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Estimation of Yield and Stability of Some Sunflower (Helianthus annuus L.) Hybrids under Rain -Fed and Irrigated Conditions of Sudan•

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ABSTRACT

Fifteen sunflower (*Helianthus annuus L*.) hybrids were evaluated at four environments (two environments under rain fed and the other two under irrigation conditions) for two consecutive summer seasons (2013 and 2014). The hybrids were tested to estimate their adaptability and stability performance for seed yield and seed oil yield at Sinnar State, Sudan. The experiment over all environments was laid in a randomized complete block design with four replicates. The analysis of variance procedure revealed highly significant differences for seed yield and seed oil yields among hybrids and environments. Significant differences were observed for hybrids (G), environments (E) and G x E interaction for both seed yield and seed oil yield. Stability analysis after Eberhart and Russell's model suggested that the hybrids used in this study were all, more or less,

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responsive to environmental changes. Most of the hybrids performed better in E1 and E2 (Allkandi). Stability analysis with their parameters (grand mean, regression coefficient a nd deviation from regression) identified five hybrids; Pan-7057, Ausigold61, Ausigold7, Hysun-33 and Pan-7033 as the most stable hybrids for seed yield and seed oil yields, since their regression coefficients were close to the value of one (*bi*=1) and had the lowest deviation from regression (S^2_{di}=0) and were stable and adapted to favorable environments. In contrast, three hybrids; SFH 301, Aguara-4 and SFH 304, with regression coefficients greater than one, were regarded as sensitive to environmental changes for seed yield and seed oil yield and were stable and adapted to unfavorable environments.

Keywords: *Sunflower hybrid; yield Stability; Adaptability; Performanc.*

1. INTRODUCTION

Sunflower *(Helianthus annuus L.)* belongs to the family Asteraceae (Compositeae) which comprises diploid (2n= 2x=34), tetraploid (2n=3x=68) and hexaploid species (2n=2x=120). Sunflower has a high potential for seed yield and oil content in the seed. Seed yield of about 1500 Kg/ha has been reported in the literature for both open-pollinated and hybrids cultivars of sunflower (Arshard *et al.*, 2007). Sunflower is one of the four most important oil crops in the world (FAO, 2010). Sunflower producing countries are Argentina, Russia, France, Ukraine, Spain, India, USA, China, Turkey, Romania and Hungarian (FAO, 2010). The total area and production yield in 2012/13 and 2013/14 were 23,839,000 ha and 24,626,000 ha producing 36,062,000 Metric Tons and 42,867,000 Metric Tons respectively (FAO, 2014).
Although sunflower is a temperate zone crop, it can perform well under a wide spectrum of climatic and soil conditions (FAO, 2010). Sunflower hybrids are preferred by farmers in many countries of the world including

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Sudan as most important source of edible oil crop. In Sudan, sunflower recently become an important cash crop, to strengthen the economy and fill the gap in vegetable oil production and provide a high value animal feed. The crop is grown both as a summer and winter crop under irrigated system and as a summer crop under rainfed system. Sunflower as a non-traditional crop provides an excellent alternative to cover large areas in the production of oil crops beside the major oil crops. The sunflower cultivated area in Sudan had shown an increasing trend in the last ten years. This is because sunflower is one of the crops which attracted the interest of both farmers and private companies. In addition, its wide adaptability, suitability to mechanization, low labor needs, short duration, high yield potential and good quality were major reasons for increasing sunflower areas (Mohamed *et al,* 2014).

