91a	4.00b	3.81b	1.21a	2.58a	3.83b	3.60c	1.35a	2.94a	4.02b	3.85b
75% ASM	1.24a	2.91a	4.01ab	3.84ab	1.21a	2.56a	3.84ab	3.61b	1.35a	2.94a	4.05ab	3.88b
90% ASM	1.24a	2.91a	4.04a	3.85a	1.21a	2.57a	3.85a	3.62a	1.35a	2.94a	4.06a	4.00a
SE±	0.005	0.005	.008	.008	0.004	0.010	0.004	0.003	0.005	0.001	0.004	0.009
Significance	NS	NS	*	*	NS	NS	*	*	NS	NS	*	*
Interaction												
V.I	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* WAS ≙ weeks after sowing; † ASM ≙ Available Soil Moisture
Means followed by the same letter within the same treatment group are statistically the same using DMRT.
NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

Table 4: Effect of variety and irrigation regime on the number of tillers, days to maturity, number of spikes/m^2, length of spike (cm) of wheat in the 1995/96 - 1997/98 dry season at Kadawa.

Treatment	*Number of Tillers per m^2*			*Days to maturity*			*Number of spikes/m^2*			*Length of spike (cm)*		
	1995/96	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*
Variety												
Siete cerros	617.7b	413.4b	504.9b	98.59a	91.78a	93.14a	402.0b	403.9a	497.2a	7.24a	6.075a	7.134a
Pavon 76	656.2a	455.3a	532.1a	90.04b	86.93b	87.33b	412.3a	411.9a	515.7a	7.06a	5.824a	6.932a
SE±	11.57	10.52	8.501	0.0123	0.107	0.10	2.43	8.14	.09	.103	0.1454	0.072
Significance	**	**	**	**	**	**	*	NS	NS	NS	NS	NS
Irrigation at												
60% ASM†	622.8a	421.8a	510.3a	93.22b	88.61b	89.21b	404.1a	405.9a	492.0a	6.89b	5.7091b	6.782b
75% ASM	648.6a	443.3a	527.3a	94.81a	89.56a	90.63a	407.4a	413.4a	509.1a	7.27a	6.016ab	7.101a
90% ASM	639.4a	437.7a	517.8a	94.91a	89.89a	90.88a	410.0	404.3a	507.7a	7.30a	6.124a	7.215a
SE±	14.17	12.89	10.41	0.150	0.13	0.12	1.75	9.97	9.40	0.110	0.126	0.088
Significance	NS	NS	NS	*	*	*	NS	NS	NS	*	*	*
Interactions												
S. V.	NS	NS	NS	**	**	**	NS	NS	NS	NS	NS	NS

† ASM≙Available Soil Moisture
Means followed by the same letter within the same treatment group are statistically the same using DMRT.
NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

Table 5: Interaction between variety and irrigation regime on days to maturity and water use efficiency (kg/mm/ha) of wheat in the 1995/96 - 1999/98 seasons at Kadawa.

Irrigation level	*Days to maturity*						*Water use efficiency (kg/mm/ha)*					
	1995/96		*1996/97*		*1997/98*		*1995/96*		*1996/97*		*1997/98*	
	Siete cerros	*Pavon76*	*Siete cerros*	*Pavon76*	*Siete cerros*	*Pavon76*	*Siete cerros*	*Pavon76*	*Siete cerros*	*Pavon76*	*Siete cerros*	*Pavon76*
60% ASM†	97.22b	89.22d	90.67b	86.50d	91.67b	86.75d	4.039b	4.616a	3.234b	3.708a	4.161b	4.767a
75% ASM	99.22ab	90.40c	92.11a	87.00c	93.75a	87.50c	2.178d	3.346c	2.404d	2.689c	2.973d	3.372c
90% ASM	99.33a	90.49c	92.56a	87.22c	94.00a	87.75c	2.172f	2.469e	1.772f	1.991e	2.256f	2.522e
SE±	0.213		0.184		0.12		0.047		0.057		0.047	

† ASM≙Available Soil Moisture
Means followed by the same letter within the same treatment group are statistically the same using DMRT.

Table 6: Effect of variety and irrigation regime on the number and weight of grains per spike, 100-grain weight and harvest index of wheat in the 1995/96 - 1997/98 dry seasons at Kadawa.

