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Factors Affecting Growth and Productivity of sorghum (Sorghum bicolor L) New Phenotype - barbarei - in South and West Darfur States, Sudan

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ABSTRACT

The study was carried out during 2005/2006 growing season to investigate the factors affecting growth and productivity of [Sorghum bicolor (L.) Moench] new phenotype locally named (barbarei).Questionnaires, field observations, personal communications, soil physical and chemical analysis were used for data collection. Results showed that barbarei crop was considered as a unique phenotype in comparison with other sorghum varieties that the crop produces flowers and grain only during the cool season (October –November).Results showed that the area cultivated by one farmer ranged between 3.3 - 10.9 feddans (1.386 - 4.578 hectare), the average area cultivated is 6.4 feddans / farmer, and the yield varies from 5.2 - 17.8 sacks/feddan (520 - 1780 kg) at barbarei production areas with average yield 11.2 sacks/feddan(1120kg). It was found that vegetables like cucurbits and okra, when intercropped with barbarei plants adversely affect their growth performance and yield. On the other hand, mixing of legumes with barbarei plants was found to increase their growth and final grain yield. Results of soil analysis showed that the soils of barbarei production areas ranged from sandy clay loam to sandy clay and clay soils at different depths and have high ability of water retention for a long time in root system zone. Soil reaction is slightly acid soil P^H ranged between 7.09-5.66. Results showed that birds, locusts and aphids were known to be the major pests of the crop in the study area (93.8%, 89.4% and73.1 respectively). But with respect to seriousness of these pests, results revealed that birds and aphids comprise the more serious ones (68.1% and 63.1% respectively) in all areas studied except Fur-Barnga, in which locust was known to be the most serious pest. With regard to the time of infection, results showed that the majority of the pests and diseases infection happened at the middle of the season while the lowest infection was reported at early growing season which is different from the case in other crops where pests and disease infection was normally higher at early growing season. In term of diseases that affect barbarei, results showed that the smut diseases were the most prevalent and serious diseases of the crop. It could be concluded that barbarei planting should receive more attention in the present production areas (West and South Darfur States), beside other promoting areas in the country with similar environmental conditions.

Keywords: *growth, productivity, sorghum, new phenotype, Sudan*

1. INTRODUCTION

Sorghum has been, for centuries, one of the most important stable food for millions of poor rural people in the semi-arid tropics of Africa and Asia; it is usually grown without application of fertilizers or the input by multitude of small holder farmers in many countries [3]. In arid, less developed regions of the world, sorghum is an important food crop, especially for subsistence farmers [8].Sorghum like many cereals has different uses, it is used for food, fodder, and the production of alcoholic beverage. Globally, over half of all sorghum is used for human consumption and is the fifth most important cereal crop grown in the world. It is also considered to be significant crop for animal feeds, it is used for silage, and sorghum straw (stem fibers) can also be made into excellent wallboard for house building, fences. Dried stalks are used for cooking fuel, a more recent use of sorghum is for ethanol production [8] .Sorghum plants finds 75% of its water in the top meter of soil, and because of this the plant's production can be severely affected by the soil water holding capacity .The plants require up to 70-100 mm of moisture every 10 days in early stage of growth, and as sorghum progresses through growth stages and the root penetrate more deeply into the soil the plants needs progressively less water. By the time of grain filling, optimum water conditions are down to about 50 mm every 10 days [8].

2. MATERIALS AND METHODS

The study was carried out at South and West Darfur States during 2004-2005 and 2005-2006 seasons to investigate the factors affecting growth and productivity of new phenotype of sorghum (Sorghum bicolor Moench) locally named barbarei .The main aims of this study is to specify the exact areas of barbarei production
in the study area, and collection the basic information that related to the barbarei production, beside the relation between barbarei and other crops that grown as intercrop with it.

2.1 Information's about the Crop

The study composed of field survey, questioners and verbal communications with barbarei farmers within the selected areas. The study area includes Tolous, Toal, Um-Mushtour, Um-Grara, and Um-Dafoog from south Darfur state and Um-Dukhn, Furbarnga and Anjokoti from West Darfur state. Primary data were collected by distributing 160 questioners randomly in the study areas at a rate of 68, 43, 25, 26 questioners in each of the following areas, Tolous, Um-Dukhn, Furbarnga and Um-Dafoog respectively, based on the density of barbarei

farmers within these areas, beside this verbal communications were done. Data collected includes, barbarei areas, agricultural practices, sowing and harvesting dates, ecological needs, soil type, productivity, marketing, beside pests, diseases and weeds available.

