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Genetic analysis of fatty acids, oil and protein percent in maize (*zea mays l.*) Using partial diallel mating design

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ABSTRACT

The aim of this research is to study the effect of herbs extracts (Mint, Dill, Tarragon and the combination of these herbs) supplementation on the chemical composition, antioxidant activities, rheological and sensory properties of local soft cheese (Paneeri Salik) during three weeks of storage. The addition ratio of herb extract was 6.5 % v/w for each cheese treatment then compared with the control cheese treatment. Only the moisture percentage was significantly different at level (P<0.05) in the cheese treatments which contain herbs from the control treatment, the herbs cheese moisture decreased in three weeks whereas the other chemical properties (Fat, Protein, Carbohydrate, Ash and Acidity) were not significantly different. Mint, Dill, Tarragon and mix herbs supplementation increased scavenging of free radicals and enhanced the antioxidant properties of Salik cheese, the DPPH were (79.85, 94.88, 90.52, 97.33, 99.18)% in each of (Control, Mint, Dill, Tarragon, and mix herbs), respectively in the first week then were decreased to (87.10, 83.62, 87.51, 83.46)% in the (Mint, Dill, Tarragon, and Mix herbs) compared to control which became 98.81% in the third week of storage. The herbs affected the hardness of cheese, which increased by increasing the storage periods. Sensory evaluation was acceptable especially in mint cheese but a few decreases in flavor were detected in the cheeses treated with herbs mix and Tarragon after three weeks of storage.

التحليل الوراثي للأحماض الدهنية، النسبة المؤية للزيت و البروتين للذرة الصفراء بأستخدام تصميم التزاوج ثنائي ألأليل الجزئي (*Zea mays L*)

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الخلاصة

تضمنت الدراسة جميع الهجن الفردية الممكنة بين ثمانية سلالات من الذرة (MGW 16, NADH 102, NADH 704, NADH 706, NADH 52, ZY 52, NADH 905, MSI 4279). وفق طريقة التهجين التبادلي الجزئي، خلال الموسم الربيعي 2020 في موقع قلياسان لأكمال خطة عمل هذه التجربة والتي أجريت خلال الموسم الربيعي 2021 في موقعين مختلفين في كوردستان العراق، قلياسان و كاني بانكة بأستخدام تصميم القطاعات العشوائية الكاملة RCBD بثلاثة مكررات. ان جميع التراكيب الوراثية (8 الأباء + 12 هجين الجيل الأول) خضعت للتحليل الكيميائى لتقدير نسبة الزيت والبروتين و الأحماض الدهنية (بالميتيك، ستياريك، لينوليك، أوليك، لينولينيك)، حيث أشارت نتائج التحليل الأحصائي الى ان متوسط المربعات للهجن و gca كانت عالية المعنوية لجميع الصفات المدروسة. متوسط المربعات الخاصة بالأباء كانت عالية المعنوية لمعظم الصفات. الهجين MSI 4279 × NADH 52 والأب MSI 4279 أظهرت أعلى قيمة لجميع الصفات. لوحظ قوة هجين موجبة لجميع الصفات، في حين أظهر الهجين MSI 4279 × NADH 52 أعلى قوة تهجن موجبة لجميع الصفات في كلا الموقعين. مشاركة الفعل الجيني الأضافي وغير الأضافي كانا مهمين في توريث هذه الصفات في الموقع الأول، أما الموقع الثاني فأن مشاركة الفعل الجيني الأضافي كان أعلى أهمية من غير الأضافي لجميع الصفات. كان هناك ارتباط معنوي وموجب بين كل زوج من الأحماض الدهنية لكلا الموقعين، بينما كان هناك أرتباط معنوي وموجب لحاصل الحبوب مع لينوليك وأوليك أسيد في موقع كانى بانكة.

الكلمات المفتاحية: التحليل الوراثي ، أحماض دهنية، ازيت ، بروتين ، ذرة صفراء.

INTRODUCTION

Demand for vegetable oils by the food and the industrial sector is expected to increase significantly in the near future (Ali and Ullah, 2012). Maize contains about 3–4% oil (Laurie *et al.*, 2004) in the maize germ, an oil-rich portion of the kernel (Moreau *et al.*, 2005). It is a concentrated source of energy, and contains essential polyunsaturated fatty acids (PUFAs) and vitamin E (Sanjeev *et al.*, 2014). It is considered to be better than most of other edible oils due to its fatty acid composition and stability during storage and cooking. There is about 3–4 % oil content in maize kernel. However, more than 6–7 % oil is reported in high-oil corn genotypes. High-oil lines, in general, have reduced yields (Singh *et al.*, 2014). The partial diallel involves two heterotic groups of parents, maximizing the information about the study groups with a lower number of crossings, yet the reciprocal effects are generally not estimated, allowing loss of additional information. Circulating diallel are represented in the design by the same number of crossings, still less than p-1, reducing the number of total combinations; however, losses of information occur regarding certain hybrid combinations, for being absent. A variable number of crossings represents incomplete diallel; this design results from combinations losses. In the unbalanced diallel are estimated all hybrid combinations and also the other generations are represented, but in variable frequency due to the unequal number of replicates per treatment (Cruz *et al.*, 2012).

