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Heterosis for grain yield and its components in topcross hybrids of maize

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ABSTRACT

Development of high yielding hybrids with high vigor is the ultimate objective of maize breeding and the success depends largely on the identification of the best parents to ensure maximum heterosis for hybrid production. This study was conducted to estimate genetic variability and heterosis of grain yield and yield components of seven local inbred lines and four introduced open pollinated varieties of maize (*Zea mays* L.) across two irrigated locations (Medani and Matuq) in 2008. The experiment was arranged in a randomized complete block design with three replicates. The traits measured were days to 50% tassel, plant height, ear length, ear diameter, hundred kernels weight and grain yield. The crosses showed high genetic variability and tall plants than their parents which suggested some degree of hybrid vigor. The tallest hybrids across locations were T3 x L5 and T4 x L3. This indicates that the crosses were late maturing than their parents. The highest yielding hybrids had long ears and better shape, e.g., T2 x L1 and T1 x L7.The top five ranking crosses for grain yield across locations were T2 x L7 (3.45 t/ha), T1 x L2 (3.44 t/ha), T2 x LI (3.32 t/ha), T4 x L4 (3.30 t/ha) and T1 x L1 (3.13 t/ha). The highest percentage of mid parent heterosis for grain yield in Medani, was given by T3 x L3 and T4x L4; in Matuq, by T1 x L5, T4 x L5 and T4 x L6 and across sites by T1 x L2 (59%), T3 x l2 (45%) and T3 x L6 (50%). These crosses can be recommended for future testing in multilocations trials for commercial utilization.

INTRODUCTION

Maize is one of the most diverse crop both genetically and phenotypically. Due to its adaptability and productivity, maize spread rapidly around the world after the Europeans brought the plant from the Americas in the 15th and 16th centuries (McCann, 2005). The Portuguese introduced maize in Africa at the beginning of the 16th century and since then the crop has replaced sorghum and millet as the main staple food in most of the continent where the climatic conditions are favorable (McCann, 2005). Today, there is an increasing interest in maize production in Sudan due to it's suitability to cultivation in the agricultural irrigated schemes, especially in the Gezira; it can occupy an important position in the economy of the country due to the possibility of blending it with wheat for making bread (Nour *et al.,* 1997; Meseka, 2000).

The grain yield of existing maize varieties and local landraces in Sudan is low. Also, maize hybrids have been reported to show high potential than the open pollinated varieties and landraces (Alhussein, 2007). Advantages of hybrids over open pollinated cultivars are higher yield, uniformity, high quality and resistance to diseases and pests. In spite of having yield potential, the production of maize in Sudan is very low. One of the reasons for this is the cultivation of exotic hybrids, which are not well adapted to our agro-climatic conditions. One of the strategies of the Agricultural Research Corporation (ARC) of the Sudan for maize breeding program is to develop new hybrids as an attempt to incorporate both advantages for higher yield and adaptability to environmental conditions. Thus, getting the benefit from the use of heterosis is the main purpose in maize breeding program of ARC. Therefore, the objective of this study is to estimate the magnitude of heterosis in 28 topcross hybrids of maize for grain yield and it's components across two irrigated locations and to identify high yielding topcross hybrids for future testing and commercial utilization.

MATERIALS AND METHODS

The plant material used consisted of 7 local inbred lines used as lines, and 4 introduced open pollinated varieties used as testers crossed in line x tester arrangement (Table 1). Hand pollination was used to develop the breeding material. Pollen grain was collected into a paper bag from the tassel of male parent (tester) and then dusted on the silk of the female parent (line). The ear was covered with a bag and information regarding the cross was written on the bag. A total of 28 cross combinations was obtained through hand pollination. In July 2008, the 11 parental material and 28 cross hybrids were grown and evaluated at two irrigated locations, Medani and Matuq. The trials were arranged a randomized complete block design (RCBD), with three replicates. The plot size was maintained as 2 rows x 3 m long with inter and intra row spacings of 80 and 25 cm, respectively. Seeds were sown at the rate of 3- 4 seeds per hill. Plants were thinned to one plant per hill after three weeks from sowing. Nitrogen was applied at 86 kg/ha in a split dose after thinning and before flowering. The crop was irrigated at intervals of 10-14 days, and plots were kept free of weeds by hand weeding. Data were analyzed using the Statistical Analysis System (SAS) computer package. The analysis was done for each season for characters days to 50% tasseling, plant height, ear length, ear diameter, kernels weight and grain yield and then combined. Mean performance was separeted using Duncan's Multiple Range Test (DMRT). The estimation of heterosis was computed as:

Heterosis over mid parent (MP) = [(F_1 – MP) x 100]/MP

where:

F_1 = the mean of hybrid variety.

