Eurasian Journal of agricultural research

GROUPING AND SELECTION OF 32 SINGLE CROSS SUNFLOWER HYBRIDS USING PRINCIPAL COMPONENT ANALYSIS

Zia Ullah ZIA[1]*, Hafeez Ahmad SADAQAT[2], Saghir AHMAD[1], Wajad NAZEER[1], Imtiaz ALI[3], Abdul JABBAR[1], Amina BIBI[1], Nadia HUSSAIN[1]

[1]Cotton Research Station, Multan
Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad
[3]Regional Agriculture Research Institute, Bahawalpur
**Corresponding author e-mail: zia_pbg@yahoo.com*

Abstract
Principal components analysis is one of the multivariate statistical methods and was used to access the genetic diversity of 32 sunflower hybrids developed at the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during 2014-15. Eight males were crossed with 32 females to produce 32 F_1 hybrids using North Carolina Mating Design-I. Data were recorded on plant height, head diameter, percent filled achenes, 100-achene weight, achene yield per plant, harvest index, oil content, palmitic acid, stearic acid, oleic acid and linoleic acid. The first four principle components with Eigen value greater than one contributed 69.28 % of the total variability. The first principal component showed higher values for 100-achene weight (0.860), achene yield per plant (0.903), harvest index (0.777), second had higher values for oleic acid (-0.780) and linoleic acid (0.834), third had higher values for head diameter (-0.749) and percent filled achenes (0.782), whereas the fourth was associated with plant height (0.741). Four distinct groups can be differentiated on the basis of biplot diagram. H-1 and H-32 were the best hybrids having higher achene (94.63g, 91.45g) and oil yield (46.24%, 44.08%) respectively.

Keywords: Genetic diversity, hybrid, principal components analysis, sunflower, variability

INTRODUCTION

Sunflower (*Helianthus annuus* L.) ranks fourth, among the crops grown for edible oil, in the world after soybean, palm and rapeseed while, second in Europe after rapeseed. Sunflower is cultivated on area of about 26 mha with the seed production of 45 million tones in the world. It is largely grown in Russia, Argentina, China, Europe, USA and India (FAOSTAT 2013).

Sunflower was introduced as an oilseed crop in early sixties in Pakistan, but now it is the third most important source of edible oil after cottonseed and rapseed/mustard. It is grown on area of 0.214 million acres with the seed production of .092 million ton in the country (GOP 2015-16). It has shown wide range of adaptability over different types of environments which made it popular among the farmers (Sattar and Abbas 2014). Sunflower breeding programs in Pakistan generally focus on development of hybrid cultivars through heterosis breeding. Exploitation of heterosis or hybrid vigor is directly correlated with the selection of parental lines. It is believed that the genetic distance among the parental lines is a good predictor of heterosis. Principal Component Analysis is an excellent tool which can be used for the estimation of genetic diversity among the parental lines by drawing a two or three dimensional scatterplot with minimal loss of the variability (Uzma, Muhammad et al. 2014). Individuals in aggregation are closely related to each other in the scatter plot. In this way differences among the individuals can be estimated and the possible groups can be identified. The original variables are transformed linearly into a new set of variables which are known as principal components (Mohammadi and Prasanna 2003; Ramzan, Noor et al. 2014). These principal components are uncorrelated and represent different properties of the original data. Because the principal components are independent of each other therefore should be interpreted separately (Mohammadi and Prasanna 2003; Tabrizi 2009; Tabrizi, Şahin et al. 2011). Previously Uzma, Muhammad et al. (2014) applied principal component and cluster analysis to approximate genetic diversity and character association among sunflower lines and hybrids. Tabrizi (2009); (2011), Arshad, Khan et al. (2010) and Ghaffari, Farrokhi et al. (2011) estimated genetic diversity of single cross hybrids using principal component analysis. Tersac, Vares et al. (1993), de la Vega and Chapman (2001), Sankar, Vanaja et al. (2004) and Ghaffari, Farrokhi et al. (2011) also demonstrated the effectiveness of principal component analysis in selection of best hybrids or genotypes in their experiments.