Nearly 95% of the maize oil is composed of palmitic, stearic, oleic and linoleic acid; whereas, linolenic acid (omega 3 fatty acid) content varies from 0.5 to 2.0% (Jellum and Widstrom, 1970). Currently, India produces about 5 thousand tons of maize oil (FAOSTAT, 2017). The international demand for improved quality traits in maize hybrids such as oil, protein, carbohydrates and starch are increasing because of its nutritional reasons (Bilgin *et al.,* 2010). There are many ways to improve maize depends most of them on the conduct of the election and vary according to the genetic material studied and the length of time it takes. Improving the quality of maize grain of the important objectives of plant breeders and particularly grain content of protein and oil, have been the work of oil to improve the protein began almost a hundred years and despite the use of maize grain as their primary source of energy they produce annually more than soy protein (Al-Azawi *et al.*, 2020). Oleic acid which has some advantages over the other fatty acids in terms of cooking and health (Mattson and Grundy, 1985) is normally found in corn oil at a level of about 25%, and genotypes with higher levels of this fatty acid is economically more valuable (Mikkilineni and Rocheford, 2003). Ahmed (2006)Pointed to be a good way full-diallel cross to improve the protein content in maize grain, has proved it can improve grain yield and protein at the same time together to get to the level of 11-12% protein in a manner fully diallel cross. Most studies that have been applied on the open-pollination and self-pollination groups indicate that success in getting the highest percentage of heterosis be using genetic models of a broad-based (Baktash and AL-Azawi, 2007). High-quality maize oil, having low level of saturated fatty acids, is highly suitable for human consumption. It is considered to be better than most of other edible oils due to its fatty acid composition and stability during storage and cooking. There is about 3–4 % oil content in maize kernel. However, more than 6–7 % oil is reported in high-oil corn genotypes. High-oil lines, in general, have reduced yields (Singh *et al.*, 2014). The linoleic and oleic acids were the most abundant fatty acids present in the maize samples. The harvesting year did not affect the oleic acid content while the other parameters were determined to be statistically significant (Kaplan *et al.*, 2017).Dubey *et al.* (2009) found heterosis over mid parents for seed oil content and grain yield per plant such as in the hybrid L10xT1-VC that revealed the hybrid performance for oil content (7.02%) and grain yield per plant (76.25g). Hybrids with higher oil content trend to have lower yield in terms of tonnages per hectare; for example, after 22 cycles of selection, the oil content of "Alexho Synthetic" was increased from 6.2 to 12.9 %, but the yield of the maize was reduced from 8.50 to 5.69 t/ha (Alexander *et al.*, 1989). Sreckov *et al.* (2011) found low correlation between grain yield and oil content in two testcross populations of maize. Kaushik *et al.* (2004) studied the protein and oil concentration in heterotic crosses of maize. Out of 72 crosses studied, 30 crosses exhibited standard heterosis either for maturity traits or for protein and oil concentration. One cross showed significant and commercially acceptable standard heterosis for grain yield per plant (22.37%) followed by protein concentration (20.40%) and oil concentration (7.35%). The average degree of dominance (ā) was zero for diallel hybrids for oil and protein percentage. The average degree of dominance (ā) for reciprocal hybrid was zero for protein percentage while more than one for oil percentage (1.5). The heritability percentage was low for broad and narrow sense for oil and protein percentage for diallel hybrids and reciprocal hybrids. Genetic variance dominance values σ^2D and genetic variance additive values σ^2A was low for characters for diallel hybrids and reciprocal hybrids (Al-Azawi et al., 2020).

Heritability in broad and narrow sense was high for all traits showing the importance of additive gene effect which controlled the inheritance of these traits. The estimates of the quadratic components showed predominance of non-additive genetic effects in the trait control. However, for

Oil Content and crude protein, the non-additive effect had a clearly negative influence on the hybrid combinations (Renuka et al., 2008).