MP = mean of the two parents involved in the cross.

RESULTS AND DISCUSSION

The performance of the different material tested for the most traits studied was high across the two locations. However, it showed significant variation among the parents and hybrids which indicates the diversity in the material tested.

Mean separation and ranking

Days to 50% tasseling

Mean days to 50% tasseling indicates that the pollen shedding ability of maize genotypes is an indicator of the earliness of genotypes. Mean days to tasseling across locations for parents scored 52 days as the general mean. Mean of parents ranged between 49 and 55 days for L6 and T3, respectively (Table 2). The mean of crosses ranged between 46 days for (T4 x L5) to 52 days for (T2 x L1) (Table 3). Identification of early tasseling genotypes is very important in developing hybrids and choosing hybrids to suit different agro-ecological zones as well as grower's requirements. Earliness was a desirable trait especially under rainfed conditions. It is important for better use of water resources and avoidance of late season infestation with stem borers. Hence, the earliest crosses were T1 x L7 (47 days), T4 x L7 (47 days), T4 x L4 (48 days) and T4 x L6 (48 days) (Table 3).

Plant height

Tallness is not a good character in grain maize production, since tall maize plants tend to be susceptible to stem and root lodging. Highly significant differences were detected among the studied parents with the general mean being of 144.4 cm. The trends in breeding work are to develop cultivars that are dwarf or of moderate height to avoid lodging of the crop which adversely affects yield. The studied parents mean ranged between 131.1 cm for L7 to 158 cm for T3 which was the tallest and latest parent across locations (Table 2). The crosses mean varied from 135.1 cm for (T3 x L7) to 155.9 cm for (T2 x L1).The tallest hybrids across locations were T4 x L6 and T4 x L3 (154 cm) (Table 3).The results indicate that crosses were later than their parents. Also, the taller crosses were late maturing than short ones. Generally, the crosses were taller than their parents which suggested some degree of hybrid vigour.

Ear length

Ear length trait is an important selection index for grain yield in maize. The ear means of parents, as expected, were found to be shorter than those of the crosses at the two sites, with the general mean of 13.5 cm. The parents mean ranged between 12.7 cm for L7 to 15 cm for L2 (Table 2). The crosses mean varied from 11.9 cm for (T3 x L4) to 16.1 cm for (T3 x L5). However, the longest ear length was recorded for crosses T1 x L7 (15.2 cm), and T2 x L6 (14.6cm) (Table 3).Vedia and Claure (1995) found that ear length was the most important yield component and that genetic gain in recurrent selection reached 9.94% for yield and 5.75% for the ear traits. Therefore, any increase in ear length would be expected to increase number of kernels/row and hence increase grain yield.

Ear diameter

Ear diameter is a good indicator of the number of kernel rows/ear. The mean of ear diameter in across sites for parents ranged between 3.4 cm for L6 and L7 to 4.1 cm for L4 (Table 2). Among the crosses, the ear diameter ranged from 3.3 cm for T3 x L6 to 4.0 cm for T2 x L1. The crosses which had a big ear diameter were T3 x L3 and T4 x L6 (3.8cm) (Table 3). This result was in agreement with the findings of Tracy (1990) who found that the maize hybrids with high yield had more ears/plant, longer ears and a better ear shape and row configuration.

One hundred kernels weight

The mean of one hundred kernels weight for parents was 21.4 g, and it ranged between 19.9 g for L2 to 22.8 g for T3 (Table 2). Among the crosses, the mean was 21.3 g. The best crosses which obtained the highest kernel weight were T1 x L2 and T4 x L3 (23.2) followed by T2 x L3 (22.8 g) (Table 3).