2.2 Soil Parameters

Soil physical and chemical parameters were determined according to [5] and [6] methods. Soil bulk density was determined using core method as described by [2] and [1]. Steel tubes of 4.5 cm diameter and 7.5 height were used for taking undisturbed soil samples randomly from three locations for four depths (0-20,20-40,40-60 and 60-80 cm) at each area except for Anjokoti that samples were taken only for 0-20 cm depth because of excessive dryness. With corresponding moisture content determined gravimetrically to the same depths (0-20, 20-40, 40-60 and 60-80 cm) according to [7], then volumetric moisture content was obtained for the same depths by multiplied gravimetric moisture content by bulk density[1].

3. RESULTS AND DISCUSSION

Results in Table (1) showed that the area cultivated by one farmer ranged between 3.3 - 10.9 feddans (1.386 - 4.578 hectare), the average area cultivated is 6.4 feddans / farmer, and the area varies from place to another and within the years this might be attributed to rainfall and the areas flooded. The same sequences was followed by the yield that varies from 5.2 - 17.8 sacks/feddan (520 - 1780 kg) at barbarei production areas with average yield 11.2 sacks/feddan(1120kg) the higher yield was recorded at Um-Grara (17.8 sacks/feddan) ,whereas the lower yield was recorded at Um-Dafoog(5.2 sacks/feddan) .The number of tillers/plant is almost similar at all places with slight variation.

Table 1: Cultivated area and yield of barbarei at South Darfur and West Darfur States

Place	State	Cultivated area by one farmer (fedan*)		Number of tillers/plant	Yield (sack**/fed)
		2003	2004		
Tolous	South Darfur	10.9	10.3	5.6	16.7
Um-dafoog	South Darfur	6.0	6.0	4.0	5.2
Toal&um-mushtour	South Darfur	9.1	8.8	3.6	18.1
Um-Grara	South Darfur	6.3	4.6	4.0	17.8
Mean	-	8.1	7.4	4.3	14.5
Um-Dkhun	West Darfur	4.6	4.4	4.0	7.6
Anjokoti	West Darfur	3.3	3.3	4.0	6.0
Furbornga	West Darfur	4.7	4.9	4.0	7.1
Mean	-	4.2	4.3	4.0	6.9
Overall mean	-	6.4	6.4	4.2	11.2

*fedan = o.42 hectare. ** Sack = 100 kg

3.1 Soil Properties

Tables (2, 3, 4, and 5) showed some soil physical and chemical properties of soils taken from the main barbarei production areas at South and West Darfur States. soil of Wadi Shakhara (Tolous) is silt clay loam at all depths except 20-40 cm depth (clay) with increasing in sand and decreasing in silt and clay with depth (Table 2) .Soil moisture content was increased with depth. Similar pattern was observed for bulk density. For Turdat Tweindy (Furbarnga) soil is described as cracking clay soil at upper depths (0-20 cm) to sandy clay in the lower depths except, at 40-60 cm depth the soil is clay soil (Table 4). Whereas, Turdat Kaily (Um-Dkhun) and Hila Brno (Anjokoti) soils are cracking lay soil with increasing in clay and decreasing in sand percentage with depth(Tables 3,5).Although, moisture content measurement was done at harvest (January -February) but results showed that the soil of barbarei production areas have high ability of water retention for long time after rainy season (July – October). Soil moisture in these areas depends on rainfall quantity and surface runoff. Soil of Wadi Shakhara (Tolous) is characterized by the high water retention ability at all depths ,that the high sand (53.5-55.6%) and silt (12.4-13%) with depth and accordingly soil porosity which reflected in increasing water infiltration and hydraulic conductivity .Whereas , the sticky clay layer that found at 2 meters below soil surface (observed in the shallow wells dug by farmers for drinking water) will intercept and collect the infiltrated water that can be used by grown plants when it was raised through the capillary movement. Results in Table (2) indicated that volumetric water content ranged between 17.6% at the upper depths (0-20cm) to 48.2% at the lower depth (60-80 cm). Soil moisture content in West Darfur (Furbarnga, Um-Dkhun and Anjokoti) ranged between 11.5% in the upper depth (0-20 cm) to 37.4% at 60-89 cm depth; this might be due to similarity in soil types and the rainfall quantity, but soil of Turdat Kaily (Um-Dkhun) has high clay percentage at 40-80 cm depth (54.4-58%) which, reflected on the low hydraulic conductivity (0.06-0.09 cm / hour) and water accumulation on the soil surface .Soil of Anjokoti area recorded the lower volumetric moisture content (Table 5)which reflected on the low yield (Table 1) ,this might be due to the fact that the land in this area did not flooded by rain water for a long time. For soil chemical properties although, these soils are not significantly different in some cations content (Ca^{+2}, Mg^{+2}, Na^{+1}) but Turdat Kaily

