STABILITY PERFORMANCE OF NEW INTRODUCED SUNFLOWER HYBRIDS FOR SEED YIELD AND ITS COMPONENTS UNDER SUDAN CONDITIONS

***Mohamed Younis MOHAMED*[1], *Abdalla A. MOHAMED*[2]**

[1] *Agricultural Research Corporation (Arc), Oilseed Crops Research Center, P.O. Box 126 Wad Medani, Sudan.*
[2] *Syngenta Company – Sudan,*

* *mymobeid@ gmail.com*

ABSTRACT

Four introduced sunflower hybrids (SY-4200, SY-4045, NK Kondi and Neoma, from Syngenta Seed Company) were testing under Sudan conditions against three checks during the period of 2011-2013. The hybrids were tested in five locations (irrigated and rainfed) for their uniformity, adaptability and yield potential. The hybrids were arranged in a RCBD with three replications overall environments. Results of combined analysis of variance for seed yield showed significant effects of hybrids, environments and hybrids x environments interaction. Mean seed yield ranged from 1646 kg ha^{-1} to 2041 kg ha^{-1}. The hybrid SY-4045 out-yielded Hysun-33 by 19 % and Bohooth-1 by 23 %. While, the hybrid Kondi out-yielded the two checks by 14 % and 17 %, respectively. The results of yield stability showed that, the two hybrids (SY-4045 and Kondi) were leading, according to their means seed yield across environments. The hybrid SY-4045 had a slope of (1.16) and Kondi of (1.09) and considered as more stable hybrids. Mean oil content of Kondi (47 %) was leading; while of SY-4045 (43 %) was similar to Hysun-33 (42 %) and Bohooth-1 (44 %). Mean oil yield of SY-4045 (884 kg ha^{-1}) and Kondi (917 kg ha^{-1}) was higher than that for Hysun-33 (714 kg ha^{-1}) and Bohooth-1 (731 kg ha^{-1}). Also, both hybrids (SY-4045 and Kondi) are a single cross hybrid, in addition to their credits of earliness, medium plant height and high self-fertility for good seedset compared to checks. The introduced hybrids SY-4045 and Kondi were released in May 2015 for commercialization under Sudan conditions.

Keywords: Sunflower, Helianthus annuus, G x E interaction, Stability performance, Seed Yield,

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a member of the family Asteraceae. In Sudan, sunflower recently become an important cash crop, to strengthen the economy and fill the gap in vegetable oil production and provides 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 to its wide adaptability, suitability to mechanization, low labor needs, short duration, high yield potential and good quality as a major reasons for increasing sunflower areas.

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 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. For the last five years, 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 (Mohamed *et al,* 2013).

Moreover, in a plant breeding program, potential genotypes are usually evaluated in different environments before selecting desirable ones that show stability across environments. For stabilizing yield it is necessary to identify the stable genotypes suitable for wide range of environments. The most widely used way to biometrically assess stability is the regression method, which is based on regression of the mean value of each genotype on the environmental index. The technique to measure stability was previously proposed by Finlay and Wilkinson (1963) and was later improved by Eberhart and Russell (1966). Therefore, the objectives of the present study were to determine the yield performance and stability of four Syngenta sunflower hybrids a cross five locations; and release of the most promising hybrids adapted to the sunflower growing areas of the Sudan.