Grain yield

Yield is a polygenic character which is influenced by the fluctuating environments. Moreover, it is a complex trait depending on many components (Sharaan and Ghallab, 1997). In this study, there was a considerable amount of variability among the genotypes for this trait. The studied parents in two environments showed a general mean of 2.4 t/ha. The parents means ranged between 2.12 t/ha for L4 to 2.93 t/ha for T4 (Table 2), while, the crosses means ranged between 2.0 t/ha for (T2 x L5) to 3.55 t/ha for (T2 x L7) (Table 3). Most of the crosses (19 hybrids) had significantly higher mean grain yield than the overall mean. It is of interest to mention that the top ranking and the best yielder hybrids were T1 x L2 (3.4 t/ha), T2 x L1 (3.3 t/ha), T4 x L4 (3.3 t/ha), T1 x L1 (3.30 t/ha) and T4 x L3 (3.1 t/ha) which were the latest and tallest crosses.

From this result, the crosses obtained a higher grain yield than their parents. These results agreed with those of Khalafalla and Abdalla (1997), who pointed to the fact that hybrids (crosses) produce higher grain yields than the open pollinated varieties due to the good performance of hybrids under Sudan conditions.

Table 1. Pedigree of the lines and testers used in this study.

Parents	Pedigree	Source
L1	RING-B-S_1-2	Inbred line developed by ARC
L2	PR-89 B-5655-S_1-1	Inbred line introduced from CIMMYT, Mexico
L3	RING-B- S_1-3	Inbred line developed by ARC
L4	RING- B-S_1-1	Inbred line developed by ARC
L5	RING-A-S_1-1	Inbred line developed by ARC
L6	RING-A-S_1-2	Inbred line developed by ARC
L7	PR-89 B-5655-S_1-3	Inbred line introduced from CIMMYT, Mexico
T1	SOBSIY-HG AB	OPV introduced from CIMMYT, Kenya
T2	ACROSS- 500 HGY-B	OPV introduced from CIMMYT, Kenya
T3	CORRALE10 -02 SIYQ	OPV introduced from CIMMYT, Kenya
T4	BAILO- 02SIYQ	OPV introduced from CIMMYT, Kenya

Table 2. Mean performance of eleven parents for the measured traits in maize at two locations, season 2008.

Parents/	DT		PH		EL		ED		KW		GY	
Traits	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
L1	49.1	10	131.4	10	14.2	4	3.7	3	20.7	6	2.8	2
L2	50.0	9	148.5	4	15.0	1	3.6	7	19.9	11	2.6	5
L3	51.7	6	145.2	6	13.2	9	3.6	6	20.7	8	2.4	8
L4	50.0	8	152.0	3	14.3	3	4.1	1	20.3	10	2.1	11
L5	51.7	5	145.6	5	13.7	5	3.6	4	22.6	2	2.7	3
L6	49.1	11	139.1	9	13.4	8	3.4	11	22.1	3	2.2	9
L7	50.1	7	131.1	11	12.7	11	3.4	10	20.7	7	2.4	7
T1	52.7	4	139.3	8	13.6	7	3.9	2	21.3	5	2.2	10
T2	54.2	2	155.9	2	14.8	2	3.6	5	21.7	4	2.4	6
T3	55.2	1	157.7	1	13.7	6	3.5	8	22.8	1	2.6	4
T4	52.8	3	143.2	7	12.9	10	3.5	9	20.5	9	2.9	1
Mean	52.3		144.4		13.5		3.55		21.4		2.4	
CV%	6.7		10.0		13		9.8		14.5		27.8	
SE+-	0.98		2.33		0.38		0.083		0.81		0.146	

DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm), ED= ear diameter (cm), KW= kernels weight (g), GY= grain yield (t/ha)

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Table 3. Performance of 28 crosses and their average mid parent heterosis (MPH %) for the measured traits in maize at two locations, season 2008.

