GENE EFFECTS AND COMBINING ABILITIES OF SUNFLOWER YIELD AND MORPHOLOGICAL TRAITS BY LINE X TESTER MATING DESIGN

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ABSTRACT

Recent changes in vegetable oil production in Uganda has realized that sunflower is now the main oilseed crop for producing vegetable oil. However the oil production is not enough for domestic needs and as such, much of the seed in production is basically from the imported sunflower hybrids. The development of sunflower hybrids with high genetic potentials for seed yield and other seed yield components requires information on the GCA and SCA for agronomically important traits. Understanding the genetic basis and mode of gene action for grain yield and important agronomic traits of sunflower would facilitate the improvement of sunflower production in Uganda. Choosing suitable lines for breeding as a parental component of a hybrid variety is of great importance. Seven CMS inbred lines used as females and six restorers used as males were crossed in a line x tester mating design to produce 42 single cross hybrids. Planting was done at the National Semi-Arid Resources Research Institute (NaSARRI) in 2013. The design was alpha-lattice (7 x 8) with three replications. One experimental hybrid (Belmonte) was used as a check. The traits recorded were days to 50% flowering, days to maturity, head diameter, plant height, number of seeds per head, and weight of seeds per head. The objective was to investigate the GCA and SCA effects of the F1 hybrids to the expression of the mentioned morphological characters.

Key words: Combining ability, gene effect, Line x tester design, Sunflower

INTRODUCTION

Sunflower (*Helianthus annuus* L.) has become the main oilseed crop in Uganda especially in the eastern and northern districts of the country. It is a source of livelihood for a number of resource poor farmers in these areas as the main immediate source of income. It is still the only main source of edible oil in the country followed by palm oil which was introduced into the country recently. By late 1980, Uganda was importing 98% of the total edible oil in the country. Considering the high oil content compared to other oilseeds, sunflower shows the greatest potential in reducing Uganda's dependence on imported edible oil. Its oil is used mainly as cooking oil and for soap making while the seed cake is being used as livestock feed. Most rural poor farmers and commercial producers in the sunflower growing areas obtain much lower yields than the expected potential yields due to lack of improved varieties and poor agronomic practices. There is severe lack of sufficient seed of acceptable varieties to meet the demand for the required plantings. Most of the released hybrids that have been released so far are being imported from South Africa. Their prices are expensive and not affordable by the poor resource farmers in Uganda.

Production of sunflower in a country needs genotypes that are widely adaptable so that it can be grown in a wider area and becomes of economic importance to the country. Breeders usually attempt to identify superior varieties for most of the characters of economic interest. A variety might be high yielding in a geographic region for which the breeder is evolving varieties but when employed as a parent in crosses, this variety may emerge as a poor combiner. In other words, this line does not appear to transmit desirable genes for the better performance to its progeny. Such a behavior could result from intra- and/or inter-allelic interaction of genes concerned with the character. Thus superior performance of a variety is not always reflected in its combining ability.

The concept of combining ability is a measure of gene action. Combining ability analysis is used in the breeding programme for testing the performance of lines in hybrid combinations and also for characterizing the nature and magnitude of gene action involved in the expression of quantitative traits. General combining ability (GCA) of a line/variety refers to the average value of that line/variety estimated on the basis of its performance when crossed with other lines (Falconer, 1989). General combining ability is largely due to additive genetic effects and additive x additive epistasis. Meanwhile specific combining ability (SCA) is used to designate in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines crossed. Specific combining ability is largely a function of non additive dominance and other types of epistasis. The concept of general and specific combining ability is of practical importance to the breeders. It is therefore, in the interest of breeders to know how the two combining abilities are related to various components of heritable variations.

A successful breeding programme depends on the variability present among the different genotypes and in-depth understanding of the underlying gene action and genetic architecture of traits related to yield. Selection of parents based on their performance *per se* alone may not always be a sound procedure, since phenotypically superior genotypes may yield inferior hybrids and/or poor recombinants in the segregating generations. It is very important to identify parents with high general combining ability (GCA) value for the trait to be improved (Banerjee and Kole, 2009).

Information on gene action and combining ability helps in the choice of suitable parents for hybridization programmes for developing superior F_1 hybrids so as to exploit hybrid vigour and building genotypes to be used in the breeding programme. The objectives of the present study were to assess the nature and magnitude of gene action controlling the inheritance of seed yield and yield characters in selected sunflower genotypes.