Keeping in view the significance of this multivariate technique, current study was carried out to group similar hybrids, selection of best hybrids and to assess the proportional contribution of variation contributed by each principal component in the expression of various qualitative and quantitative traits in sunflower.

MATERIAL AND METHODS

This study was carried out at the Department of Plant Breeding and Genetics University of Agriculture Faisalabad during 2014-15. The plant material consisted of a set of 32 sunflower hybrids (Table 1.).

Table 1. List of 32 F_1 single cross sunflower hybrids

Hybrids	Parentage	Source	Hybrids	Parentage	Source
H-1	A12 × HBRS-5	PBG UAF*	H-17	V12 × L44	PBG UAF*
H-2	L49 × HBRS-5	〃	H-18	V18× L44	〃
H-3	L52 × HBRS-5	〃	H-19	L33× L44	〃
H-4	L54 × HBRS-5	〃	H-20	L35× L44	〃
H-5	A30 × L42	〃	H-21	L38 × L53	〃
H-6	L45 × L42	〃	H-22	L48 × L53	〃
H-7	L61 × L42	〃	H-23	L62 × L53	〃
H-8	V1 × L42	〃	H-24	V9 × L53	〃
H-9	G32 × A19	〃	H-25	V27 × L36	〃
H-10	A2 × A19	〃	H-26	HBRS1 × L36	〃
H-11	L50 × A19	〃	H-27	G82 × L36	〃
H-12	L37 × A19	〃	H-28	A23 × L36	〃
H-13	V3 × A41	〃	H-29	A1 × L31	〃
H-14	V6 × A41	〃	H-30	A18 × L31	〃
H-15	V10 × A41	〃	H-31	G40 × L31	〃
H-16	L41 × A41	〃	H-32	A45 × L31	〃

* Department of Plant Breeding and Genetics University of Agriculture Faisalabad

These hybrids were evaluated in triplicate in the field using randomized complete block design. The planting scheme was 75 and 25 cm. All standard cultural and agronomic practices were performed for a good crop stand. Competitive/representative plants 10 in number were tagged randomly for each entry in each replication. The data were recorded on plant height, head diameter, percent filled achenes per head, 100-achene weight, achene yield per plant, oil content, palmitic acid, stearic acid, oleic acid and linoleic acid contents. Principal Component Analysis (PCA) was used to arrange the entries in two dimensional biplots (Kroonenberg 1995) based on their field performance. Data were analyzed using XLSTAT software for computation of Principal Component Analysis (Kroonenberg 1995; Dong, Liu et al. 2007). The character loadings were used to calculate the accession component scores. The first two components were extracted for a two dimensional ordinations of accessions.

RESULTS AND DISCUSSION

PCA is a data reduction technique which is used to obtain small number of linear combinations with minimum loss of variability (Biabani and Pakniyat 2008; Sultana and Ghafoor 2008). In this technique, each principal component is uncorrelated with the other one but the variables in each component display correlations with each other. Number of principal components is always equal to the number of variables but the selected components are not always equal to the number of variables (Leite 2012). Usually first 2-3 principal components or components having eigenvalue greater than 1 are selected which are enough to explain maximum variability and only a small fraction of the total variability is lost (Biabani and Pakniyat 2008; Ijaz, Shabir et al. 2011; Ghaffari, Toorchi et al. 2012). In this study four principal components have been extracted which accounted for 69.28 % of the total variability. Only those principal components were retained which have Eigen value greater than or equal to 1. The proportion of each of the four components was 23.54, 20.08, 15.51 and 10.14 percent of total variance respectively (Table 2). Good separation of genotypes is highly influenced by the amount of variability represented by these components. Principal component provides suitable grouping of the genotypes if there exist any correlation among various traits or similarities among the genotypes (Tabrizi 2009).