(Um-Dkhun) soil showed high adsorbed and exchangeable sodium ($Na_{ad.}$, $Na_{exch.}$)percentage , low in $CaCo_3$ at 0-20 and 20-40-cm depth and Ca^{+2}+ Mg^{+2} at 0-20 cm depth (Table 2).On the other hand Table(1) showed that Ca^{+2}+ Mg^{+2} at the upper depth(0-20cm) is high (3.6 mm mol ⁄ L)in Wadi Shakhara (Tolous) soil compared with other areas. Whereas, base saturation percentage for the same depth is lower in Wadi Shakhara (Tolous) soil (43.5%) compared with soils of other areas (Tables 3 and 4), this might be due to leaching or runoff or reaction of soluble carbonate with Calcium and Magnesium in the soil producing $CaCo_3$ complex or low solubility MgCO3.Whereas, intercropped of some plants like tomato, water melon and sweet potato(which are known as exhausted plants to the soil) with barbarei specially in Wadi Shakhara (Tolous) might negatively affected cations percentage and soil fertility , but increasing soil moisture content at Wadi Shakhara (Tolous) explained the increase in crop yield (Table 1).

Table 2: Soil physical and chemical properties at Tolous area (Wadi Shakhara) South Darfur State

Soil parameters	Soil depth (cm)			
	0-20	**20-40**	**40-60**	**60-80**
Total sand %	51.2	44.0	53.5	55.6
Total clay %	34.0	43.0	33.5	32.0
Total silt %	14.8	13.0	13.0	12.4
Textural class	SCL	C	SCL	SCL
Gravimetric moisture content %	13.01	22.00	31.00	31.09
Volumetric moisture content %	17.56	31.68	47.12	48.19
Hydraulic conductivity(cm ⁄hour)	0.18	0.14	0.17	0.15
Electrical conductivity (ds⁄m)	0.45	0.35	0.50	0.35
Base saturation percentage (%)	43.5	54.5	42.5	40.5
Soil P^H	7.09	6.43	6.12	6.53
Bulk density (g ⁄cm^3)	1.35	1.44	1.52	1.55
Sodium adsorption ratio (SAR)	0.60	0.46	0.68	1.03
Exchangeable sodium (mmol⁄l)	0.80	0.55	0.95	1.10
Calcium + Magnesium (mmol⁄l)	3.60	2.80	3.90	2.30
Calcium carbonate $CaCo_3$ %	0.38	0.40	0.39	0.30

SCL = sandy clay loam
C = clay

Table 3: Soil physical and chemical properties at Um-Dkhun area (Turdat Kaily) -West Darfur State

Soil parameters	Soil depth (cm)			
	0 - 20	**20 - 40**	**40 - 60**	**60 – 80**
Total sand %	36.6	37.6	35.6	30.0
Total clay %	53.3	53,5	54.4	58.4
Total silt %	10.1	9.9	10.0	11.6
Textural class	C	C	C	C
Gravimetric moisture content %	9.56	17.27	25.02	23.47
Volumetric moisture content %	13.38	25.91	38.78	37.55
Hydraulic conductivity(cm ⁄hour)	0.14	0.14	0.12	0.10
Electrical conductivity (ds⁄m)	0.40	0.40	0.45	0.30
Base saturation percentage (%)	67.5	66.5	69.0	74.0
Soil P^H	5.66	5.87	5.91	6.13
Bulk density (g ⁄cm^3)	1.40	1.50	1.55	1.60
Sodium adsorption ratio (SAR)	1.61	1.40	0.73	0.84
Exchangeable sodium (mmol⁄l)	1.60	1.50	0.95	0.86
Calcium + Magnesium (mmol⁄l)	1.98	2.30	3.40	2.10
Calcium carbonate $CaCo_3$ %	0.29	0.32	0.42	0.48