MATERIAL AND METHODS

This experiment was conducted in a partial diallel cross was implemented according to Kempthorne and Curnow 1961, using eight maize inbred lines, which have been received from Baghdad University, and three samples of crosses for each inbred line to produce 12 single crosses. Replicated at two locations, Qlyasan and Kanipanka in Sulaimani- Iraq. The current study used 8 parents from inbred lines and their F1 crosses. All genotypes (8 parents + 12 F_1s hybrids) were prepared to chemical analysis for estimating oil%, protein% and fatty acids (Palmitic, Stearic, Linolic, Oleic, Linolenic and Oil). The experiment was conducted in a randomized complete block design replicated three times in each location. Each genotype is planted in one row 3-meter-long 0.75 meter spacing between rows and 0.25m spacing between plants within a row. Least Significant Differences (LSD0.05) was carried out to compare the characters means.

Table 1. Studied breeding materials

No.	Genotypes and parents	Parentage
1	1×4	MGW 16 × NADH 706
2	1×5	MGW 16 × NADH 52
3	1×6	MGW 16 × ZY 52
4	2×5	NADH 102 × NADH 52
5	2×6	NADH 102 × ZY 52
6	2×7	NADH 102 × NADH 905
7	3×6	NADH 704 × ZY 52
8	3×7	NADH 704 × NADH 905
9	3×8	NADH 704 × MSI 4279
10	4×7	NADH 706 × NADH 905
11	4×8	NADH 706 × MSI 4279
12	5×8	NADH 52 × MSI 4279
13	1	MGW 16
14	2	NADH 102
15	3	NADH 704
16	4	NADH 706
17	5	NADH 52
18	6	ZY 52
19	7	NADH 905
20	8	MSI 4279

A sample was taken for each genotype in each replicate, meaning twenty genotypes (12 hybrids + 8 parents) to perform the following measures

Extract the fat from the model: The fat was estimated based on the (AOAC 1995) method using the Soxhlet fat extraction device.

Fat esterification: The sample was prepared according to the method approved by (AOAC 1995) which depends on the esterification of fats by interacting with methanolic potassium hydroxide and prepared by dissolving 11.2 gm of potassium hydroxide and dissolving it in 100 ml of methanol, then taking 1 gm of fat and adding to it 8 ml of methanolic potassium hydroxide. With 5 ml of hexane, shake quickly for 30 seconds and then leave to separate into two layers, taken from the top layer (hexane layer) that contains the esterified fat and injected into the device. AOAC (Association of Official Analytical Chemists) 1995. Official Methods of Analysis, 16th Edition. AOAC International, Gaithersburg, MD.

Chromatographic analysis of the sample: The fatty acid compounds were analyzed using a gas chromatography device (GC - 2010) of the Japanese-origin Shimadzu model, where the ionized flame detector (FID) was used and a capillary column type (SE-30) with lengths (30m × 0.25 mm) was used according to the following conditions:

Table 2. The paragraph name and temperature for fatty acid analysis

No.	Paragraph name	temperature
1	Injection area temperature	280 C
2	Detector temperature	310 C
3	Separator column temperature	120 – 290 (10 C / MIN)
4	gas flow rate	100 Kpa

Genetic Parameters:

eneral Combining Ability (GCA), Specific Combining Ability (SCA), Heterosis %, Heritability in Broad Sense, Heritability in Narrow Sense and Average Degree of Dominance (ā) Singh and Chaudhry (1985).

Standard Error:

$$Average\ Variance\ (g_i - g_i) = 2\left[\frac{na^0}{n-1} - \frac{1}{2s(n-1)}\right]\left[\left(\frac{\sigma^2_{sca} + \sigma^2_e}{r}\right)\right]$$

Where,

a^0: The diagonal element of the inverse matrix (A^{-1})

$$S.E.(g_i - g_i) = [(Average\ Variance\ )]^{\frac{1}{2}}$$

Heterosis:

It was estimated as the percentage deviation of F_1s hybrid from mid parental value: AGB301 (2004).

$$Heterosis\ (H)\% = \frac{F_1' - M.P}{M.P} \times 100$$

Where: F'_1: Mean of the hybrid,

M.P: Mid Parental value.

Where: $M.P = \frac{P_1 + P_2}{2}$

P_1 : Parent no. 1,

P_2 : Parent no. 2.