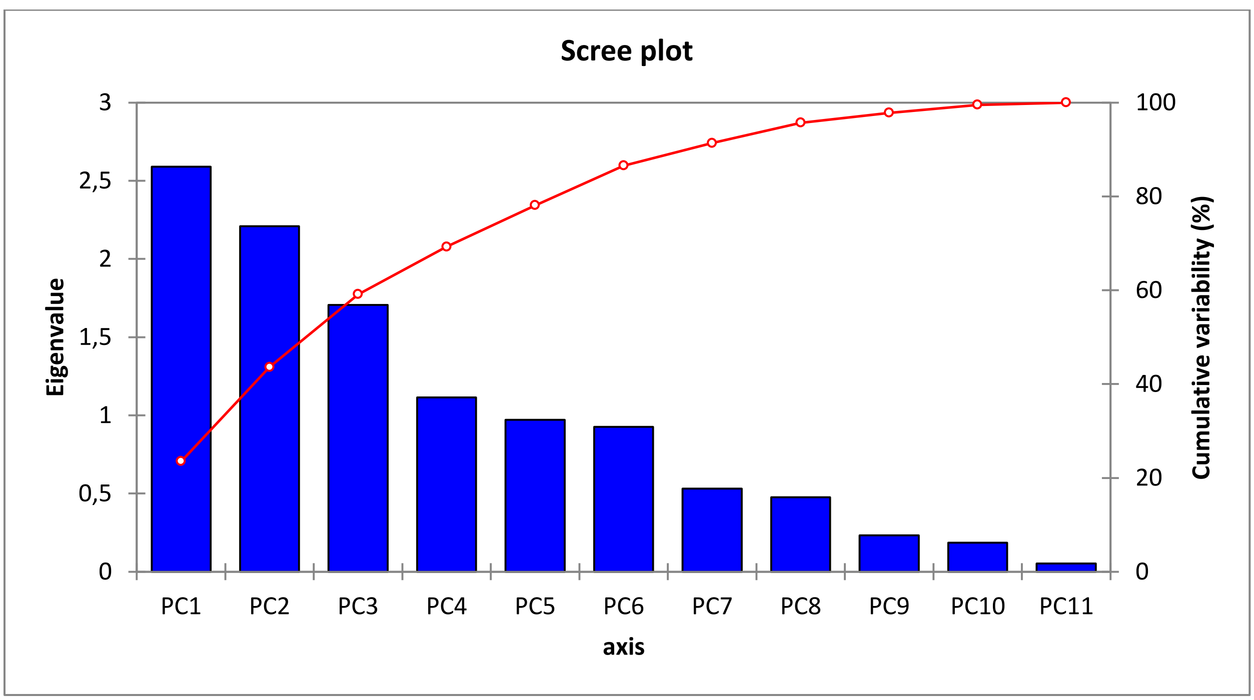

Fig 1. Scree plot diagram for quantitative and qualitative traits of 32 sunflower hybrids

Table 2. Principal components analysis of 32 single cross sunflower hybrids

	Eigenvalue	Variability (%)	Cumulative %
PC-1	2.59	23.54	23.54
PC-2	2.21	20.08	43.62
PC-3	1.71	15.51	59.13
PC-4	1.12	10.14	69.28
PC-5	0.97	8.83	78.12
PC-6	0.93	8.43	86.54
PC-7	0.53	4.84	91.37
PC-8	0.48	4.33	95.71
PC-9	0.23	2.12	97.82
PC-10	0.19	1.69	99.52
PC-11	0.05	0.48	100.00

Table 3 shows each component weight. Only those traits which have component weights greater than 0.5 were considered to be important and are highlighted in bold in Table 3. For example in first component achene yield per plant, 100-achene weight and harvest index had the highest weights respectively along with the positive signs. This indicates that the first principal component was associated with achene yield per plant. The sign and magnitude of the factor loadings with in same component shows the type of association between the two traits (Seiler and Stafford 1985; Tabrizi 2009). The highest factor loadings of achene yield per plant, 100-achene weight and harvest index with positive sign clearly shows the presence of a strong positive correlation among these traits (Dagustu 2002; Zia, Sadaqat et al. 2013). These relations can be easily seen in Fig. 1, where achene yield per plant, 100-achene weight and harvest index are at the right side of the biplot diagram (first component) and had a narrow angle with each other. A strong positive correlation between these three traits can also be verified from the correlation matrix in Table 4.