Treatment	*Grain weight per spike (g)*			*Grain number per spike*			*1000-grain weight (g)*			*Harvest Index*		
	1995/96	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*	*1995/96*	*1996/97*	*1997/98*
Variety												
Siete cerros	1.277a	0.911a	1.212a	41.96a	37.59a	40.84a	36.408b	33.49b	35.88b	0.35a	0.28b	0.35a
Pavon 76	1.263a	0.850b	1.176b	30.76b	26.26b	31.22b	42.134a	38.95a	41.47a	0.35a	0.29a	0.35a
SE±	0.646	0.007	0.008	0.226	0.219	0.253	.119	.165	0.210	.149	.009	.002
Sign.	NS	*	*	*	*	*	**	**	**	NS	*	NS
Irrigation at												
60% ASM[†]	1.2650a	0.8794a	1.2039a	36.14a	31.84a	35.77a	41.00a	36.80a	41.52a	0.35a	0.28a	0.33a
75% ASM	1.2639a	0.8772a	1.2073a	36.36a	31.86a	36.10a	41.18a	36.23ab	41.17a	0.35a	0.28a	0.33a
90% ASM	1.2706a	0.8844a	1.2075a	36.59a	32.08a	36.23a	41.08a	35.83b	38.33b	0.35a	0.30a	0.34a
SE±	0.011	0.009	0.009	0.279	0.279	0.310	.015	0.20	0.18	0.02	0.01	0.002
Sign.	NS	NS	NS	NS	NS	NS	NS	*	*	NS	NS	NS
Interactions												
I. V.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[†] ASM≙Available Soil Moisture
Means followed by the same letter within the same treatment group are statistically the same using DMRT.
NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

Table 7: Effect of variety and irrigation regime on the number and weight of grains per spike, 100-grain weight and harvest index of wheat in the 1995/96 - 1997/98 dry seasons at Kadawa.

Treatment	*Grain yield (kg/ha)*					*Water Use Efficiency*				
	Year			*Combined*		*Year*			*Combined*	
	1995/96	*1996/97*	*1997/98*	*Y1 & Y3*	*Y2 & Y3*	*1995/96*	*1996/97*	*1997/98*	*Y1 & Y3*	*Y2 & Y3*
Variety										
Siete Cerros	2600a	2035b	2695a	2761a	2341a	2.996b	2.470b	2.886b	3.18b	2.732b
Pavon 76	2588a	2142a	2728a	2731a	2324a	3.499a	2.796a	3.345a	3.65a	3.079a
SE±	12.98	0.71	20.79	12.02	12.92	0.027	0.033	0.027	0.021	0.023
Sign.	NS	*	NS	NS	NS	**	**	**	*	*
Irrigation at										
60% ASM†	2584a	2070a	2696b	2640a	2383a	4.327a	3.471a	4.464a	4.567a	3.866a
75% ASM	2586.8a	2094a	2702b	2644a	2398a	3.062b	2.547b	3.173b	3.237b	2.784b
90% ASM	2598.4a	2102a	2736a	2667a	2419a	2.321c	1.882c	2.389c	2.444c	2.065c
SE±	15.90	12.12	5.66	14.72	15.83	0.032	0.041	0.031	0.024	0.035
Sign.	NS	NS	*	NS	NS	**	**	**	**	**
Interactions										
V.I	NS	NS	NS	NS	NS	**	**	**	NS	NS

† ASM≙Available Soil Moisture; Y1 = 1995/96, Y2 = 1996/97, Y3 = 1997/98
Means followed by the same letter within the same treatment group are statistically the same using DMRT.
NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

Table 8: Simple Correlation coefficient between grain yield, yield components sown growth parameters, water use and water use efficiency (WUE) in the 1995/96 1996/97 and 1997/98 dry seasons at Kadawa.