Heritability:

Heritability in broad and narrow sense was estimated depending on the variance of general and specific combining abilities, and on the variance of experimental error according to Singh and Chaudhry (1985) as follows:

$$h^2_{b.s} = \frac{\sigma^2_G}{\sigma^2_P} = \frac{\sigma^2_A + \sigma^2_D}{\sigma^2_A + \sigma^2_D + \sigma^2_e} = \frac{2\sigma^2_{gca} + \sigma^2_{sca}}{2\sigma^2_{gca} + \sigma^2_{sca} + \sigma^2_e}$$

$$h^2_{n.s} = \frac{\sigma^2_A}{\sigma^2_P} = \frac{\sigma^2_A}{\sigma^2_A + \sigma^2_D + \sigma^2_e} = \frac{2\sigma^2_{gca}}{2\sigma^2_{gca} + \sigma^2_{sca} + \sigma^2_e}$$

The average degree of dominance (ā)

The degree of dominance for the studied traits was estimated as follows:

$$\bar{a} = \sqrt{\frac{2\sigma^2_D}{\sigma^2_A}} = \sqrt{\frac{2\sigma^2_{sca}}{2\sigma^2_{gca}}} = \sqrt{\frac{\sigma^2_{sca}}{\sigma^2_{gca}}}$$

Studied characters: Palmitic%, Stearic%, Linolic%, Oleic%, Linolenic%, Oil% and Protein%.

RESULTS AND DISCUSSIONS

The analysis of variance present in table (3) revealed that the mean squares of the crosses and *gca* was highly significant for all fatty acid compositions, oil% and protein% at Qlyasan location, while due to *sca* it was highly significant for stearic acid, linolenic acid and oil%, significant for palmitic and oleic acid, and non-significant for linolic acid and protein%. From the same table it was obtained that the mean squares of parents were highly significant for all fatty acid compositions and protein% and it was not significant for oil% at the same location. The partition of the sum of squares of genotypes in the sum of squares for general *gca* and specific *sca* combining ability showed that both *gca* and *sca* were significant, indicating that additive and non-additive effects were involved in the genetic control of these traits (Werle *et al.*, 2014).

Table 3. Mean squares of variance analysis for fatty acid compositions at Qlyasan location

Source of Variance	**Replications**	**Crosses**	**gca**	**sca**	σ_e^2	**Replications**	**Parents**	σ_e^2
df / Characters	2	11	7	4	22	2	7	14
Palmitic (%)	0.0002	0.929^{**}	1.223^{**}	0.416^{*}	0.110	0.002	0.139^{**}	0.015
Stearic (%)	0.0002	0.557^{**}	0.690^{**}	0.324^{**}	0.074	0.004	0.020^{**}	0.0015
Linolic (%)	0.0006	1.511^{**}	2.034^{**}	0.596 n.s	0.277	0.027	0.257^{**}	0.013
Oleic (%)	0.0002	1.750^{**}	2.183^{**}	0.992^{*}	0.239	0.0012	0.253^{**}	0.0017
Linolenic (%)	0.0002	0.133^{**}	0.173^{**}	0.062^{**}	0.014	0.003	0.024^{**}	0.0008
Oil (%)	0.0114	0.514^{**}	0.708^{**}	0.174^{**}	0.039	0.137	0.016 n.s	0.0096
Protein (%)	0.106	0.837^{**}	1.232^{**}	0.145 n.s	0.080	0.042	0.102^{**}	0.004

The average performance of crosses due to fatty acid composition, oil% and protein% for F_1 crosses present in table (4) revealed that the cross 5×8 showed maximum percentage of all fatty acid compositions, oil% and protein % reached 12.100, 2.51, 50.08, 23. 94, 1.18, 5.28 and 9.18% for palmitic, stearic, linolic, oleic, linolenic, oil% and protein % respectively, while the minimum value for these compositions recorded by the cross 2×6, recording 10.44, 1.22, 48.04, 21.64 and 0.56% respectively, but for oil% it was 4.13% produced by the cross 1×4 and for protein% it was 7.18% showed by the cross 1×6. Lambert (2001) reported that the oil concentration of widely used maize hybrids varies between 3.5-5%.

Table 4. Average of studied fatty acid compositions for the F_1 crosses at Qlyasan location

Crosses	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
1×4	10.795	1.605	48.490	22.205	0.685	4.125	8.135
1×5	10.540	1.260	48.220	21.715	0.580	4.190	8.190
1×6	10.515	1.340	48.175	21.815	0.585	4.190	7.180
2×5	11.485	2.135	49.490	23.075	0.930	4.935	8.850
2×6	10.440	1.215	48.040	21.640	0.560	4.135	8.125
2×7	10.860	1.610	48.880	22.470	0.690	4.400	8.455
3×6	10.740	1.565	48.375	22.075	0.670	4.315	8.345
3×7	10.590	1.275	48.260	21.865	0.605	4.200	8.230
3×8	10.575	1.430	48.250	21.945	0.610	4.225	8.250
4×7	11.840	2.250	49.845	23.625	1.100	5.125	9.090
4×8	11.170	1.945	49.200	22.650	0.815	4.675	8.635
5×8	12.100	2.505	50.080	23.940	1.175	5.275	9.175
LSD (≤0.05)	0.563	0.462	0.8905	0.8283	0.1978	0.333	0.478

The average of fatty acid composition, oil% and protein% performed by parents at Qlyasan location in table (5), confirming that the parent 8 showed maximum percent of these traits reached 10.47, 1.26, 47.86, 20.93,0.54, 3.85 and 8.00% respectively, while the lowest value for palmitic, oleic and linolic acid and protein% recorded by parent 3, showing 9.73, 20.01, 0.32 and 7.45% respectively, while for stearic acid the lowest value was 1.02% obtained by parent 2, but for linolic acid it was 47.09% produced by parent 1. The lowest value for oil% was 3.60% showed by parent 5.