C = clay

Table 4: Soil physical and chemical properties at Furbarnga (Turdat Tweindy) West Darfur State

Soil parameters	Soil depth (cm)			
	0 – 20	**20 - 40**	**40 - 60**	**60 – 80**
Total sand %	36.3	34.4	42.7	47.5
Total clay %	48.3	43.4	45.0	41.0
Total silt %	14.4	13.2	12.2	11.5
Textural class	C	SC	C	SC
Gravimetric moisture content %	7.48	14.66	23.22	23.23
Volumetric moisture content %	10.47	21.99	35.76	37.17
Hydraulic conductivity(cm ⁄hour)	0.09	0.07	0.06	0.06
Electrical conductivity (ds⁄m)	0.40	0.35	0.35	0.25
Base saturation percentage (%)	62.0	55.0	57.0	52.0
Soil P^H	6.45	6.47	6.58	6.74
Bulk density (g ⁄cm^3)	1.40	1.50	1.54	1.60
Sodium adsorption ratio (SAR)	0.68	1.03	1.12	0.58
Exchangeable sodium (mmol⁄l)	0.80	1.10	1.20	0.55
Calcium + Magnesium (mmol⁄l)	2.80	2.30	2.30	1.80
Calcium carbonate $CaCo_3$ %	0.77	0.80	0.58	0.60

SC = sandy clay
C = clay

Table 5: Soil physical and chemical properties at Anjokoti area West Darfur State

Soil parameters	Soil depth 0-20(cm)
Total sand %	39.8
Total clay %	46.6
Total silt %	13.6
Textural class	C
Gravimetric moisture content %	7.08
Volumetric moisture content %	9.49
Hydraulic conductivity(cm ⁄hour)	0.14
Electrical conductivity (ds⁄m)	0.25
Base saturation percentage (%)	59.0
Soil P^H	6.63
Bulk density (g ⁄cm^3)	1.34
Sodium adsorption ratio (SAR)	0.64
Exchangeable sodium (mmol⁄l)	0.61
Calcium + Magnesium (mmol⁄l)	1.80
Calcium carbonate $CaCo_3$ %	0.41

C = clay

3.2 Pests, Diseases and Weeds that Affect the Crop

Results showed that birds, locusts and aphids were known to be the major pests of the crop in the study area, where 93.8%, 89.4% and73.1 of the population studied were agreed the presence of the above mentioned pests respectively (Table 6). But with respect to seriousness of these pests , results revealed that birds and aphids comprise the more serious ones with 68.1% and 63.1% of the agreement respectively in all areas studied except Furbaranga, in which locust was known to be the most serious pest. With regard to the time of infection, results showed that the majority of the pests and diseases infection happened at the middle of the season - 64.4% of the population studied agreed that - while the lowest infections were reported at early growing season which is different from the case in other crops where pests and disease infection was normally higher at early growing season, the reason behind this may be due to the fact that the crop sowing date was known to be started at the end of autumn up to early winter, where the level of the majority of pests and pathogens that causes diseases were become in lowest level at this period due to unfavorable conditions, in addition to that the crop was sown by transplanting which is give it chance to scab the infection of pests and pathogens that affect seeds and pre-emergence seedlings as in case of direct seeding. In term of diseases that affect barbarei, results showed that the smut diseases were the most prevalent and serious diseases of the crop, where 62.5% of the studied population agreed that (Table7). Four types of smuts were reported, including covered kernel smut, head smut, loose smut and long smut which were caused by Sphacelotheca

sorghi, Sphacelotheca cruenta, Sphacelotheca reiliana and Tolyposporium ehrenbergii respectively [4]. Generally barbarei seams to be highly diseases resistance comparing to other phenotypes of sorghum as shown in Table (8) in which 89.4% of the population studied agreed that. On the other hand results of direct observation during the survey, revealed that the most abundant weed in barbarei growing areas was the fola weed (Syperus papyrus), and this may be due to the fact that suitable areas for barbarei production was flooded areas, which is suitable for fola weed too. Beside the fola weed there are other weeds such as Tibin weed (Hygrophila auriculata) and Um-shoka (Oryza paythii), but these were of minor importance comparing to the above mentioned weeds.