(a) 1995/96	Grain yield	No. of spike/m^2	No. of grain/spike	1000 grain weight	Tiller/m^2 at 7 WAS	Plant height	Grain filling period	Length of spike	LAI at 9 WAS	Grain wt/ spike	Harvest Index	Total aerial phytomass	Water use
Grain yield	1												
No of spike/m^2	0.842**	1											
No of grains/spike	0.254NS	0.121NS	1										
1000 grain wt	0.265NS	0.251NS	-0.846**	1									
Grain wt/spike	0.679**	0.632**	0.614**	0.178NS	0.374**	0.728**	0.411**	0.698**	0.553**	1			
Harvest Index	0.905**	0.802**	0.085NS	0.259NS	0.370**	0.271*	0.646**	0.297*	0.647**	0.555**	1		
WUE	0.288*	0.098NS	-0.307*	0.280	-0.037NS	-0.191NS	0.421**	-0.271*	0.034NS	-0.097NS	0.306*	0.204NS	-0.924**
(b) 1996/97													
Grain yield	1												
No of spike/m^2	0.373**	1											
No of grains/spike	0.221NS	0.214NS	1										
1000 grain wt	0.261NS	0.041NS	-0.799**	1									
Grain wt/spike	0.831**	0.408**	0.502**	-0.003NS	0.449**	0.638**	0.556**	0.631**	0.670**	1			
Harvest Index	0.221NS	0.074NS	-0.007NS	0.172NS	0.055NS	-0.120NS	0.202NS	0.277*	0.177NS	0.202NS	1		
WUE	0.367*	0.182NS	-0.220NS	0.212NS	0.037NS	-0.108NS	0.346**	-0.014NS	0.090NS	0.100NS	0.020NS	0.143NS	-0.883**
(c) 1997/98													
Grain yield	1												
No of spike/m^2	0.443**	1											
No of grains/spike	0.305**	0.204NS	1										
1000 grain wt	0.652**	0.358**	-0.398**	1									
Grain wt/spike	0.905**	0.403**	0.402**	0.613**	0.442**	0.537**	0.673**	0.799**	0.871**	1			
Harvest Index	0.898**	0.408**	0.230NS	0.466**	0.463**	0.499**	0.444**	0.635**	0.630**	0.740**	1		
WUE	0.428*	0.074NS	-0.164NS	0.411**	0.154NS	0.063NS	0.387**	0.121NS	0.197NS	0.308**	0.352**	0.432**	-0.852**

NS ≙ Not significant; ** and * ≙ significant at 1% and 5% level respectively.

3.3 Water Use Efficiency

Water use efficiency (WUE) of Pavon 76 was consistently superior to that of Siete cerros (Table 7). Each increase in irrigation frequency from 60 to 90% ASM significantly depressed the WUE throughout the three seasons. WUE of each variety decreased with each increase in irrigation frequency in the three seasons. At all the irrigation levels, Pavon 76 had a higher WUE than Siete cerros in the three years (Table 5).

3.4 Correlation Analysis

In all the three seasons grain yield was found to have a positive relationships with number of spike/m^2, tiller number, plant height, duration of grain filling, length of spike and grain wt/spike (Tables 8a-c). Grain yield also had a strong association with parameters such as number of grain/spike and 1000-grain weight only 1997/98. The correlation between number of grains/spike and 1000 grain weight was however negative. Water use did not correlate with grain yield whereas WUE correlated with grain yield.

4 Discussion

4.1 Performance of Cultivars

The study revealed considerable similarities and some differences in the growth of the Siete cerros and Pavon 76. The trend of dry matter accumulation and leaf area indices (LAI) of the two cultivars was similar. This may be due to the fact that both cultivars have similar genetic background having been developed from Nario 10 (Hanson *et al.*, 1982). The response to agronomic treatments among cultivars with similar genotypes did not differ in the studies by Stapper and Fischer (1990), as in this current study.

Leaf Area Index increased progressively until 9 WAS and thereafter decreased at 12 WAS in both cultivars. Benbi (1994) and Abubakar (1999) also observed similar decrease of LAI among wheat cultivars after anthesis and is an indication cessation of growth.

The study revealed some consistency in grain yield superiority of Pavon 76 over Siete cerros in contrast to Abubakar (1999) findings that indicated sustained superiority of Siete cerros over Pavon 76. The factors responsible for the superiority of Pavon 76 over Siete cerros may include higher number of tillers and spikes/m^2, larger grain size, and higher harvest index. The present finding agrees with the reports by Hanson *et al.* (1982), Orakwe and Olugbemi (1990) that predicted superior yields from Pavon 76 over Siete cerros. The result indicates that high spike/m^2 and large grain size may compensate high number and weight of grain /spike in determination of grain yield.