Table 5. Average of studied fatty acid composition for Maize parents at Qlyasan location

Parents	**Palmitic (%)**	**Stearic (%)**	**Linolic (%)**	**Oleic (%)**	**Linolenic (%)**	**Oil (%)**	**Protein (%)**
1	10.093	1.073	47.090	20.153	0.337	3.693	7.543
2	10.090	1.023	47.270	20.207	0.340	3.670	7.513
3	9.727	1.053	47.200	20.007	0.317	3.677	7.453
4	10.290	1.137	47.443	20.263	0.333	3.710	7.730
5	10.267	1.183	47.743	20.603	0.480	3.597	7.843
6	10.163	1.183	47.530	20.343	0.470	3.753	7.700
7	10.180	1.200	47.807	20.413	0.477	3.713	7.767
8	10.473	1.260	47.863	20.933	0.543	3.850	8.003
LSD ($p \leq 0.05$)	0.216	0.069	0.1959	0.073	0.049	0.172	0.108

The estimation of heterosis values as the percentage of F_1s deviated from mid parental values for fatty acid compositions, oil% and protein% present in table (6) at Qlyasan location. It was revealed that all heterosis values due to all fatty acid compositions and oil% for the F_1s crosses showed positive values. The highest positive values due to heterosis for palmitic, stearic, linolic and oil% reached 16.68, 105.05, 4.76 and 41.67% respectively produced by the cross 5×8, while for oleic, linolenic acid and protein% the maximum percentage of heterosis was 16.16, 171.60 and 17.32% obtained from the cross 4×7. The cross 2×6 exhibited minimum heterosis percentage for palmitic, stearic, linolic, linolenic acid and oil%, showing 3.09, 10.12, 1.35, 38.27 and 11.41% respectively, while for oleic acid it was 6.56% recorded by the cross 1×5. The cross 1×6 showed negative heterosis for protein%, recording -5.79%. Oliveira *et al.* (2004) reported that the oil content among the hybrid crosses, CMS 456 x CMS 463 (6.84 g/100 g) presented the highest value. The average heterosis (-9.83%) indicates average dominance of the alleles for low oil content (Abou-Deif *et al.*, 2012).

Table 6. Estimation of heteroses values (percentage of F1s deviation from mid parental values) for fatty acid compositions at Qlyasan location

Crosses	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
1×4	5.92	45.25	2.59	9.88	104.48	11.44	6.53
1×5	3.54	11.67	1.69	6.56	42.04	14.95	6.46
1×6	3.82	18.76	1.83	7.74	45.04	12.53	-5.79
2×5	12.84	93.50	4.17	13.09	126.83	35.83	15.26
2×6	3.09	10.12	1.35	6.73	38.27	11.41	6.81
2×7	7.15	44.83	2.82	10.64	68.98	19.19	10.67
3×6	7.99	39.94	2.13	9.42	70.34	16.15	10.14
3×7	6.40	13.17	1.59	8.19	52.52	13.67	8.15
3×8	4.70	23.63	1.51	7.21	41.86	12.27	6.75
4×7	15.68	92.58	4.66	16.16	171.60	38.08	17.32
4×8	7.59	62.31	3.25	9.96	85.93	23.68	9.77
5×8	16.68	105.05	4.76	15.27	129.64	41.67	15.80
SE	1.342	9.923	0.361	0.932	12.458	3.250	1.744

The estimation of some genetic parameters for fatty acid composition, oil% and protein% at Qlyasan location present in table 7. It was confirmed that the magnitude of σ^2_{gca} was higher than the σ^2_{sca} due to palmitic and linolic acid, oil% and protein%, while for stearic, oleic and linolenic acid the magnitude of σ^2_{sca} was larger than the σ^2_{gca}. The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was higher than one for palmitic, linolic acid, oil% and protein% 1.027, 1.751, 1.533 and 6.499 respectively, while for the others it was less than one. The average degree of dominance was more than one for stearic acid, oleic acid and linolic acid reached 1.324, 1.275 and 1.064 respectively. Indicating the high participation of both additive and non-additive gene effect in controlling the inheritance of these traits. Heritability in broad sense was high for almost all traits, while it was low to moderate in narrow sense for fatty acid composition, and high for oil and protein%.