Second principal component had the highest factor loading for oleic acid and linoleic acid. This component was associated with the oil quality. The negative sign for oleic acid and positive sign for linoleic acid indicates the existence of a strong negative correlation between the two traits. This association can be viewed in the biplot as well where both the traits are close to the y-axis but in the opposite direction and far from the origin. The correlation estimates in Table 4 are also in conformity with these results. A negative correlation between oleic acid and linoleic acid is also well supported in the literature (Singh, Singh et al. 2002; Tahmasebi-Enferadi, Rabiei et al. 2004; Joksimović, Atlagić et al. 2006). Negative correlation between the two traits is due to combined action of two enzymes oleate desaturase and linoleic acid desaturase at the endoplasmic reticulum. Oleate desaturase converts the oleic acid into linoleic acid, whereas the linoleic acid desaturase converts the linoleic acid into oleic acid. Therefore, increase in oleic acid content will always be at the cost of linoleic acid and vice versa. (Mollers 2002; Tahmasebi-Enferadi, Rabiei et al. 2004; Zia, Sadaqat et al. 2013).

The third principal component was associated with the achene filling percentage. Factor loadings of head diameter and filled achenes were high but with opposite signs which shows a strong negative correlation between the two traits. Fourth component was associated with plant height and this was the only trait which has considerable loading at this component.

Table 3. Loadings of the first four principal components of quantitative and qualitative traits of sunflower hybrids

Traits	PC-1	PC-2	PC-3	PC-4
Plant height	0.026	0.464	0.227	**0.741**
Head diameter	0.115	0.459	**-0.749**	0.082
Filled achenes	-0.201	-0.323	**0.782**	0.157
100-achene weight	**0.860**	-0.226	0.125	-0.087
Achene yield per plant	**0.903**	-0.022	-0.262	-0.080
Harvest index	**0.777**	-0.109	0.341	0.155
Oil content	-0.424	0.174	-0.192	0.298
Palmitic acid	0.115	-0.443	-0.220	0.439
Steric acid	-0.400	-0.291	0.060	-0.367
Oleic acid	-0.112	**-0.780**	-0.308	0.258
Linoleic acid	0.109	**0.834**	0.316	-0.118

Principal component analysis has been used as an efficient multivariate tool for identification of superior genotypes, inbred lines and hybrids in sunflower (Ghafari 2003; Ghaffari and Farrokhi 2008; Tabrizi 2009; Tabrizi, Şahin et al. 2011; Leite 2012; Uzma, Muhammad et al. 2014). This technique enables us to group the genotypes by using the weights of the traits on principal components. Achene yield per plant has the highest weight on first principal component followed by 100-achene weight and harvest index. H-1, H-31 and H-32 are the hybrids scattered around harvest index, 100-achene weight and achene yield per plant vector. These hybrids can be selected for higher achene yields based on the PCA. This can also be verified from the mean values of these hybrids in Table 5 which verifies that these three hybrids produced the highest achene yield. The second group consisted of H-4, H-6 and H-24. These hybrids had higher values of palmitic acid and filled achenes. The third group comprised of H-10, H-14 and H-16 which were clustered around linoleic acid vector. These hybrids were relatively taller with larger heads and had high linoleic acid content. The fourth group consisted of four hybrids i.e. H-2, H20, H23 and H-26. These hybrids had lower values of achene yield per plant and harvest index therefore were clustered together on the opposite side of achene yield per plant and harvest index vectors in the negative region. Hybrid H-5 and H-27 because of low values for majority of the traits were in negative region of the two components and far from the vector loadings and origin. Biplot provided a clear cut grouping of hybrids for multi-trait selection procedure. The hybrids positioned closer to the tail end of a vector have higher values for the corresponding trait and vice versa (Ghaffari 2014). For example H-31, the highest yielding hybrid, was positioned on the extreme right side of the biplot close to the achene yield vector, whereas H-12 and H-27 had the lowest achene yield and were positioned on the extreme left side of the biplot but opposite to the achene yield vector. It was also observed that vectors for achene yield and most of the related traits were projected towards the right side of the biplot whereas vectors associated with oil content and quality traits were projected towards the left side of the biplot. The hybrids related to these traits were also scattered around their respected vectors. For example the highest yielding hybrids H-31 (102.55g), H-1 (94.63g) and H-32

