GENOTYPE-ENVIRONMENT INTERACTIONS AND STABILITY ESTIMATES FOR SUNFLOWER (HELIANTHUS ANNUUS L.) VARIETIES GROWN IN DIVERSE ENVIRONMENTS IN KENYA

Wilson M. THAGANA ,
Oilseed Breeding section, Kenya Agricultural Research Institute,
National Plant Breeding Research Centre,P.O. Njoro, Kenya.
Fax:254-37-61576 ; Email: karinjr@net2000ke.com

John W. KAMUNDIA,
Biometry section, Kenya Agricultural Research Institute,
National Plant Breeding Research Centre,P.O. Njoro, Kenya.
Fax:254-37-61576 ; Email: karinjr@net2000ke.com

Dr. Teresio C. Riungu,
Oilseed Breeding section, Kenya Agricultural Research Institute,
National Plant Breeding Research Centre,P.O. Njoro, Kenya.
Fax:254-37-61576 ; Email: karinjr@net2000ke.com

Abstract
Genotype by environment (GXE) interactions has often been observed during on going sunflower evaluation trials in Kenya. The aim of these trials is selection for varieties that yield well across environments and has been complicated by those interactions. In the past, selection of superior genotypes has solely been based on analysis of variance of seed yield, multiple comparison of means and ranking of genotypes. We have studied seed yield data of thirteen sunflower genotypes which were grown in randomized complete block design in seven sites in 1993. Since the combined analysis of variance for seed yield revealed highly significant differences between sites($P<0.01$), genotypes($P< 0.01$) and GxE interactions($P<0.01$), the data was subjected to stability analysis using relative yield. Relative yield was defined as ratio of entry yield at each site to the site mean. Genotype S455 had high mean relative yield and the highest stability whereas H4794 had low mean relative yield and low stability. Genotypes such as Kenya Fedha, Kenya Shaba and H891 had high stability and low mean relative yield. Genotype S430, OCD-382 and OCD-381 had high relative yield, large variances for relative yield and may be good for specific sites. Though, genotypes Kenya Fedha, Kenya Shaba, H891, OCD-381, OCD-382, S400, and S430 have been recommended for commercial production, Genotype S455 has always been left out inspite of it's high stability. Recommendations based on analysis of variance of seed yield across sites are different from those based on relative yield. Therefore, one criterion of selection is not sufficient for the selection of superior varieties.

Key words: Sunflower, genotype by environment interactions, stability analysis, relative yield.

Introduction

Genotype-environment interactions caused by differential responses of genotypes to environmental changes is a problem that complicates and confounds the selection of superior varieties. Cultivar crossover interactions that is, genotypic rank change across environments are of importance in plant breeding and may slow down the selection process(Abdalla *et al.,* 1997). The environment is defined as the sum total of the external conditions which affect growth and development of an organism (Allard, 1960). The different attributes of the environment include, moisture supply, temperature and soil type among others(Yau, *et al.,* 1991).

Scientists have developed various strategies to help breeders to select superior varieties whenever statistically significant genotype-environment interactions are observed. Those strategies include various stability measurements and cluster analysis(Lin *et al.,* 1986). Biological stability is analogous to the concept of homeostasis and refers to the production of constant yield by a genotype in all environments whereas a genotype is considered to have agronomic stability if its yield varies in proportion to the productivity of the environments(Becker, 1981; Lin *et al.,* 1986). Variance of actual yield across sites-a measure of biological stability, could be converted into a simple agronomic measure of stability if relative yield is used(Yau & Hamblin, 1994).

Over the last 23 years about 30 varieties of sunflower have been released for commercial production in the variable environments of Kenya on the basis of mean yield performance(Thagana *et al.,* 1999). Environments in Kenya are characterized by drastic changes in altitude which ranges from O m asl to 5199 m asl. Altitude which affects temperatures, combined with variable rainfall and soil types are important environmental attributes that may change within short distances. Sunflower Evaluation Trials are ongoing experiments whose aim is to select varieties that yield well across test sites. Those trials were conducted in seven sites in 1993. Genotype-environment interactions were observed therefore, stability estimates were calculated using the simple method of Yau & Hamblin, 1994.