Table 7. Estimations of some genetic parameters for fatty acid compositions at Qlyasan location

Genetic parameters	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
σ^2_e	0.1104	0.0744	0.2766	0.2393	0.0136	0.0386	0.0797
σ^2_{gca}	0.1046	0.0474	0.1864	0.1544	0.0143	0.0692	0.1410
σ^2_{sca}	0.1019	0.0831	0.1065	0.2510	0.0162	0.0451	0.0217
$\sigma^2_{gca}/\sigma^2_{sca}$	1.027	0.5704	1.751	0.615	0.8835	1.533	6.499
σ^2_A	0.2092	0.0949	0.3729	0.3088	0.0287	0.1383	0.2820
σ^2_{Dr}	0.1019	0.0831	0.1065	0.2510	0.0162	0.0451	0.0217
$\bar{\alpha}$	0.9870	1.3240	0.7558	1.2749	1.0639	0.8078	0.3923
h^2_{bs}	0.7380	0.7051	0.6341	0.7006	0.7671	0.8260	0.7922
h^2_{ns}	0.4963	0.3758	0.4933	0.3865	0.4899	0.6228	0.7356

The analysis of variance of fatty acid components, oil and protein% at Kanipanka location present in table 8. The mean squares of crosses, and *gca* was highly significant for traits present in this table, while for *sca* it was highly significant for stearic acid, linolenic acid, oil% and protein%, but it was significant for the rest. The mean squares due to the parents was highly significant for stearic acid, oleic acid and linolenic acid, and it was not significant for the rest.

Table 8. Mean squares of variance analysis for fatty acid composition at Kanipanka location

Source of Variance	Replications	Crosses	*gca*	*sca*	σ_e^2	Replications	Parents	σ_e^2
df / Characters	2	11	7	4	22	2	7	14
Palmitic (%)	0.0002	1.1512 **	1.6630 **	0.2555 *	0.0696	0.2025	0.075 n.s	0.1207
Stearic (%)	0.0001	1.3241 **	1.8756 **	0.3591 **	0.0726	0.003	0.0295 **	0.0011
Linolic (%)	0.0124	2.6214 **	3.7663 **	0.6179 *	0.1500	0.4349	0.1746 n.s	0.2271
Oleic (%)	0.0161	1.7953 **	2.6077 **	0.3735 *	0.0941	0.0020	0.2629 **	0.0043
Linolenic (%)	0.0003	0.3938 **	0.5562 **	0.1097 **	0.0120	0.0002	0.0254 **	0.0013
Oil (%)	0.0027	0.714**	1.0165 **	0.185**	0.0132	0.0006	0.0165 n.s	0.0089
Protein (%)	0.001	0.709**	1.0156 **	0.173**	0.0122	0.0035	0.085 n.s	0.042

The average performance of crosses due to fatty acid compositions, oil and protein% at Kanipanka location present in table 9, revealing that the cross 5×8 produced maximum values for all traits present in this table recording 12.18, 3.14, 52.36, 24.80, 1.79, 5.52 and 9.60% for palmitic, stearic, linolic, oleic, linolenic, oil and protein% respectively. the cross 1×4 showed the minimum values for these traits recording 10.23, 1.15, 49.25, 22.15, 0.58, 4.02 and 8.02% respectively. Some workers reported that the typical profile of fatty acids in a maize kernel is composed of 57.9% linoleic acid, <1% Linolenic acid, 25.2% oleic acid, 11.6% Palmitic acid and 1.8% stearic acid (White and Weber, 2003, Abou Gabal and Zaitoun, 2015).

Table 9. Average of studied characters for the F1 crosses at Kanipanka location

Crosses	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
1×4	10.23	1.15	49.25	22.15	0.580	4.020	8.020
1×5	10.65	1.58	50.36	23.19	0.850	4.420	8.500
1×6	10.33	1.20	49.55	22.58	0.650	4.080	8.140
2×5	11.53	2.66	51.31	23.81	1.310	5.135	9.140
2×6	11.13	2.04	50.89	23.63	1.035	4.380	8.415
2×7	10.63	1.63	50.28	23.13	0.815	4.380	8.410
3×6	11.23	2.28	51.08	23.75	1.035	4.835	8.855
3×7	10.54	1.36	50.12	23.00	0.790	4.295	8.355
3×8	11.18	2.18	50.99	23.58	0.990	4.720	8.790
4×7	11.91	2.90	52.11	24.66	1.580	5.345	9.345
4×8	11.39	2.36	51.24	23.97	1.080	4.900	8.920
5×8	12.18	3.14	52.36	24.80	1.790	5.520	9.600
LSD (≤0.05)	0.447	0.456	0.656	0.52	0.1856	0.195	0.187