Crosses	DT			PH			EL		
	Mean	Rank	MPH%	Mean	Rank	MPH%	Mean	Rank	MPH%
T1 x L1	48.5	22	-3.29	14.6	13	7.45	14.2	6	2.14
T1 x L2	48.5	20	6.76	148.3	14	15.03	14.2	7	2.16
T1 x L3	50.0	13	1.00	149.8	7	14.47	13.7	18	3.47
T1 x L4	50.1	12	-1.63	145.0	18	7.88	13.3	22	-7.78
T1 x L5	49.0	19	-7.05	145.6	16	3.49	12.9	25	-1.83
T1 x L6	50.1	11	-6.03	152.3	4	2.29	14.3	5	-4.77
T1 x L7	46.8	27	-2.28	138.9	25	8.85	15.2	2	1.10
T2 x L1	52.3	1	-3.58	155.9	1	1.81	14.1	8	-16.01
T2 x L2	49.5	17	-1.00	149.2	10	4.18	13.2	21	-4.92
T2 x L3	51.2	4	0.66	145.2	17	3.82	12.2	27	-11.33
T2 x L4	50.2	9	-6.45	141.0	22	-3.25	13.2	24	-6.65
T2 x L5	49.5	18	-3.49	140.8	24	1.10	14.0	10	-5.58
T2 x L6	50.0	14	-5.66	143.4	19	-5.84	14.6	4	-8.37
T2 x L7	48.2	21	-3.23	149.1	11	-3.31	13.9	14	-5.85
T3 x L1	50.3	7	-3.85	150.3	6	-1.72	13.9	12	-11.85
T3 x L2	49.7	16	-6.58	149.8	8	4.81	13.7	16	1.75
T3 x L3	48.0	23	-4.89	139.2	24	5.43	13.3	20	0.00
T3 x L4	50.2	10	-6.03	142.9	21	-1.06	11.9	28	5.09
T3 x L5	51.2	3	-4.38	151.4	5	0.78	16.1	1	15.17
T3 x L6	50.8	5	-15.17	138.8	26	-11.26	13.9	13	3.22
T3 x L7	52.2	2	-4.76	135.1	28	5.54	14.1	9	9.30
T4 x L1	50.3	8	-2.89	146.1	15	-4.22	12.8	26	1.16
T4 x L2	50.0	15	0.33	149.8	9	-5.23	13.7	17	-2.80
T4 x L3	50.3	6	-5.88	154.2	3	8.18	14.0	11	-4.56
T4 x L4	47.5	25	-10.83	148.9	12	-5.23	13.6	19	6.16
T4 x L5	45.7	28	-7.84	135.1	27	-3.45	13.8	15	-7.33
T4 x L6	48.0	24	-2.48	154.2	2	-13.80	13.2	23	-1.85
T4 x L7	47.2	26	-8.92	143.1	20	-3.70	15.2	3	6.54
Mean	49			145.9			13.8		
CV%	6.7			10			13		
SE	0.64		1.36	3.8		7.37	0.46		0.94

DT= days to 50% tasseling, PH= plant height (cm), EL= ear length (cm), MPH% = mid parent heterosis.

Tables 3. Continued.

Crosses	GY								
	Mean	Rank	Rank	MPH%	Mean	Rank	MPH%	Mean	Rank
T1 x L1	3.8	4	3.60	22.0	9	2.28	3.1	5	29.60
T1 x L2	3.5	22	10.70	23.2	1	2.09	3.4	2	58.97
T1 x L3	3.7	9	2.33	21.7	14	0.70	2.9	12	16.16
T1 x L4	3.7	14	-2.18	22.1	7	2.24	2.9	11	1.16
T1 x L5	3.5	23	-2.70	22.2	6	4.46	3.0	10	47.24
T1 x L6	3.7	11	2.28	21.8	18	-2.32	2.7	21	23.26
T1 x L7	3.4	26	2.75	20.3	24	4.24	2.9	16	9.46
T2 x L1	4.0	1	2.28	20.8	22	1.26	3.3	3	10.13
T2 x L2	3.7	15	5.66	19.9	27	8.59	2.4	26	30.04
T2 x L3	3.7	16	4.72	22.8	3	8.59	3.1	7	19.49
T2 x L4	3.7	17	2.66	22.1	8	7.69	2.4	15	-7.19
T2 x L5	3.7	13	5.02	21.3	17	6.26	2.0	28	30.45
T2 x L6	3.3	27	3.70	20.1	25	10.71	3.1	8	28.56
T2 x L7	3.4	25	5.12	19.7	28	8.77	3.5	1	1.10
T3 x L1	3.6	20	4.11	21.6	16	-4.25	2.8	18	8.36
T3 x L2	3.7	7	7.55	21.7	13	7.30	2.9	13	53.90
T3 x L3	3.8	2	1.89	22.4	5	3.85	2.7	22	5.30
T3 x L4	3.7	12	0.00	20.6	23	0.63	3.0	9	-21.17
T3 x L5	3.6	21	0.46	22.5	4	1.80	2.9	17	37.49
T3 x L6	3.3	28	5.56	20.9	21	6.86	2.6	24	49.96
T3 x L7	3.5	24	6.05	21.0	20	3.89	2.2	27	-8.66
T4 x L1	3.7	18	-9.82	21.7	12	-10.99	2.5	25	30.72
T4 x L2	3.7	8	-6.91	21.7	15	-2.26	2.9	14	36.37
T4 x L3	3.8	5	5.99	23.2	2	-10.50	3.1	6	36.91
T4 x L4	3.7	6	-10.82	21.8	10	-8.10	3.3	4	15.44
T4 x L5	3.7	10	-7.14	21.8	11	-14.85	2.8	19	48.59
T4 x L6	3.8	3	-4.07	20.1	26	-1.86	2.7	20	10.36
T4 x L7	3.6	19	0.91	21.2	19	-2.79	2.6	23	4.38
Mean	3.7			21.3			2.8		
CV%	9.8			14.5			27.8		
SE	0.077		0.16	0.56		1.36	0.14		0.31