Sunflower producers in the country depended almost exclusively on imported seeds. Therefore, virtually 98% of oilseed sunflower production is with hybrid cultivars, which necessitate the need for the development and release of more hybrids that can meet farmers' standards (Mohamed *et al,* 2014). Also, this situation necessitates considerable research efforts by the Agricultural Research Corporation (ARC) to cope with increasing demand for seeds of high yielding and well adapted hybrids. Hence, attempts have been made to improve hybrid seed supply through testing and releasing more sunflower hybrids as collaboration between private and public institutes. The collaboration program between ARC with some international sunflower seed companies (Pannar, Advanta, Syngenta, May, Nuseed …etc) was started during 2006-2007 as main step for improving stability/sustainability of seed supply and probably lowering seed prices through creating free competition among more seed companies and ensures the seed supply at the optimum time. This program resulted in the releasing of new introduced sunflower hybrids such as Pan-7049, Pan-7033 and Aguara-4 (Mohamed *et al,* 2011), Opera and Sirena (Mohamed *et al,* 2012) Nugold Dowana and Nugold Darya

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(Mohamed *et al,* 2013). Moreover, development of local sunflower hybrids with superior yields and stable across different environments is the main objective in sunflower breeding program of Agricultural Research Corporation, Sudan (Mohamed *et al*, 2014).

The adaptability of a hybrid or a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. A hybrid or genotype is considered to be more adaptive or stable one if it has a high mean yield but a low degree of fluctuation in yielding ability when grown over diverse environments. Eberhart & Russell (1966) proposed a model to test the stability of varieties under various environments. They defined a stable variety as having unit regression over the environments (bi= 1.00) and minimum deviation from the regression (S2di= 0). Therefore, a variety with a high mean yield over the environments, unit regression coefficient (b=1) and deviation from regression as small as possible (S2di = 0) will be a better choice as a stable variety. Moreover, successful oilseed-sunflower cropping depends on the yielding ability of genotypes, as well as on the reliability of production systems. Also, evaluation of hybrids characterized by high productivity (seed and oil) and stability performance under varying environmental conditions for yield has become an essential part of any sunflower breeding program. Therefore, the objective of this study was to evaluate stability performance of fifteen sunflower hybrids across four environments for seed yield and to select the most adapted hybrid (s) for both favorable and unfavorable environments at Sinnar State, Sudan.

2. MATERIALS AND METHODS

Fifteen sunflower hybrids from different countries were used in this study (Table, 1). They were provided by Agricultural Research Corporation (ARC), Wad Medani, Sudan.

Table1. List of the sunflower hybrids used in the study.

No	Hybrid	Origin	No	Hybrid	Origin
1	SFH301	ARC-Sudan	9	Pan-7033	Pannar-South Africa
2	SFH302	ARC-Sudan	10	Pan-7049	Pannar-South Africa
3	SFH303	ARC-Sudan	11	Pan-7057	Pannar-South Africa
4	SFH304	ARC-Sudan	12	Pan-7351	Pannar-South Africa
5	SFH310	ARC-Sudan	13	Opera	Syngenta-France
6	Ausigold7	Nuseed-Australia	14	Aguara-4	Advanta-Argentina
7	Ausigold4	Nuseed-Australia	15	Hysun-33	Advanta-India
8	Asigold61	Nuseed-Australia			

ARC-Sudan =Agricultural Research Corporation, Wad Medani, Sudan.

These hybrids were sown at two different locations for two consecutive summer seasons of 2013 and 2014 at Sinnar State, Sudan. The first location was at Ellkandi (latitude 12^0 32´ N, longitude 34^0 29´ E and Altitude 469 meters above sea level), where the seed were sown under rain-fed conditions, and the second location was at Elsuki (latitude 13^0 40´ N, longitude 34^0 60´ E and Altitude 445 meters above the sea level), where the seeds were sown under irrigation conditions. The soil is deep cracking clays, very grayish brown and moderately well- drained. The pH was 7.7 at Ellkandi and 7.9 at Elsuki. The total porosity was 28.5% at Ellkandi and 29% at Elsuki. The available water content was 9.0 and 18.1 cm, in the 0-30 and 30-120 cm soil depth in Ellkandi and Elsuki, respectively, (SSMAD, 2016). The fifteen hybrids overall environments were arranged in a randomized complete block design with four replications. At each environment the plot size was 4 ridges and 6 m (0.70 m apart). The effective sowing dates in season 2013 was on 10th of July for Ellkandi and Elsuki locations, while in season 2014 it was on 15th of July for both locations. Three seeds were sown in the holes of 5 cm depth and 0.25 m distance along the ridge, and then thinned to one plant per hole three weeks after sowing. Ellkandi location was fully under rainfed, while Elsuki location was irrigated at intervals of two weeks, although some sporadic rains were recorded and considered during summer. Plots were kept weed-free through frequent hand weeding. Nitrogen was applied only at irrigated sites at 80 kg urea (46%