(91.45g) were grouped together in the lower right corner of the biplot around yield vectors whereas the hybrids H-12 (48.80%) and H-20 (46.83) with the high oil content were scattered around the oil content vector in the upper left corner of the biplot.

It is obvious from the results that H-1 and H-32 are the best hybrids with respect to achene yield and oil content, whereas H-12 had the highest oil content but low achene yield and H-31 had the highest achene yield but low oil content.

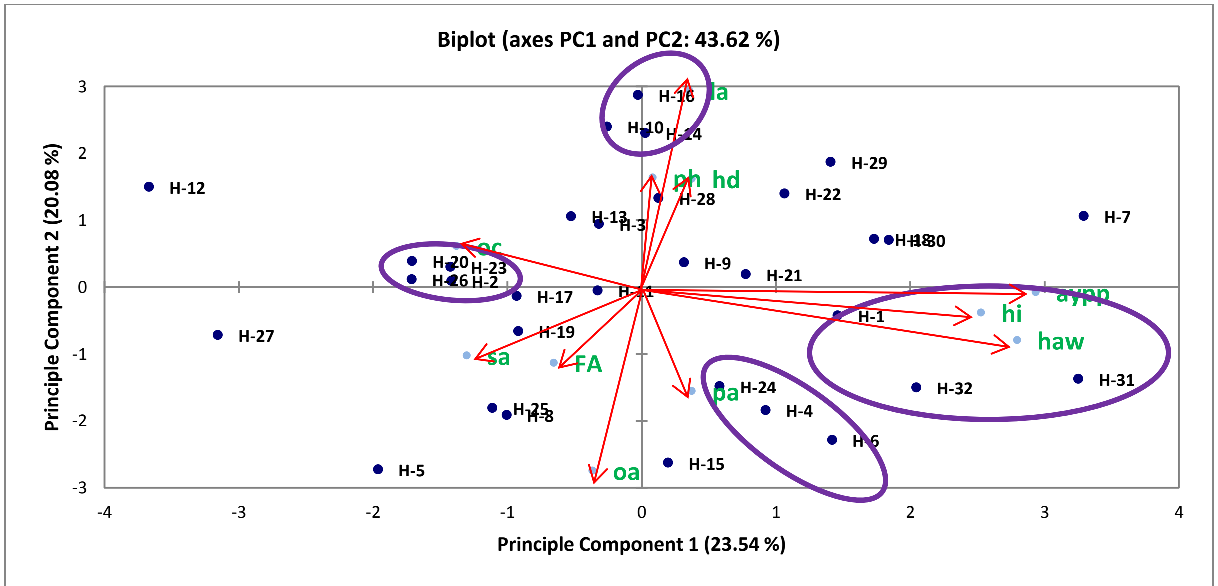

Fig. 2. Biplot of the 1st and the 2nd principal component for agronomic means

Table 4. Correlation (Pearson) coefficient of various plant traits in sunflower

	PH	HD	FA	HAW	AYPP	HI	OC	PA	SA	OA
HD	0.11									
FA	0.07	-0.57								
HAW	-0.04	-0.20	-0.11							
AYPP	-0.10	0.31	-0.32	0.73						
HI	0.11	-0.16	0.18	0.63	0.65					
OC	0.15	0.07	-0.12	-0.36	-0.21	-0.16				
PA	0.02	0.03	-0.04	0.18	0.00	0.08	-0.13			
SA	-0.22	-0.19	0.08	-0.13	-0.30	-0.18	0.14	0.08		
OA	-0.23	-0.15	0.07	0.01	0.01	-0.06	0.08	0.28	0.06	
LA	0.33	0.11	-0.12	0.00	-0.04	0.08	0.02	-0.31	-0.17	-0.75