The average performance of parents due to fatty acid composition, oil and protein% at Kanipanka location present in table 10. Maximum values for the studied traits were 10.39, 1.30, 47.96, 20.98, 0.58, 3.87 and 8.01% respectively recorded by parent 8, while the minimum values for palmitic, oleic and linolic acid was 9.88, 20.08 and 0.32 respectively recorded by parent 3, while parent 2 showed the lowest value for stearic, oil and protein% showing 1.00, 3.62 and 7.52% respectively. the lowest percentage of linolic acid was 47.23% produced by parent 1. Previously it was confirmed that the linoleic and oleic acids were the most abundant fatty acids present in the maize samples (Kaplan et al., 2017).

Table 10. Average of studied characters for Maize parents at Kanipanka location

Parents	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
1	10.063	1.097	47.227	20.180	0.367	3.733	7.617
2	10.123	1.000	47.497	20.220	0.360	3.617	7.523
3	9.880	1.017	47.267	20.077	0.317	3.687	7.540
4	10.320	1.117	47.507	20.307	0.340	3.733	7.563
5	10.237	1.200	47.623	20.693	0.500	3.653	7.707
6	10.183	1.150	47.557	20.373	0.457	3.713	7.803
7	10.220	1.200	47.767	20.420	0.480	3.740	7.570
8	10.387	1.297	47.957	20.977	0.577	3.867	8.010
LSD (p≤0.05)	0.6085	0.059	0.835	0.114	0.064	0.165	0.359

The percentage of heterosis for fatty acid composition, oil and protein% at Kanipanka location present bin table (11). It was confirmed that all crosses showed positive heterosis for all traits. Maximum heterosis percentage for palmitic, stearic, linolic and oil% were 18.12, 151.54, 9.56 and 46.81% recorded by the cross 5×8, while for oleic, linolenic and protein% the highest heterosis percentage was 21.10, 285.37 and 23.50% respectively showed by the cross 4×7. The cross 1×4 gave minimum heterosis values for all traits reached 0.33, 3.92, 3.98, 9.42, 64.15, 7.68 and 5.67% respectively. Significant and commercially acceptable standard heterosis for grain yield per plant (22.37%) followed by protein concentration (20.40%) and oil concentration (7.35%) (Abou-Deif *et al.*, 2012). High heterosis for oil content up to 28.76% in the cross (ICRISAT-279 x Sarhad HSRB) in autumn and 31.92% (ICRISAT-1849 x FRD-73) in spring season (Renuka *et al.*, 2008).

Table 11. Heteroses values (percentage of F1s deviation from mid parental values) for studied characters at Kanipanka location

Crosses	**Palmitic (%)**	**Stearic (%)**	**Linolic (%)**	**Oleic (%)**	**Linolenic (%)**	**Oil (%)**	**Protein (%)**
1×4	0.33	3.92	3.98	9.42	64.15	7.68	5.67
1×5	4.88	37.59	6.19	13.47	96.15	19.68	10.94
1×6	1.99	6.82	4.55	11.36	57.89	9.58	5.58
2×5	13.21	141.82	7.87	16.37	204.65	41.27	20.03
2×6	9.62	89.30	7.08	16.40	153.47	19.51	9.81
2×7	4.46	47.73	5.56	13.80	94.05	19.08	11.44
3×6	11.95	110.00	7.74	17.40	167.67	30.68	15.42
3×7	4.83	22.71	5.48	13.59	98.33	15.66	10.59
3×8	10.28	88.47	7.10	14.87	121.64	24.98	13.05
4×7	15.97	150.36	9.39	21.10	285.37	43.04	23.50
4×8	10.01	95.58	7.35	16.12	135.64	28.95	14.55
5×8	18.12	151.54	9.56	19.03	232.51	46.81	22.16
SE	1.605	15.677	0.504	0.928	20.105	3.721	1.696

The estimation of some genetic parameters for fatty acid compositions, oil and protein% at Kanipanka location present in table 12, confirming the predominance of the magnitude of σ^2_{gca} on σ^2_{sca} for all traits, making the ratio of σ^2_{gca} / σ^2_{sca} be more than one for these characters, showing 2.944, 2.059, 2.617, 3.11, 1.778, 1.879 and 2.045 for palmitic, stearic, linolic, oleic linolenic, oil and protein% respectively. This confirmed the importance of additive gene effect in the inheritance of these traits. The average degree of dominance was found to be less than one for all traits recording 0.583, 0.697, 0.618, 0.567, 0.750, 0.730 and 0.699 respectively. Heritability in broad and narrow sense was high for all traits showing the importance of additive gene effect which controlled the inheritance of these traits. The estimates of the quadratic components showed predominance of non-additive genetic effects in the trait control. However, for Oil Content and crude protein, the non-additive effect had a clearly negative influence on the hybrid combinations (Renuka et al., 2008).