Materials and Methods

Thirteen sunflower varieties were used in the trials. The trials were conducted at Kakamega, Embu, Alupe, Mtwapa, Kisii, Endebess and Njoro. The environmental attributes of those sites are shown in Table 1. The entries were planted in a randomized complete block design (RCBD) with four replicates in 1993. The spacing was 75 cm between rows and 30 cm within rows. The rows were 6 metres long and the plot size was 18 m^2. The recommended agronomic package was used for the management of the trials. Data analysis was done using SAS version 6.12. The yield of genotypes at any site was expressed relative to the mean of that site(site mean coding) using the method of Yau & Hamblin, 1994 as follows:

RY_{ij}= 100 X $Y_{ij}/Y_{.j}$ where RY denotes relative yield; RY_{ij} is yield of entry I at site j; $Y_{.j}$ denotes mean yield of site j.

The mean relative yield ($RY_{i.}$), is the average of the individual relative yield across sites i.e,

$RY_{i.}=(\Sigma RY_{ij})/n$ where n is the number of sites.

The variance (s_i^2) of the entry relative yield is

$s_i^2= [\Sigma(RY_{ij}-RY_{i.})^2]/n-1$.

Table 1. Environmental attributes for the seven sites used in the experiment.

	Njoro	Kisii	Endebess	Alupe	Mtwapa	Embu	Kakamega
Latitude	O0 20' S	00 41'S	1 4' N	00 29' N	3 56'S	00 30' S	00 17' N
Longitude	35 57' E	34 47' E	34 52' E	34 8' E	39 44' E	37 27' E	34 46' E
Altitude(m)	2185	1723	1890	1170	22	1508	1585
Annual Precipitation(mm)	943	2029	1041	2048	1370	1333	2046
Mean Temperature(^oC)	16	20	18	22	26	19	21
Temperature range(^oC)	9-24	15-25	12-23	16-29	22-30	14-24	14-27
Dew point 1200 (^oC)	14	15	-	-	23	14	14
Soils	Andosols	Nitosols	Nitosols	Acrisols	-	Nitosols	Nitosols

Results and discussion

The genotypes were significantly different ($P<0.01$) at all the other sites except Alupe where the genotypes were not significantly different ($P>0.05$). The combined analyses of variance for seed yield and relative yield revealed highly significant differences between genotypes($P< 0.01$) and GxE interactions($P<0.01$). Combined analysis of variance of seed yield revealed highly significant differences for sites($P<0.01$). It was necessary to perform stability analysis since the GXE interactions were highly significant.

Genotype rank change was observed in all the seven sites. Genotypes rank changes was exhibited by varieties S515, S455, OCD-381, H4794, OCD-382 and S430 which ranked first in mean seed yield in at least one site(Table 2). Varieties which were inferior in mean seed yield in at least one site included H4794, Kenya Shaba, Kenya Fedha and H4791. Variety S430 had the highest mean seed yield but was average in performance at Mtwapa and Alupe. Genotypes with low among-environment variance for seed yield have good biological stability whereas genotypes with low among variance for relative seed yield have good agronomic stability(Yau and Hamblin, 1994). Variety H4794 had the lowest mean seed yield but was the best at Mtwapa. When variance of seed yield across sites was used as a measure of biological stability, H4791, H4794, Kenya Shaba and Kenya Fedha had low variances for seed yield and therefore high stability but are undesirable because of their low mean seed yield. Varieties OCD-381 and S430 had large variances for seed yield and therefore low biological stability but high mean seed yield. Varieties S455 and OCD-382 had high mean seed yield and medium biological stability.