Table 6: Effect of pests and there distribution time on a new Sorghum Phenotype (barbarei)

Items	Areas									
	Tolous		Um-Dafoog		Um-Dukhn		Furbarnga		The four areas together	
	Questioners									
	No.	%	No.	%	No.	%	No.	%	No.	%
	68	42.5	24	15.0	43	26.9	25	15.6	160	100.0
*** With regard to pests prevalent among the above areas.**										
Locust	67	98.5	24	100	27	62.8	25	100	143	89.4
Birds	67	98.5	24	100	34	79.1	25	100	150	93.8
Stem borers	1	1.5	0.0	0.0	12	27.9	20	80	33	20.6
Aphids	68	100	24	100	0.0	0.0	25	100	117	73.1
Red beetles	0.0	0.0	0.0	0.0	9	20.9	0.0	0.0	9	5.6
White ants	0.0	0.0	6	8.8	7	16.3	0.0	0.0	13	8.1
Antad	0.0	0.0	0.0	0.0	2	4.7	0.0	0.0	2	1.3
Rats	2	2.9	0.0	0.0	1	2.3	0.0	0.0	3	1.9
American boll worm	0.0	0.0	0.0	0.0	3	7.0	0.0	0.0	3	1.9
Mole crickets	3	4.4	0.0	0.0	2	4.7	2	8.0	7	4.4
White flies	11	16.2	7	29.2	11	25.6	0.0	0.0	67	41.9
Grazing animals	49	72.1	0.0	0.0	4	9.3	0.0	0.0	15	9.4
*** With regards to the pests seriousness**										
Birds	62	91.2	24	100	21	48.8	2	8.0	109	68.1
Locust	4	5.9	0.0	0.0	3	7.0	21	84.0	28	17.5
Aphids	68	100	24	100	0.0	0.0	9	36	101	63.1
Grazing animals	11	16.2	0.0	0.0	6	14	0.0	0.0	17	10.6
White ants	0.0	0.0	0.0	0.0	2	4.7	0.0	0.0	2	1.6
Stem borers	0.0	0.0	0.0	0.0	5	11.6	0.0	0.0	5	3.1
*** Time of pests appearance during the season**										
Early of the season	12	17.6	0.0	0.0	12	27.9	0.0	0.0	24	15
Middle of the season	41	60.3	24	100	13	30.2	25	100	103	64.4
Late of the season	15	22.1	0.0	0.0	18	41.9	0.0	0.0	33	20.6

Table 7: Effect of plant diseases on new sorghum phenotype (barbarei)

Items	Areas									
	Tolous		Um-Dafoog		Um-Dukhn		Furbaraga		The four areas together	
	Questioners									
	No.	%	No.	%	No.	%	No.	%	No.	%
	68	42.5	24	15.0	43	26.9	25	15.6	160	100.0
*** Diseases available and there seriousness.**										
Smut diseases	55	80.9	17	70.8	13	30.2	15	60	100	62.5
Leaf yellowing	0.0	0.0	1	4.2	1	2.3	0.0	0.0	2	1.3
Rusts	0.0	0.0	0.0	0.0	0.0	0.0	8	32	8	5
With the exception of smut diseases there is no serious diseases	13	19.1	6	25	29	67.5	2	8	50	31.2
*** In terms of presence of epidemic diseases**										
There are no epidemic diseases affecting barbarei.	68	100	24	100	41	95.4	22	88	155	96.9
There are epidemic diseases										

affecting barbarei.	0.0	0.0	0.0	0.0	2	4.6	3	12	5	3.1

Table 8: new sorghum phenotype - barbarei- resistance to pests and diseases

Items	Areas									
	Tolous		Um-Dafoog		Um-Dukhn		Furbaranga		The four areas together	
	Questioners									
	No.	%	No.	%	No.	%	No.	%	No.	%
	68	42.5	24	15.0	43	26.9	25	15.6	160	100.0
*** Comparison between barbarei and other sorghum phenotypes in term of pests and disease resistance.**										
Highly resistant	57	83.8	24	100	39	90.7	23	92	143	89.4
Highly susceptible	11	16.2	0.0	0.0	4	9.3	2	8	17	10.6
Same as other sorghum phenotypes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
*** Comparison between different cultivars of barbarei in term of pests and disease resistance.**										
Abu-Kunjara	67	98.5	23	95.8	22	51.2	20	80	132	82.5
White cultivar	1	1.5	0.0	0.0	18	41.8	5	20	24	15
Yellow cultivar	0.0	0.0	1	4.2	3	7	0.0	0.0	4	2.5

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