4.2 Effect of Irrigation Regime

Increasing irrigation regime from 60% to 90% ASM only slightly enhanced growth attributes such as dry matter accumulation, LAI, tiller number/m^2 and plant height. The tend in the response to the irrigation treatment suggests that the crop was exposed to very light stress that only slightly impaired proper vegetative growth and development. Similar result of minor decreases in growth attributes following imposition of various irrigation regimes were obtained by FALAKI (1994) and KUMAR and YAYOCK (1980) and is probably related to high level of adaptability of the cultivars used in the study.

The decrease in number of days to maturity with reduced level of irrigation was probably a hormone-induced response to lack of stress that delayed the development of the plant. ATMAN and JACOBS (1975) documented a similar hormonal response to temperature and light regimes that supports the present finding.

Increasing irrigation regime from 60% ASM to 90% increased grain yield marginally in two seasons (1995/96 and 1996/97) but remarkably in one season. The lack of significant increase of grain yield in the two seasons following increased moisture supply was probably due to the high water table of the experimental site used. HANKS *et al.* (1977) found insignificant influence of irrigation treatments on yield of corn and alfalfa and ascribed the lack of response to upward flow of water through capillary spaces from high water table into the root zone. ECKERT *et al.* (1978) also reported a similar lack of response to irrigation treatments in their experiment that was conducted under higher water table.

Yield components such as weight of spike, number of spike/m^2 number of sterile spikelets, 1000 grain weight, harvest index, grain weight and grain number per spike were not influenced by the irrigation treatments in the same manner as the grain yield. The lack of response of these yield attributes to the irrigation treatments may have accounted for the insignificant differences in grain yield.

The results indicate that irrigation at 60% ASM was sufficient for the cultivation of wheat at Kadawa. This moisture regime is less than 75% ASM reported by FALAKI (1994) and about 15% and 10% more than 50% ASM at which KUMAR (1992) and SINGH *et al.* (1980) respectively obtained the best water use efficiency. However, the 60% ASM falls within the range of 60-70% ASM recommended by ERIE (1962) for wheat cultivation at Arizona.

The total irrigation water use by maintaining irrigation at 60% ASM in the three-year study ranged from 595 mm to 604 mm. This range is less than the range of 650-850 mm obtained under a fixed irrigation interval by SIEWIERSKI (1979), and MAURYA and SACHAN (1985) at Ngala and Kadawa respectively. The range was also remarkably lower than 720 - 1080 mm obtained by KUZNIAR *et al.* (1989) at Bakura. The lower irrigation regime proposed might however have implications for salinity build up over time that may need to be monitored.

4.3 Interaction between Variety and Irrigation Regime

High irrigation regime of 90% ASM increased the number of days to maturity more in Siete cerros than Pavon 76, because of the genetic difference and difference in their length of maturity. Water use efficiency of Pavon 76 was consistently higher than that of Siete cerros at each of the irrigation levels evaluated because it used less water and gave superior yields. The fact that both varieties gave the highest WUE at 60% ASM suggests that their optimum irrigation requirement is about the same.

4.4 Correlation

A high level of correlation between grain yield and characters such as number of spike per m^2, grain weight per spike and harvest index total indicate that these characters are vital yield determinants. This is in line with findings of KINYERA and AYIECHO (1992), and ABUBAKAR (1999). The negative correlation between 1000 grain weight and attributes such as number of grain /spike and grain weight/spike indicate some compensatory tendencies among these yield attributes. Also the inconsistency in the level of significance in terms of the correlation between grain yield and number of grain/spike or 1000-grain weight suggests that the level of compensation among the attributes could vary between seasons. NEGEDU (1994) obtained similar result that supports this explanation.

A lack of significant correlation between grain yield and water use probably imply that moisture was not very limiting in the experiment and support the need to advocate the lower irrigation regime of 60% ASM for Kadawa.

5 Conclusion

The results of the study indicate that irrigation at 60% ASM is suitable for both varieties at Kadawa. Grain yield superiority of Parvon 76 predicted by ORAKWE and OLUGBEMI (1990) was only observed in one season. From the study, it was found that grain weight per spike rather than grain number per spike was more relevant to grain yield.

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