MATERIALS AND METHODS

The performance of four Syngenta sunflower hybrids (SY-4200, SY-4045, NK Kondi, and Neoma) along with three checks; Hysun-33, Bohooth-1, and Sirena were evaluated during the period of 2011-2013 at five locations (Table 1). The seven sunflower hybrids were tested over 21 environments (seventeen environments at irrigated sites and four environments at rainfed sites). At each environment, sunflower hybrids were arranged in a randomized complete block design with three replications. The plot size was 4 rows and 8 m long ridges spaced 0.80 m apart. The effective sowing dates were during second week of July for Kharif plantings and second to third week of November for winter plantings. Seeds were sown in hills spaced 0.30 m apart within ridges and thinned to one plant per hill two weeks after planting. Irrigation was at intervals of 12-14 days depending on weather conditions. 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. Data were collected from the middle two rows on days to 50% flowering, plant height (cm), number of seeds per head, percentage of empty seeds, 1000-seed weight (g), seed yield (kg ha^{-1}), seed oil content and oil yield (kg ha^{-1}). For easy reference the location/year/season combination was considered as an environment and given a number (Table 1). Analysis of variance was performed on individual trials (each environment) and the F-test was made. Combined analysis was performed separately on irrigated and rainfed environments and pooled over 21 environments, assuming random environment and fixed hybrid (Gomez and Gomez, 1984). Stability performance of each hybrid over twenty one environments was determined following the model of Eberhart and Russell (1966). IRRISTAT statistical analysis package for windows (2006) was used for the data analysis.

RESULTS AND DISCUSSION

The pooled analysis of variance showed highly significant differences ($p>0.01$) among the hybrids (G) and environments (E) for seed yield (Table 2), indicating the presence of variability among the hybrids (G) as well as environments under study. The hybrid x environment (G x E) interaction was also highly significant for seed yield, this shows that hybrids react differently at different environments for seed yield. The genotype x environment (G x E) interaction was further partitioned into linear and non-linear components (Table 2). Both hybrid-environment (linear) and pooled deviation (non-linear) were highly significant, indicating involvement of linear as well as non-linear components of variation shared G x E interaction. The significant hybrid x environment (linear) indicated that linear response of genotypic stability to change in environment was not the same for all hybrids evaluated. However the significant deviation from regression revealed the importance of linear regression component in

determining the interaction between hybrids with environments. Different models have been proposed to evaluate the yield stability of the genotypes. Finlay and Wilkinson (1963) proposed linearity of regression as a measure of stability, however, Eberhart and Russell (1966) emphasized that both linear (b_i) and non-linear components of G x E interaction should be considered in judging the phenotypic stability of a particular genotype. Further, Samuel *et al*. (1970) suggested that the linear regression could simply be regarded as a measure of response of a particular genotype that depend largely upon a number of environments whereas the deviation from regression line was considered as measure of stability, genotypes with the lowest or non-significant standard deviation being the most stable and vice versa.

Therefore, a hybrid must not only yield well in the area of its initial development or evaluation, but preferably maintains a high yielding and quality capacities in a wide range of environments intended for commercial production. Stability parameters were calculated according to procedure described by Eberhart and Russell (1966). The stability analysis results are presented in Table 3. The results showed clear differences in values of regression coefficients (b_i) greater than or around unity and relative minimal deviation from regression. This means these introduced sunflower hybrids are more responsive to environmental changes, which give the breeder an advantage to select hybrids for both adverse and favorable environments. Therefore, the resultant regression coefficient (b_i) and deviation from regression (S^2_{di}) and mean yield for each hybrid are parameters for estimating the stability of yield over the environments. The two Syngenta hybrids SY-4045 (2041 kg ha^{-1}) and Kondi (1947 kg ha^{-1}) gave the highest seed yield over the grand mean with the regression coefficients of 1.16 and 1.09, respectively; these results were very close to unity indicating their adaptability to a range of environments. They also had lower deviation from regression (S^2_{di}), indicating that these hybrids had stable seed yield over a wide range of environments.