MATERIALS AND METHODS

The sunflower lines were introduced from USA, Canada and Australia. Seven CMS inbred lines were used as females and six restorers used as males in a line x tester mating design to produce 42 single cross hybrids. Planting was done at the National Semi-Arid Resources Research Institute (NaSARRI), Serere in 2013. The design was alpha-lattice (7 x 8) with three replications. One experimental hybrid (Belmonte) was used as a check. Each plot had four rows and two middle rows were used for data recording. The spacing was 75 x 30 cm at a length of 4 m long. No fertilizer was applied since most farmers do not use fertilizer in their fields. Yield data was obtained from the two middle rows during harvest. The traits recorded were days to 50% flowering, days to maturity, head diameter, plant height, number of seeds per head, and weight of seeds per head.

RESULTS AND DISCUSSIONS

Analysis of variance is presented in Table 1. There was highly significant difference among the female lines for days to 50% flowering, days to maturity and plant height. No significant difference was recorded for head diameter, number of seeds per head and seed weight per head. Similar observations were recorded for males whereby high significant differences were observed for days to 50% flowering, days to maturity and plant height. Female x male interaction only showed significant difference for days to 50% flowering and days to maturity.

Table 1: Mean square variances for the different traits studied

SoV	d.f	Days to 50% flowering	Days to maturity	Head diameter (cm)	No of seeds per head	Plant height (cm)	Seed weight per head (gm)
Rep	2	11.90***	6.16	10.89	127586	185	553
Female	6	9.47**	5.76***	9.34	73216	772***	352
Male	5	25.48***	4.32***	6.78	39936	987***	165
F x M	30	3.67***	0.74***	8.51	49920	231	226
Residual	60	1.20	3.20	8.05	83735	155	
Total	124	3.61		8.22		240	

*, **, *** Significant at 5%, 1% and 0.1% Probability level.

Table 2 shows the mean performance of the single cross hybrids evaluated. Days to 50% flowering ranged from 57 to 63 days while days to maturity ranged from 88 days in Cms850 x RHA346 to 99 days in Cms850 x RHA374-1, Cms850 x RHA373 and Cms412 x RHA374-1. The highest number of seeds per head was recorded in Cms383 x RHA447 with 1291 mean number of seeds per head followed by Cms404 x RHA447 and Cms383 x RHA271. The tallest hybrid was cms403 x RHA374-1 which recorded 153 cm in height followed by Cms404 x RHA373. For seed weight per plant, Cms383 x RHA271 and Cms383 x CM632 had the highest seed weight per plant with 79 gms.

Table 2. Mean performance of the single crosses evaluated at Serere, 2013

Hybrids	Days to 50% flowering	Days to maturity	Head diameter (cm)	No of seeds per head	Plant height (cm)	Seed weight per head (gm)
Cms383x CM632	58	91	19	1112	129	79
Cms 402x CM632	61	95	14	704	109	46
Cms 403x CM632	60	96	13	662	112	44
Cms 404x CM632	60	98	16	959	111	67
Cms 412x CM632	61	95	20	905	133	72
Cms 433x CM632	60	91	15	870	119	53
Cms 850x CM632	58	91	16	1057	144	66
Cms383XRHA271	60	95	18	1208	136	79
Cms 402x RHA271	61	98	15	990	113	63
Cms 403x RHA271	61	98	15	691	116	45
Cms 404x RHA271	61	98	15	707	128	51
Cms 412x RHA271	60	96	18	941	141	66
Cms 433x RHA271	62	95	16	685	119	57
Cms 850x RHA271	58	89	16	1174	150	68
Cms383x RHA346	61	92	12	690	114	41
Cms 402x RHA346	60	96	15	880	130	50

Cms 403x RHA346	60	92	16	889	117	77
Cms 404x RHA346	60	97	17	1196	134	77
Cms 412x RHA346	62	96	14	703	129	37
Cms 433x RHA346	61	91	15	966	122	57
Cms 850x RHA346	59	88	14	615	121	47
Cms383x RHA373	61	98	15	719	142	57
Cms 402x RHA373	61	98	15	621	122	45
Cms 403x RHA373	63	98	14	612	115	37
Cms 404x RHA373	61	98	15	955	148	64
Cms 412x RHA373	61	95	16	778	139	48
Cms 433x RHA373	61	91	14	795	116	47
Cms 850x RHA373	63	99	18	1107	141	72
Cms383X RHA374-1	65	98	17	794	139	49
Cms 402x RHA374-1	63	98	14	750	133	44
Cms 403x RHA374-1	63	99	16	852	153	51
Cms 404x RHA374-1	62	98	16	939	145	70
Cms 412x RHA374-1	63	99	16	925	146	64
Cms 433x RHA374-1	63	98	14	643	137	43
Cms 850x RHA374-1	60	93	14	760	147	44
Cms383x RHA447	60	92	16	1291	141	70
Cms 402x RHA447	61	97	13	705	104	37
Cms 403x RHA447	60	97	16	951	138	61
Cms 404x RHA447	62	97	17	1284	136	72
Cms 412x RHA447	61	98	14	840	134	44
Cms 433x RHA447	60	91	16	969	128	65
Cms 850x RHA447	57	91	13	610	122	33