When variance of relative seed yield was used as a measure of agronomic stability S455, which yielded highly, had low variance for relative seed yield and therefore high agronomic stability(Table 3). Varieties S430, OCD-381 and OCD-382 had high relative seed yield with large variances and may be good for specific sites. Variety S430 is good for all sites except Alupe and Mtwapa. Variety OCD-381 may be recommended for Njoro, Endebess, and Kakamega whereas OCD-382 may be recommended for Endebess, Embu and Mtwapa. Genotypes such as H4794 had high biological stability but low agronomic stability. Though, genotypes Kenya Fedha, Kenya Shaba, H891, OCD-381, OCD-382, S400, and S430 have been recommended for commercial production(Thagana *et al.*, 1999), Genotype S455 has always been left out inspite of its high agronomic stability.

Table 2. Mean seed yield(Kg/ha) for 13 sunflower varieties grown at seven sites in 1993.

Entry	Njoro	Endebess	Embu	Alupe	Kisii	Mtwapa	Kakamega	Mean	SD
H891	842(7)	2003(5)	755(4)	561(9)	1833(6)	1236(9)	2820(8)	1436(9)	813(5)
S412	836(8)	2061(4)	657(6)	899(3)	1208(11)	2247(3)	2420(9)	1476(8)	945(9)
H8943	1056(5)	1815(7)	409(11)	885(4)	2000(4)	1278(8)	2940(7)	1483(7)	879(7)
S515	1412(2)	1342(11)	606(8)	406(12)	1875(5)	2347(1)	3080(5)	1581(6)	973(10)
S455	1064(4)	1972(6)	631(7)	926(2)	2208(1)	1819(4)	3100(4)	1674(4)	853(6)
OCD381	1388(3)	2090(3)	747(5)	698(8)	1597(8)	1583(6)	3960(1)	1723(2)	1103(12)
H4794	255(12)	1224(13)	336(12)	1016(1)	1024(12)	417(12)	1460(12)	819(13)	515(2)
OCD382	987(6)	2422(1)	794(3)	711(7)	1757(7)	2333(2)	2960(6)	1709(3)	911(8)
S430	1827(1)	2142(2)	818(1)	731(6)	2083(2)	1708(5)	3580(3)	1841(1)	1025(11)
Kenya Fedha	390(10)	1389(8)	498(9)	420(11)	932(13)	1347(7)	2040(11)	1002(10)	677(3)
Kenya Shaba	785(9)	1371(10)	281(13)	393(13)	1264(10)	556(11)	2120(10)	967(11)	677(3)
H4791	334(11)	1320(12)	434(10)	842(5)	1328(9)	-	1320(13)	930(12)	475(1)
S400	-	1382(9)	864(2)	538(10)	2069(3)	1222(10)	3920(2)	1666(5)	1293(13)
Mean	931	1733	602	694	1629	1508	2748	-	-
SD	550	457	257	379	584	849	969	-	-
LSD(0.05)	491	389	245	533	640	966	825	-	-

CV(%)	37	16	28	54	27	45	21	-	-
r!	0.88^{**}	0.72^{**}	0.84^{**}	0.00	0.91^{**}	0.66^{*}	0.81^{**}	-	-

!Correlation coefficient of site entry yield with mean entry yield.

The rank of the entry is indicated in parenthesis. The standard deviation of the entries is ranked from the smallest to the largest.

Table 3. Mean relative seed yield (Entry yield as percentage of site yield) for 13 sunflower varieties grown at seven sites in 1993.