Hybrid vigor has been the main driving force for acceptance of this oilseed crop in both the world and Sudan. The overall means seed yield for hybrids across the 21 environments ranged between 1646 kg ha^{-1} (Sirena) to 2041 kg ha^{-1} (SY-4045) with grand mean of 1772 kg ha^{-1}(Table 4). The highest means seed yield were recorded by the Syngenta hybrid SY-4045 followed by Kondi. Under irrigated sites (environments) seed yield ranged between 1183 kg ha^{-1} (E9) to 2951 kg ha^{-1} (E7) and for rainfed sites varied from 361 kg ha^{-1} (E18) to 2272 kg ha^{-1} (E20). The maximum seed yield of 2951 kg ha^{-1} was recorded by the hybrid Kondi followed by Sirena (2769 kg ha^{-1}) and SY-4045 (2749 kg ha^{-1}) at irrigated environment E7. The minimum means of seed yield were recorded by all hybrids under rainfed environments (E18 and E21). These results indicated wide variability for seed yield among Syngenta sunflower hybrids over different environments (i.e., irrigated and rainfed environments). The hybrid SY-4045 out-yielded the three checks (Hysun-33, Bohooth-1 and Sirena) across the twenty one environments. Also, Kondi (across the 21 environments) out-yielded both Hysun-33 and Sirena in 18 environments, and out-yielded the local Sudanese hybrid (Bohooth-1) in across the 21 environments. The mean seed yield across the twenty one environments for SY-4045 was 19% more than that of Hysun-33 (1709 kg ha^{-1}) and 23% more than Bohooth-1 (1664 kg ha^{-1}). Also, Kondi showed about 14 % and 17% more seed yield than Hysun-33 and Bohooth-1 respectively (Table 4). Therefore, the mean seed yield rank of the Syngenta hybrids (SY-4045 and Kondi) across the 21 environments was first for SY-4045 and second for Kondi.

Results for days to 50% flowering are shown in Table (5). There was significant difference among the hybrids for flowering time that ranged from 64 to 70 days with a mean of 68 days. Kondi was earlier than Hysun-33 by four days and earlier than Bohooth-1 by two days. Hence, this hybrid can be planted late under rainfed areas and/or under irrigation to make use of available water and to reduce irrigation cost. Across all environments the overall mean of hybrids plant height was 139 cm (Table 5). Plant heights for the selected hybrids were 141 cm for SY-4045, and 138 cm for Kondi compared to 149 cm for Hysun-33 and 141 cm for Bohooth-1. However, development of dwarf or semi-dwarf plant height is the recent trend in breeding work to avoid lodging of sunflower hybrids during storm or heavy rains. Hence, these hybrids had reasonable height, suitable for mechanical harvest and had good resistance to lodging. The mean numbers of seeds per head of individual hybrid are presented in Table (5) only for irrigated sites. Overall the irrigated environments, the hybrids; SY-4045, Kondi and Neoma recorded a higher number of seeds as compared to the three checks. This indicated that irrigated environments were the

most favorable conditions and the selected hybrids (SY-4045 and Kondi) had the capacity to exploit such environments by attaining the highest number of disc flowers formed seedset and hence high number of seeds per head. On the other hand, the lower percentage of empty is an indicator of higher seed setting and consequently high self-fertility and increased seed yield. Also, the results in Table (5) showed that the Kondi had the lowest mean percentage of empty seeds per head (6.2 %) compared to 7.7 % for Hysun-33 and 7.8 % for Bohooth-1. These results confirmed that the higher number of seeds and lower number of empty seeds per head were greatly influence by the genetic and the level of self-compatibility of hybrid and the environmental stress during the reproductive phase. Seed mass or weight is one of the most important yield components. The overall mean of thousand seed weight was 55 g (Table 5). SY-4045 (61 g) showed a mean of thousand seed weight different from that of Hysun-33 and Bohooth-1 (57 g for both), while Kondi (55 g) had a mean 1000-seed weight to some extended not different from that of checks across the 21 environments. The oil content was determined by Soxhelt method only for Medani irrigated site during kharif and winter season of 2012-2013 (Table 5). Oil content is an important component of oil yield per unit area. Results showed that the mean of oil content of SY-4045 (43%), Hysun-33 (41%), Bohooth-1 (39%) and Sirena (44.6%) were very similar in oil content percentage. While, Kondi (47%) showed higher mean oil content compared to the three checks. Regarding the mean of oil yield in Table (5), SY-4045 out-yielded Hysun-33, Bohooth-1 and Sirena by 24%, 21% and 20%, respectively. Also, Kondi out-yielded Hysun-33 by 28%, Bohooth-1 by 26% and Sirena by 25% under the environments of the study.