N) per hectare. All recommended agronomic practices were followed throughout the season. Five plants from inner two rows were taken from each plot randomly and their heads were bagged using paper bags after flowering to ensure self-pollination and to avoid later bird's damage. No infestation of pests or diseases was registered. Data were collected from the middle two rows on seed yield (t/ha). The oil content of the seeds was determined by the Soxhelt extraction method. The extraction process using soxhlet was conducted to determine the percentage of oil in the raw material used. The extractions were performed in a triplicate way. Approximately 5 g of seeds, with 200 ml of hexane was used. The extraction time was fixed in 8 hours, after reaching the boiling temperature around 70 °C according to the official method of (AOAC, 2010). Analysis of variance was performed on individual trials (each environment) and the F-test was performed. Combined analysis was performed separately for rain fed and irrigated environments and pooled over four environments, assuming random environment and fixed hybrid (Gomez and Gomez, 1984). Stability performance of each hybrid over the four environments was determined following the model of Eberhart and Russell (1966) as: Yij=µi + biIj +s2 dij; where Yij = the mean performance of ith hybrid in jth environment, µi = the mean of ith variety over all environments; bi = the regression coefficient which measures the response of ith variety to varying environment; s2 dij = deviation from regression of ith variety in the jth environment, and Ij = the environmental index of jth environment. Regression coefficient (bi) was considered as an indication of the response of the genotype to varying environment. If the regression coefficient was not significantly different from one (bi = 1.0), the genotype was adapted to all environments, genotypes with bi > 1.0 were more responsive or adapted to high yielding environments, whereas any genotype with bi significantly lower than 1.0 was adapted to low yielding environments (Eberhart and Russell, 1966).

For easy reference the location/year/season combination was considered as an environment and given a number (En).

3. RESULTS AND DISSCUSSION

Pooled analysis of variance of sunflower hybrids for seed yield and seed oil content data across the four environments in Sinnar State, Sudan were performed as shown in Table 2. These results showed highly significant differences ($P<0.01$) among the hybrids (G), environments (E) and hybrids x environment interaction (G x E) for both seed yield and seed oil content, which indicate the presence of genetic variability among the hybrids as well as the effect of environments.

The sums of squares due to environments and hybrid x environment are partitioned into environments (linear), hybrid x environment (linear) and deviations from the regression model. The significance of both components showed that both predictable and unpredictable components shared G x E interaction. The G × E (Linear) interaction was highly significant (tested against pooled deviation) which demonstrated that hybrids (G) respond differently to variation in environmental conditions. Moreover, Becker and Leon (1988) and CVEJIĆ *et al* (2015) stated that successful new hybrids must show good performance for yield and other essential agronomic traits and their superiority should be reliable over a wide range of environmental conditions. Also, in practice the scientists usually relay on least significant difference test (LSD) and Duncan's Multiple Range test (DMRT) for grouping the hybrids of similar average means. These tests do not show the performance of the hybrids (G) across all distinct environments. To make the stability statements for average yield on all different locations, stability analysis based on environmental index was performed. Thus, the presence of a highly significant G × E interaction for seed yield and seed oil yields in the present study necessitated the identification of the most stable and high-yielding hybrids using the Eberhart and Russell (1966) stability model.