Entry	Njoro	Endebess	Embu	Alupe	Kisii	Mtwapa	Kakamega	Mean	SD
H891	90(7)	116(5)	125(4)	81(9)	113(6)	82(9)	103(8)	101(9)	27(2)
S412	90(7)	119(4)	109(6)	130(3)	74(11)	149(3)	88(9)	108(7)	53(13)
H8943	113(5)	105(7)	67(11)	127(4)	123(4)	85(8)	107(7)	104(8)	33(5)
S515	152(2)	77(11)	101(8)	59(12)	115(5)	156(1)	112(5)	110(5)	47(10)
S455	114(4)	114(6)	105(7)	133(2)	136(1)	121(4)	113(4)	119(4)	26(1)
OCD381	149(3)	121(3)	124(5)	101(8)	98(8)	105(6)	144(1)	120(3)	41(8)
H4794	27(12)	71(13)	56(12)	146(1)	63(12)	28(12)	53(12)	63(13)	48(12)
OCD382	106(6)	140(1)	132(3)	102(7)	108(7)	155(2)	108(6)	122(2)	38(6)
S430	196(1)	124(2)	136(2)	105(6)	128(2)	113(5)	130(3)	133(1)	45(9)
Kenya Fedha	42(10)	79(10)	83(9)	60(11)	57(13)	89(7)	74(11)	69(11)	29(3)
Kenya Shaba	84(9)	80(8)	47(13)	56(13)	78(10)	37(11)	77(10)	65(12)	29(3)
H4791	36(11	76(12)	72(10	121(5	82(9)	-	48(13)	72(10	38(6)

	)		)	)				)	
S400	-	80(8)	143(1)	77(10)	127(3)	81(10)	143(2)	109(6)	47(10)
Mean	931	1733	602	694	1629	1508	2748	-	-
SD	59	26	43	55	36	56	35	-	-
LSD(0.05)	53	22	41	77	39	64	30	-	-
CV(%)	37	16	28	54	27	45	21	-	-
r!	0.86^{**}	0.77^{**}	0.82^{**}	0.120	0.78^{**}	0.74^{*}	0.85^{**}	-	-

*,** Significant at P<0.05 and P<0.01, respectively.

The rank of the entry is indicated in parenthesis. The standard deviation of the entries is ranked from the smallest to the largest.

Conclusion

Mean seed yield is an important criterion for the selection of superior varieties in the absence of Genotype-environment interactions. However, stability analyses are necessary when genotype-environment interactions are significant. Varieties with high biological stability may be different from the varieties superior in agronomic stability. Varieties with high agronomic stability such as S455 have always been left out when selection is based on analysis of variance of seed yield. Therefore, one criterion of selection is not sufficient for the selection of superior varieties.

Acknowledgement

The authors of this paper are thankful to the scientists who participated in the Trials. We are also grateful to all the collaborators for their invaluable roles. We are indebted to the Kenya Meteorological Department who provided most of the climatic data in Table I.

References

Abdalla, S. O., Jose' Crossa & Paul. L. C. 1997. Result and biological interpretation of shifted multiplicative model clustering of durum wheat cultivars and test sites. Crop Sci. **37,** 88-97.

Allard, R. W. 1960. In: Principles of Plant Breeding. John Wiley & Sons, Inci. New York, Chichester, Brisbane, Toronto, Singapore. 467pp.

Becker, H. C. 1981. Correlations among statistical measures of phenotypic stability. Euphytica. **30,** 835-840.

Lin, C.S., Binns, M.R. & Lefkovitch, L.P. 1986. Stability analysis: Where do we stand? Crop Sci. **26,** 894-900.

Thagana, W. M, Nderitu, S.W.K. & Riungu, T.C. 1999. Characteristics of Sunflower(Helianthus annuus L.) Varieties grown in Kenya. Proceedings of the International Symposium on sunflower and other oilseed crops in Developing countries. Eduardo Mondlane University, Faculty of Agronomy and Forestry Engineering. International Sunflower Association. February 9-12, 1999. Maputo, Mozambique. pp. 263-268.

Yau, S. K & Hamblin J. 1994. Relative yield as a measure of entry performance in variable environments. Crop sci. **34,** 813-817.

Yau, S. K, Ortiz-Ferrara, G. & Srivastava, J. P. 1991. Classification of diverse bread wheat-growing environments based on differential yield responses. Crop Sci. **31,** 571-576.