Table 12. Estimations of some genetic parameters for studied characters at Kanipanka location

Genetic Parameters	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)
σ_e^2	0.0696	0.0726	0.1500	0.0941	0.0120	0.0132	0.0122
σ_{gca}^2	0.1825	0.1966	0.4081	0.2896	0.0579	0.1077	0.1093
σ_{sca}^2	0.0620	0.0955	0.1560	0.0931	0.0325	0.0574	0.0534
$\sigma_{gca}^2/\sigma_{sca}^2$	2.944	2.059	2.617	3.1097	1.778	1.879	2.045
σ_A^2	0.3649	0.3932	0.8162	0.5792	0.1158	0.2155	0.2186
σ_D^2	0.0620	0.0955	0.1560	0.0931	0.0325	0.0574	0.0534
$\bar{\alpha}$	0.5828	0.6969	0.6182	0.5671	0.7499	0.7296	0.6992
h_{bs}^2	0.8599	0.8706	0.8663	0.8772	0.9251	0.9537	0.9571
h_{ns}^2	0.7351	0.7005	0.7273	0.7557	0.7221	0.7532	0.7691

It was confirmed from table (13) the presence of highly significant and positive correlation between palmitic acid with each of stearic, linolic, oleic, linolenic, oil% and protein%. Stearic acid showed also highly significant and positive correlation with any of the other fatty acids, oil% and protein% at both locations. The same for linolic, oleic, linolenic, oil% and protein%, while not significant association was observed between kernel yield with each of the studied traits at both locations. Previously (Okporie and Obi, 2004, Okporie and Obi, 2002, Obi and Onyishi, 1994, Raman *et al.*, 1983), and (Jaya Mohan Rao *et al.*, 1984), found that protein and oil contents and kernel weight were not correlated in random-mated population selected in protein content. Negative association between the protein and oil ratios reported by others (Dudley *et al.*, 2007). But (Abou-Deif et al., 2012) reported that the relationship between protein and oil contents was negative in the majority of maize inbred lines. Seiam and Khalifa (2007) showed that phenotypic correlation coefficients manifested significant negative correlation (-0.55) between oil and protein content in the studied genotypes. Medici *et al.* (2009) who observed positive correlation between lysine and oil content, which indicated the possibility of achieving both high lysine and oil content in maize grains. It was indicated that a negative correlation of yield increase with the CP and OC (Prasanna *et al.*, 2001, Oliveira et al., 2004).

Table 13. The simple correlation coefficient between each pair of traits at Qlyasan location (upper values) and Kanipanka location (lower values)

Characters	Palmitic (%)	Stearic (%)	Linolic (%)	Oleic (%)	Linolenic (%)	Oil (%)	Protein (%)	Kernel Yield (Tons ha^{-1})
Stearic (%)	0.978							
	0.992							
Linolic (%)	0.976	0.969						
	0.916	0.904						
Oleic (%)	0.950	0.926	0.975					
	0.894	0.878	0.997					
Linolenic (%)	0.982	0.974	0.986	0.963				
	0.979	0.974	0.939	0.923				
Oil (%)	0.966	0.958	0.972	0.970	0.968			
	0.970	0.973	0.958	0.941	0.976			
Protein (%)	0.911	0.894	0.913	0.881	0.908	0.892		
	0.961	0.959	0.965	0.955	0.976	0.991		
Kernel Yield (Tons ha^{-1})	0.018	-0.061	-0.023	0.081	0.027	0.025	0.079	
	0.336	0.336	0.495	0.490	0.401	0.424	0.425	

**Correlation is significant at the 0.05 level (2-tailed), $t_{0.05}(18) = 2.100$*
***Correlation is significant at the 0.01 level (2-tailed), $t_{0.01}(18) = 2.878$*

CONCLUSION

This study successfully identified promising maize hybrids for improved oil and protein content. The cross NADH 52 × MSI 4279 and parent MSI 4279 exhibited both high yield and superior chemical composition across diverse environments. Additionally, the study revealed the complex interplay of genetic factors influencing these traits, emphasizing the importance of considering location-specific breeding strategies. Further research focused on these promising lines and understanding their adaptability could pave the way for developing high-performance maize varieties for sustainable food production.

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