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Table 2. Analysis of variance for stability of seed and oil yield in 15 sunflower hybrids across four environments (in Sinnar State, Sudan).

Source of Variation	d.f	Mean squares for seed yield (t/ha)	Mean squares for oil yield (%)
Hybrid (G)	**14**	**0.031****	**133.196****
Environment + (ExG)	**45**	**0.010****	**1.070****
Environment (linear)	**1**	**0.001**	**0.001**
Hybrid × Env.(linear)	**14**	**0.009****	**0.826****
Pooled deviation	**30**	**0.003**	**0.104**
Pooled error	**180**	**0.002**	**1.379**

** Significant at (0.01) probability level

Stability of Performance for Seed Yield (t/ha)

The mean performance of the individual hybrid along with their stability parameters (b_i and S^2_{di}) for seed yield (t/ha) are presented in Table 3. From the mean of hybrids at different environments, it was noted that E1 (Ellkandi, 2013) had the highest mean of seed yield (1.68 t/ha), while E3 (Elsuki, 2013) had the lowest values of seed yield (1.41 t/ha) (Table 3).The overall mean of seed yield (t/ha) was 1.56 t/ha. Analysis of the stability parameters of individual hybrids indicated that five hybrids had higher mean performance. These hybrids were: Pan-7057, Ausigold61, Ausigold7, SFH 301, and Hysun-33 with the mean seed yield (t/ha) of 2.09, 2.01, 1.91, 1.88, and 1.72 (t/ha), respectively. Also, the above mentioned five hybrids had a regression coefficients close to unity of 1.02, 1.04, 1.07, 1.08, and 1.09, respectively, and deviation from regression not significantly different from zero (b_i>1 and S^2_{di}=0).These results indicate that the stability of these hybrids at the favorable environments shown in (Table 3). On the other hand, Pan-7033, Aguara-4 and SFH 304 hybrids had also mean yield over grand mean and regression coefficients (b_i) below unity and they were considered as adapted hybrids to unfavorable environments. The rest of the hybrids had mean seed yield (t/ha) below grand mean, regression coefficients not close to unity and deviation from regression not close to zero, hence these hybrids were considered as unstable regarding seed yield . The last ranked hybrid in terms of mean seed yield was Pan-7351(1.14 t/ha).

Table 3. Estimates of stability and adaptability parameters of seed Yield (t/ha) in 15 sunflower hybrids evaluated across four environments at Sinnar State, Sudan.

Hybrid/Env.	Ellkandi		Elsuki		stability parameters			
	2013 (E1)	2014 (E2)	2013 (E3)	2014 (E4)	µ	b_i		S^2_{di}
SFH 301	1.75	1.94	1.98	1.90	1.88	(4)	0.79	0.00
SFH 302	1.50	1.48	1.1	1.20	1.32	(11)	0.20	0.13
SFH 303	1.37	1.26	1.1	1.32	1.26	(12)	0.29	0.20
SFH 304	1.83	1.46	1.14	1.95	1.59	(8)	0.71	0.01
SFH 310	1.18	1.21	1.26	0.99	1.16	(14)	0.39	0.16
Ausigold7	1.95	2.13	1.92	1.67	1.91	(3)	1.07	0.00
Ausigold4	1.72	1.60	1.06	1.12	1.37	(10)	0.50	0.25*
Asigold61	1.71	2.05	2.16	2.12	2.01	(2)	1.04	0.00
Pan-7033	1.77	1.62	1.09	2.16	1.66	(6)	1.09	0.01
Pan-7049	1.60	1.18	1.12	1.07	1.24	(13)	0.58	0.05
Pan-7057	2.35	1.57	2.10	2.36	2.09	(1)	1.02	0.00
Pan-7351	1.34	1.20	1.07	0.97	1.14	(15)	0.56	0.33*
Opera	1.62	1.07	1.61	1.66	1.49	(9)	0.29	0.04
Aguara-4	1.90	2.31	1.07	1.21	1.62	(07)	0.88	0.00
Hysun-33	1.67	2.04	1.42	1.76	1.72	(5)	1.08	0.00
G M	1.68	1.61	1.41	1.56	1.56			