CONCLUSION

Consistent high mean seed and oil yields demonstrated by two Syngenta sunflower hybrids (SY-4045 and NK Kondi) and their adaptability and stability make them suitable hybrids for cultivation over a wide range of environments. In addition to credits of both hybrids for earliness, medium plant height and high self-fertility for good seedset compared to checks. Hence, the both hybrids were released last May 2015 for commercial production under both irrigated and rainfed (500-800 mm) systems in the central clay plains of the Sudan. Therefore, introduction and release of a large number of hybrids with high yielding from different countries is expected to ensure timely delivery of seeds and will probably result in lower seed prices due to free competition between suppliers.

Table 1: Locations and environments under which Syngenta sunflower hybrids were evaluated during 2011-2013

Location	**Medani**	**Suki**	**Rahad**	**Damazin**	**Gedarif**
Latitude	14° 23' N	13° 25' N	13° 28' N	11° 49' N	14° 20' N
Longitude	33° 29' E	33° 51' E	33° 31' E	34° 24' E	35° 21' E
Elevation (m.a.s.l.)	405 m	430 m	421 m	470 m	592 m
Environment (Season) code	E1,E2 (2011) E3,E4(2012) E5,E6(2013)	E7 (2011) E8,E9(2012) E10,E11(2013)	E12,E13(2011) E14,E15(2012) E16,E17(2013)	E18(2012) E19(2013)	E20(2012) E21(2013)
Soil type (%)	Clay 54 %	Clay 68 %	Clay 60 %	Clay 63%	Clay 75 %
pH	8.0	7.8	8.1	7.2	
Available P	3.0 mg kg $^{-1}$	3.0 mg kg $^{-1}$	1.8 mg kg $^{-1}$	1.8 mg kg $^{-1}$	3.3 mg kg $^{-1}$
O.C. %	0.36	0.60	0.60	0.63	0.60
N %	0.03	0.03	0.05	0.03	0.03

Source: Soil Survey Department, ARC-Sudan

Table 2: Pooled analysis of variance of seed and yields (kg ha^{-1}) in Syngenta sunflower hybrids evaluated in twenty one environments

Source of variation	d.f	Mean square
Hybrid (G)	6	603661.95**
Environment (E)	20	1592153.12**
Hybrid (G) x Environment (E)	120	61649.74**
Environment + (Hybrid x Environment)	140	280293.08**
Environment (Linear)	1	7035229.11**
Hybrid x Environment (Linear)	6	60456.53**
Pooled deviation	133	52896.46**
Pooled error	294	14092.19

** Denote significant at 0.01 probability level

Table 3: Estimates of stability parameters for seed yield of Syngenta sunflower hybrids evaluated at 21 environments.

Hybrid	Seed yield (kg ha^{-1})	Slope (b_i)	SE ±	S^2_{di}
SY-4200	1708	0.94	0.104	35138
SY-4045	2041	1.16	0.089	21870
NK Kondi	1947	1.09	0.119	49272
Neoma	1692	1.08	0.065	5086
Hysun-33	1709	0.87	0.066	5512
Bohooth-1	1664	0.87	0.070	7871
Pan-7351/Sirena	1642	0.99	0.099	30090
Mean	1772			

Where; b_i = regression coefficient, S^2_{di} = deviation from regression

Table 4: Means of seed yield (kg ha^{-1}) of sunflower hybrids evaluated over 21 environments.