The GCA effects for females and males are presented in Table 3. For days to 50% flowering, Cms850 was the only female line that recorded significant negative GCA effect. In order to reduce the time for days to 50% flowering, HA850 could be useful. No male showed any significant difference in days to 50% flowering however, RHA374-1 could be used for increasing days to 50% flowering as days to 50% flowering is positively correlated to yield. All the female lines recorded highly significant difference ($P<0.001$) for days to maturity. Since days to maturity is positively correlated to yield, the females with positive GCA effects such as Cms402, Cms403, Cms404 and Cms 412 would be useful. In areas with less rainfall, Cms433 and Cms850 could be useful in the breeding programme. Among the males, highly significant difference ($P<0.001$) was also recorded. RHA373 and RHA374-1 had high positive GCA effects which could also improve yield. CM632 and RHA346 had high negative GCA effects which would be good for rainfall areas. No significant GCA effects were recorded for head diameter for the females and the males. However, Cms383, Cms404 and Cms412 among the females and CM632 and RHA271 among the males could be useful in improving the head diameter in the breeding programme. For number of seeds per head, only Cms404 had a significant positive GCA effect. For plant height, Cms402 was the only female line with a significant negative effect GCA effect. It could be useful in decreasing the plant height against lodging. Meanwhile, among the males, RHA374-1 had high significant positive ($P<0.001$) GCA effect. No any genotype among both the female and male lines had any positive significant GCA effect for seed weight per head. However, among the female lines, Cms383, Cms404 and among the male lines, CM632 and RHA271 could be useful in improving the yield performance of the sunflower lines.

Table 3. General combining ability effects for various yield components in sunflower at Serere

	Days to 50% flowering	Days to maturity	Head diameter (cm)	Number of seeds per head	Plant height (cm)	Seed weight per head (gm)
Females						
Cms383	0.096	-0.92***	0.68	99.82	3.5	6.4
Cms402	0.270	1.61***	-0.93	-94.13	-11.3**	-8.6
Cms403	0.253	1.59***	-0.48	-93.12	-4.7	-3.6
Cms404	0.123	2.50***	0.52	137.7*	3.8	10.4
Cms412	0.430	1.10***	0.96	-20.4	7.2	-1.0
Cms433	0.443	-2.46***	-0.54	-47.93	-6.2	-2.4
Cms850	-1.615*	-3.42***	-0.21	18.07	7.6	-1.2
SE	0.365	0.153	0.945	67.98	4.2	5.0
Males						
Cm632	-0.993	-1.59***	0.76	26.36	-7.4	5.0
RHA271	-0.487	0.37*	0.65	44.52	-0.6	5.1
RHA346	-0.733	-2.17***	-0.67	-20.81	-6.1	-0.9
RHA373	0.828	1.53***	-0.15	-70.90	1.8	-3.5
RHA374-1	2.041	2.39***	-0.20	-60.07	13.1***	-4.0
RHA447	-0.656	-0.53***	-0.39	80.90	-0.8	-0.5
SE	0.337	0.14	0.88	62.94	3.8	4.6

The SCA effects are presented in Table 4. SCA effects are indicators of dominance gene effect. For days to 50% flowering, positive SCA effects were observed in the crosses Cms433 x RHA271, Cms850 x RHA373, Cms383 x RHA374-1 and Cms404 x RHA447. For negative SCA effect, this was recorded in Cms383 x CM632, Cms403 x RHA374-1 and Cms850 x RHA447. This results in early flowering hybrids. For days to maturity, Cms850 x RHA373 had the highest positive SCA indicating that it had the highest maturity period. Meanwhile, Cms403 x RHA374-1 had the highest negative SCA effect indicating that it was the earliest hybrid in maturity. For number of seeds per head, Cms850 x RHA373 had significant ($P<0.05$) positive SCA effect followed by Cms850 x RHA271 and Cms383 x RHA 447. For plant height, negative significant SCA effect were recorded in Cms404 x CM632, Cms403 x RHA 374 and Cms850 x RHA 447 while positive significant SCA effect for seed weight per head was recorded in Cms403 x RHA346 and Cms850 x RHA373.