ED= ear diameter (cm), KW= kernels weight (g), GY= grain yield (t/ha) and MPH% = mid parent heterosis.

Heterosis

Table 3 showed high values of mid parent heterosis for the studied traits. Also, there was a great variation in the estimates of heterosis from cross to cross; however, certain traits exhibited higher heterosis than others. In this study, the magnitude of heterosis through average of mid-parent heterosis was adopted for traits under study as follow:

Days to 50% tasseling

Estimate of mid parent heterosis percentage for days to 50% tasseling pointed to negative heterosis as the favorable direction and ranged from-1.0 for (T2 x L2) to -15.7 for (T3 x L6). The earliest crosses across locations were T3 x L6 followed by T4 x L4 and T4 x L7 (Table 3). These crosses appear to be early in terms of maturity that would be suitable for water utilization efficiency and avoidance of late season stem borer infestation.

Plant height

Short maize plants are desirable for resistance to lodging; accordingly negative heterosis for plant height is desirable. Among the 28 F_1 top cross hybrids, 12 hybrids had negative mid parent heterosis and that the crosses were taller than their parents. However, the mid parent heterosis ranged from -1.06% to -13.8 % in the desirable direction and from 0.78% to 15.03% in the undesirable direction (Table 3). So the highest and negative heterosis with short plants among the crosses was given by T3 x L6 and T4 x L6. For grain yield, tall plants are not desirable, therefore, short ones have a vital importance in breeding programs for early maturity and resistance to lodging. So the best crosses with short plants were T3 x L6 followed by T4 x L4.

Ear length

The mid parent heterosis for ear length ranged from 0.10% to 15.2% in the desirable direction and from -1.83 % to -16 % in the undesirable direction (Table 3). However, among the F_1 topcross hybrid, 12 hybrids have positive mid parent heterosis. The best crosses (hybrids) were T3 x L5 (15.2%), T3 x L7 (9.3%) and T4 x L7 (6.5%). Hence, the magnitude of mid parent for certain traits like effective ear length can help in the identification of superior cross combinations for commercial exploration of hybrid (Singh and Narayan, 1993).

Ear diameter

The mid parent heterosis for ear diameter ranged from 0.46% to 10.69 % in the desirable direction and from -2.18% to -10.82 % in the undesirable direction (Table 3). Among the F_1 top cross hybrids, 19 crosses had positive mid parent heterosis. So the highest heterosis crosses were shown byT1 x L2 (10.7%) and T3 x L7 (6.1%).

One hundred Kernels weight

For one hundred kernel weight, mid parent heterosis ranged from 0.63% to 10.71% in the desirable direction and from -1.86% to -14.85% in the undesirable direction (Table 3). Among the F_1 top cross hybrids, 19 crosses had positive mid parent heterosis. However, the highest top crosses with the high mid parent heterosis for 100 kernels weight were T2 x L6 (10.7%), T2 x L7 (8.8%) and T2 x L2 (8.6%).