Between brackets refer to rank, *Significant at $p< 0.05$ level, G M= grand mean
b_i =Regression coefficient, S^2_{di} =Deviation from regression&, µ = Mean seed yield

Stability of Performance for Oil Yield (t/ha)

Table 4 displayed the mean (µ), regression coefficients (b_i), deviation from regression line (S^2_{di}) with their ranking on seed oil yield. From the environmental means it was observed that E1 (Ellkandi, 2013) had the highest means of oil yield (0.622 t/ha), while E3 (Elsuki, 2013) had the lowest values of oil yield (0.530 t/ha) (Table 4). The overall mean for oil yield was 0.585 t/ha. Eight hybrids showed means above the average of oil yield per hectare. These hybrids were; Pan-7057, Ausigold61, Ausigold7, SFH 301,Hysun-33, Pan-7033, Aguara-4 and SFH 304, with e mean oil yield of 0.982, 0.904, 0.843, 0.794, 0.705, 0.647, 0.599 and 0.581 t/ha. The first five out of the above mentioned eight hybrids (Pan-7057, Ausigold61, Ausigold7, SFH 301 and Hysun-33) had regression coefficients (b_i) above unity of 1.00, 1.01, 1.01, 1.03 and 1.06 and deviation from regression around zero. These hybrids were considered as most stable hybrids for this character and adapted to favorable environments. On the other hand, the three hybrids; Pan-7033, Aguara-4 and SFH 304 had regression coefficients (b_i) below unity of 0.77, 0.82 and 0.78 and deviation from regression not significantly different from zero and were considered to be adapted to unfavorable environments. The rest of the hybrids had means of oil yield below the overall mean, regression coefficients not close to unity and deviation from regression not around zero and were considered as unstable hybrids for seed oil yield.

Table 4: Estimates of stability and adaptability parameters of seed oil yield (t/ha) in 15 sunflower hybrids evaluated in four environments at Sinnar State, Sudan.

Hybrid/Env.	Ellkandi 2013 (E1)	Ellkandi 2014 (E2)	Elsuki 2013 (E3)	Elsuki 2014 (E4)	stability parameters			
					μ		b_i	S^2_{di}
SFH 301	0.735	0.814	0.831	0.798	0.794	(4)	1.03	0.02
SFH 302	0.495	0.488	0.363	0.396	0.435	(10)	0.27	0.42*
SFH 303	0.411	0.378	0.330	0.396	0.378	(11)	0.41	0.32*
SFH 304	0.667	0.532	0.416	0.711	0.581	(8)	0.78	0.01
SFH 310	0.306	0.314	0.327	0.257	0.301	(13)	0.55	0.24*
Ausigold7	0.858	0.937	0.844	0.734	0.843	(3)	1.01	0.01
Ausigold4	0.584	0.544	0.360	0.380	0.465	(14)	0.22	0.29*
Asigold61	0.769	0.922	0.972	0.954	0.904	(2)	1.01	0.00
Pan-7033	0.690	0.631	0.425	0.842	0.647	(6)	.077	0.00
Pan-7049	0.448	0.330	0.313	0.299	0.347	(12)	0.51	0.21
Pan-7057	1.104	0.737	0.987	1.109	0.982	(1)	1.00	0.00
Pan-7351	0.335	0.300	0.267	0.242	0.285	(15)	0.32	0.49*
Opera	0.550	0.363	0.547	0.564	0.506	(9)	0.27	0.56*
Aguara-4	0.703	0.854	0.395	0.447	0.599	(7)	0.82	0.00
Hysun-33	0.684	0.836	0.582	0.721	0.705	(5)	1.06	0.02
G. M	0.622	0.598	0.530	0.590	0.585			

Between brackets refer to rank, *Significant at $p< 0.05$ level, G M= grand mean, b_i= Regression coefficient, S^2_{di} =Deviation from regression, μ = Mean of oil yield.