Conclusion

A number of genotypes have shown variability with desirable GCA and SCA effects that can be used in the sunflower breeding programme in Uganda. High variability is recorded especially in days to maturity.

Table 4: Estimates of specific combining ability effects for yield and yield components in sesame at Serere

Hybrids	Days to 50% flower	Days to maturity	Head diameter (cm)	No of seeds per head	Plant height (cm)	Seed weight per head (gm)
Cms383x CM632	-1.47*	-1.87***	2.41	116.2	2.8	11.7
Cms 402x CM632	0.50	-0.73**	-1.31	-97.5	-1.9	-6.7
Cms 403x CM632	-0.48	0.89**	-2.75	-140.4	-5.5	-13.2
Cms 404x CM632	0.53	1.65***	-0.42	-74.0	-15.5*	-4.6
Cms 412x CM632	0.64	-0.24	3.13	29.8	3.7	12.0
Cms 433x CM632	0.15	-0.31	-1.04	22.3	3.2	-5.6
Cms 850x CM632	0.13	0.62*	-0.02	143.7	13.9	6.3
Cms383XRHA271	-0.67	-0.17	1.19	194.6	3.4	11.8
Cms 402x RHA271	0.08	0.92***	-0.20	170.8	-4.7	10.4
Cms 403x RHA271	0.12	1.07***	-0.99	-130.0	-8.4	-13.2
Cms 404x RHA271	0.69	0.01	-1.65	-344.3**	-4.9	-20.8*
Cms 412x RHA271	-1.13	-0.54*	0.57	47.9	5.0	5.8
Cms 433x RHA271	1.48*	1.74***	0.74	-181.2	-3.7	-1.6
Cms 850x RHA271	-0.58	-3.03***	0.34	242.1*	13.3	7.6
Cms383x RHA346	0.54	-0.03	-3.49*	-258.5*	-13.6	-20.6**
Cms 402x RHA346	0.19	1.12***	1.45	125.5	17.6*	3.6
Cms 403x RHA346	-0.61	-2.45***	2.00	133.3	-2.4	25.6*
Cms 404x RHA346	-1.18	1.46***	1.68	210.4	6.5	11.0
Cms 412x RHA346	1.08	1.40***	-1.44	-124.7	-2.2	-17.6*
Cms 433x RHA346	0.56	0.24	0.39	165.5	4.7	4.5
Cms 850x RHA346	-0.58	-1.73***	-0.59	-251.5*	-10.8	-6.6
Cms383x RHA373	-0.59	2.36***	-0.68	-178.9	6.5	-2.5
Cms 402x RHA373	-1.14	-0.32	0.93	-82.7	1.7	0.8
Cms 403x RHA373	0.98	-0.13	-0.85	-92.8	-12.5	-11.8
Cms 404x RHA373	-0.62	-1.07***	-0.52	19.5	12.5	0.5
Cms 412x RHA373	-1.23	-2.64***	-0.63	0.4	0.2	-3.5
Cms 433x RHA373	-0.77	-3.42***	-1.13	44.0	-9.9	-3.6
Cms 850x RHA373	3.37*	5.22***	2.88	290.3*	1.5	20.1*
Cms383X RHA374-1	2.49***	1.35***	0.69	-115.0	-7.8	-9.6
Cms 402x RHA374-1	-0.24	-1.11***	-0.03	35.2	1.2	0.5
Cms 403x RHA374-1	-60.42***	-95.74***	-14.62***	-733.0***	-115.0***	-53.9***
Cms 404x RHA374-1	-1.05	-1.98***	-0.14	-8.0	-1.3	7.1
Cms 412x RHA374-1	0.06	-0.36	0.09	136.4	-4.3	12.6
Cms 433x RHA374-1	-0.52	3.06***	-0.74	-118.0	0.4	-6.5
Cms 850x RHA374-1	-1.07	-0.62*	-0.74	-66.7	-3.1	-6.5
Cms383x RHA447	-0.30	-1.63***	-0.12	241.6*	8.6	9.2
Cms 402x RHA447	0.61	0.12	-0.84	-151.4	-13.9	-8.7
Cms 403x RHA447	-0.35	0.96***	1.72	93.7	14.0	10.2
Cms 404x RHA447	1.63*	-0.08	1.05	196.4	2.6	6.8
Cms 412x RHA447	0.58	2.38***	-1.72	-89.8	-1.9	-9.4
Cms 433x RHA447	-0.90	-1.31***	1.77	67.3	5.2	12.7
Cms 850x RHA447	-1.27*	-0.45	-1.88	-358.0**	-14.8*	-20.8*
SE	0.63	0.26	1.64	117.8	7.2	8.7