Location	**Medani**						**Suki**				
Hybrid/Envi.	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11
SY-4200	1775	1917	2049	1435	1533	1765	2026	2024	1205	1795	2012
SY-4045	2356	2405	2243	1740	1731	1896	2749	2263	1611	2373	2571
NK Kondi	2129	2178	2209	1633	1629	1807	2951	2107	1547	2753	1538
Neoma	1781	1864	1715	1201	1407	1579	2311	1739	1183	2167	2004
Hysun-33	1564	1746	1828	1457	1468	1737	2302	1828	1401	2051	2346
Bohooth-1	1311	1782	1996	1495	1536	1761	1903	1816	1536	2251	1758
Sirena	1430	1479	1802	1610	1597	1742	2769	1816	1240	2104	1538
Mean	*1764*	*1910*	*1977*	*1510*	*1557*	*1755*	*2430*	*1942*	*1389*	*2213*	*1967*
SE ±	*196*	*154*	*73.5*	*45.2*	*18.4*	*32.6*	*156*	*77.9*	*99.5*	*184*	*139*
Level of sig.	**	*	**	**	**	**	**	**	*	*	**
C.V.%	*19.2*	*14.0*	*6.4*	*5.2*	*2.0*	*3.2*	*11.1*	*6.9*	*12.4*	*14.4*	*12.2*
Mean loca.	*1746*						*1988*				
Location	**Rahad**						**Damazin**		**Gedarif**		**Overall mean**
Hybrid/Envi.	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	
SY-4200	2362	2397	2154	1459	1216	2000	465	1340	2111	823	**1708**

SY-4045	2674	2553	2153	1945	2570	2250	382	1635	1816	949	**2041**
NK Kondi	2362	2188	2188	1598	2049	2333	677	2133	2272	603	**1947**
Neoma	2431	2397	1945	1494	2188	2000	361	1451	1578	735	**1692**
Hysun-33	2119	2345	1945	1598	1563	1958	616	1590	1571	856	**1709**
Bohooth-1	2084	2292	1841	1424	1841	1917	469	1601	1603	722	**1664**
Sirena	1911	2501	1910	1355	1841	1792	528	1132	-	702	**1646**
Mean	*2277*	*2382*	*2019*	*1553*	*1896*	*2036*	*500*	*1555*	*1825*	*770*	***1772***
SE ±	*130*	*80.0*	*96.8*	*88.2*	*124*	*79.8*	*44.3*	*18.0*	*227*	*43.3*	***26.04***
Level of sig.	*	*	*ns*	*	**	**	**	**	*ns*	*Ns*	**
C.V.%	*9.9*	*5.8*	*8.3*	*9.8*	*11.4*	*6.8*	*15.4*	*2.0*	*21.5*	*21.0*	***11.7***
Mean loca.	*2027*						*1028*		*1298*		***1617***

Table 5: Means of some traits of SYNGENTA sunflower hybrids evaluated over 21 environments.

Hybrid/trait	***DF**	**PH**	**NSH**	**ES**	**SW**	**OC**	**OY**
SY-4200	70	136	1092	10.4	54	41.53	709.33
SY-4045	68	141	1115	8.2	61	43.32	884.16
NK Kondi	66	138	1152	6.2	55	47.10	917.04
Neoma	64	133	1178	7.3	48	45.53	770.37
Hysun-33	70	149	1094	7.7	57	41.76	713.68
Bohooth-1	68	141	1047	7.8	57	43.90	730.50
Sirena	68	139	1045	9.0	56	44.69	733.81
Mean	***68***	***139***	***1103***	***8.1***	***55***	***43.97***	***779.15***
SE ±	*0.18*	*0.85*	*17.1*	*0.47*	*0.58*		
Sign. Level	**	**	**	**	**		
C.V.%	*2.1*	*4.8*	*12.3*	*46.6*	*8.3*		

**DF= days to 50% flowering, PH = plant height (cm), NSH = number of seeds per head, ES = percentage of empty seeds (%), SW = 1000- seed weight (g), OC = oil content (%) & OY = oil yield (kg ha^{-1}).*

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