Grain yield

Mid parent heterosis for grain yield averaged over the two locations ranged from 1.10% to 59 % in the desirable direction and from -7.19% to -21.17% in undesirable direction (Table 3). Among the F_1 topcross, 25 hybrids had highly positive heterosis. This result indicates that most of crosses gained a positive heterosis and higher yielding than their parents. Also, the magnitude of mid parent heterosis in the favorable direction varied from cross to cross for grain yield. This indicates that the mechanism of expression of heterosis was different in various crosses under different environments. These finding are in agreement with those of Sharma and Shrikant (2006) who explained the differential behavior of various hybrids in different environments for expression of heterosis. However, the highest positive mid parent heterosis across two locations were shown by T1 x L2 (59%), T3 x L2 (54%) and T3 x L6 (50%). T1 x L2 combined high heterosis for grain yield with higher ear diameter. Also, there was a wide range of genetic variability and magnitude of mid parent heterosis for traits involving the line L2 and /or the tester T3 in their crosses. These traits included grain yield, ear diameter, days to 50% tasseling for L2 and plant height, effective ear length and diameter and grain yield for T3. Hence, their combined (T3 x L2) was the best second cross for the ear diameter and grain yield for evaluated material and their future research.

Conclusion

Based on the results obtained in this study, it could be concluded that variability and magnitude of heterosis was present in the evaluated material for grain yield. Such variability could be exploited in maize breeding especially for inbred L2 (PR-89B5655-S1-1) and tester T3 (CORRALE10-SIYQ) through recurrent selection method. Also, their combination (T3 x L2) resulted in considerable mid parent heterosis (54%) for grain combining with other traits like ear diameter. Therefore, mid parent maybe a useful guide for selection of crosses (hybrids) for future evaluation of maize hybrids through topcross method. The topcross yielded more than open pollinated varieties and the best hybrid (s) can be recommended for future testing in multi-location trails for commercial utilization.

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قوة الهجين لإنتاجية الحبوب ومكوناتها في محصول الذرة الشامية (*Zea mays* L.)

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الخلاصة

تحسين صفات الإنتاجية لمحصول الذرة الشامية هي الغاية المنشودة من خلال التربية لإنتاج الهجن والتي تعتمد على تحديد أفضل الآباء وأكثرها قوة لإنتاج الهجين. لذا أجريت هذه الدراسة لتقدير التباين الوراثي و قوة الهجين لأربعة سلالات تربية داخلية وسبعة أصناف مستقدمة مفتوحة التلقيح من الذرة الشامية (*Zea mays* L.) تحت ظروف ري مستدام، موسم 2008 .استخدم تصميم القطاعات العشوائية الكاملة بثلاثة مكررات لتنفيذ التجربة. الصفات التي تمت دراستها شملت 50% لعدد أيام الإزهار المذكر ، طول النبات، طول الكوز، حجم الكوز، وزن المائة حبة وإنتاجية الحبوب.أظهرت النتائج فروق معنوية لكل الصفات في الموقعين وأكثر تباينا وراثياً في طول النبات وفترة النضج. وجد أن الهجن متأخرة في الأزهار وفترة النضج مقارنة بالآباء. أما طول وحجم صفات القندول فقد وجد أن لها أهمية كبرى في زيادة الإنتاجية وأفضل الهجن هيT1 x L7 و T2 x L1 .أعلى الهجن إنتاجية هى T2 x L7 (3.45طن/هكتار) و T1 x L2 (3.44 طن/هكتار) وT2 x LI(3.32 طن/هكتار) و T4 x L4(3.30طن/هكتار) و T1 x L1(3.13طن/هكتار). الهجن التي أظهرت أعلى قوة هجين في مدني هي T3 x L3و T4x L4 وفي معتوق للهجنT1 x L5, T4 x L5 وT4 x L6 وعبر الموقعين هى T1 x L2(59%)و T3 Xl2(45%) وT3 x L6(50%) . ومن خلال هذه الدراسة نوصى باستخدام هذه الهجن بعد إجراء بعض الاختبارات الخاصة بالإنتاجية في مواقع ومواسم مختلفة.