4. CONCLUSIONS

Based on the mean performance of the individual hybrid along with their stability parameters (b_i and S^2_{di}) for both seed yield and seed oil yield, it could be concluded that, the hybrids: Pan-7057, Ausigold61, Ausigold7, SFH 301, Hysun-33, Pan-7033, Aguara-4 and SFH 304 are the highest yielding hybrids and could be of great potential for enhancing sunflower production under arid and semi-arid conditions. The hybrids Pan-7057, Ausigold61, Ausigold7, SFH301 and Hysun-33 were considered adapted to favorable environments, and the hybrids: Pan7057, Aguara-4 and SFH 304, were regarded as adapted to unfavorable environments.

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المستخلص

تم تقيمها خمسة عشرَ هجين من محصول زهرةِ الشمس (*Helianthus annuus* L.) في أربع بيئاتِ (بيئتان تحت ظروف المطرِ وبيئتان تحت ظروف الريِّ) لموسمين صيفين متتاليينِ (لعام 2013م وعام 2014م). تم اختبار هذه الهجن لتقدير درجة تأقلمها وثبات الإنتاجية لصفتي إنتاجية البذور وإنتاجية الزيت من البذور فى ولاية سنار بالسودان. أُستخدم تصميم القطاعات العشوائية الكاملة بأربعة مكررات لتنفيذ التجربة في كل موقع خلال الموسمين. أوضحت النتائج وجود فروقات كبيرة فى إنتاجية المحصول من البذور وإنتاجية الزيت من البذور بين الهجن والبيئات. كما أوضح تفاعل الطرز الوراثية مع البيئة genotype x environment interaction وجود فروقات معنوية عالية لصفتي إنتاجية البذور وإنتاجية الزيت من البذور لوحدة الطن للهكتار. أوضح تحليل ثبات الإنتاجية Stability Analysis باستخدام نموذج Eberhart and Russell model بأن جميع الهجن لها إستجابات متباينة مع المتغيرات البيئية فى الموقعين وكان أفضل الأداء فى موقع اللكندى (E1 and E2). كما أوضح التحليل و بمكوناته (المتوسط العام و معامل الإرتداد والإنحراف عن الإرتداد) بأن خمسة هجن وهي Pan-7057 و usigold 61 وAusigold 7 و SFH 301 و Hysun-33 هي الهجن المستقرة والثابته الأداء لصفتي إنتاجية البذور وإنتاجية الزيت من البذور ومتأقلمة مع البيئات المفضلة. حيث أن تلك الهجن كان لها معامل إرتداد قريب من قيمةِ الواحد الصحيح (bi = 1) وكَانَ عِنْدَها إنحرافُ عن الإرتدادِ قريباً من قيمة الصفر (S^2_{di}=0) وكانتْ ثابتة الأداء ومتأقلمة مع البيئات المناسبة ذات الإنتاجية العالية، وعلى النقيض من ذلك أوضح تحليل ثبات الإنتاجية أن ثلاثة هجن (SFH 301 وguara-4 وSFH 304) لها معاملات إرتداد اكبر من قيمة الواحد الصحيح وتعتبر حساسة للتغيرات البيئية فى إنتاجيتها من البذور والزيت من البذور ولكنها متأقلمة مع البيئات الأقل تفضيلاً وذات الإنتاجية الأقل حيث يظهر ثبات الأداء فيها بصورة جيدة.

كلمات مفتاحية: *الإنتاجية؛ التأقلم ؛ ثبات أداء؛ زهرة الشمس.*

[1] جزء من أطروحة تقدم بها المؤلف الأول لنيل درجة الدكتوراة لجامعة السودان للعلوم والتكنولوجيا.