PH = Plant height (cm), HD = Head diameter (cm), FA = Percent filled achenes (%), HAW = 100-achene weight (g), AYPP = Achene yield per plant (g), HI = Harvest index (%), OC = Oil content (%), PA = Palmitic acid (%), SA = Stearic acid (%), OA = Oleic acid (%), LA = Linoleic acid (%)

CONCLUSION

Principal component analysis is a useful technique for grouping and selection of promising breeding material based on their quantitative and qualitative traits. PCA showed that first four components contributed most of the variability (69.28%). First principal component has the highest proportion, and achene yield per plant, harvest index and 100-achene weight were the most important traits. Principle component analysis effectively grouped the high yielding hybrids (H-31, H-1 and H-32) in Quadrant-I, while hybrids (H-12 and H-20) with high oil content in Quadrant-III. Among the evaluated material H-1 and H-32 are the best hybrids with respect to achene yield and oil content.

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Table 5. Mean values for different traits of 32 sunflower hybrids

	PH	HD	FA	HAW	AYPP	HI	OC	PA	SA	OA	LA
H-1	237.23	19.24	80.62	7.30	94.63	21.47	46.24	6.30	4.43	21.92	64.98
H-2	237.05	21.13	96.95	5.16	69.07	12.29	44.24	5.61	2.76	23.98	65.77
H-3	237.05	20.95	97.70	5.45	66.87	20.04	43.98	5.60	2.13	19.37	66.01
H-4	239.55	19.15	94.33	6.79	70.47	18.95	39.48	7.66	2.56	23.17	62.75
H-5	238.33	18.75	93.31	4.79	56.44	15.41	42.44	6.26	2.96	27.60	56.61
H-6	251.70	21.34	97.32	7.09	86.18	21.80	40.27	6.76	3.53	26.66	60.80
H-7	270.60	17.64	95.59	7.66	82.17	33.89	40.61	7.28	2.98	16.66	71.28
H-8	240.82	19.25	94.62	5.75	68.15	19.99	45.40	6.30	4.17	25.48	60.99
H-9	265.79	22.27	95.00	5.70	72.14	21.46	46.42	7.31	1.57	23.53	65.28
H-10	274.29	23.67	88.30	5.42	67.37	14.75	42.69	6.64	2.41	20.02	68.95
H-11	251.70	23.05	86.88	5.63	68.76	13.53	38.87	6.97	3.64	22.99	64.77
H-12	258.19	20.30	90.73	3.97	46.80	8.19	48.80	6.17	3.12	21.78	67.17
H-13	243.97	22.87	85.43	5.23	67.34	12.30	41.93	6.49	2.05	21.66	65.89
H-14	242.78	25.29	78.49	5.50	72.80	13.91	42.65	6.26	2.75	18.00	66.34
H-15	245.55	15.77	93.16	7.18	59.12	14.40	38.78	7.50	2.56	25.39	61.99
H-16	266.42	20.20	97.09	5.92	65.27	18.85	42.16	5.35	2.75	16.74	71.93
H-17	234.10	22.30	95.33	5.04	67.48	16.74	41.43	6.51	3.65	21.61	65.43
H-18	237.18	25.04	76.95	7.20	89.98	15.60	41.90	6.38	3.29	21.81	65.16
H-19	239.02	21.93	95.69	5.26	68.24	14.23	41.55	7.44	3.61	17.60	60.10
H-20	248.40	19.01	94.21	6.01	56.24	12.26	46.83	6.25	3.47	19.56	65.03
H-21	264.37	23.48	90.04	6.15	83.23	15.24	40.17	6.37	2.55	22.56	61.83
H-22	254.55	24.05	84.57	6.67	85.87	11.56	43.06	6.53	1.87	20.50	65.13
H-23	247.22	19.15	91.86	5.85	58.59	12.86	43.57	5.77	3.63	21.02	65.33
H-24	228.57	21.00	96.55	6.37	74.04	16.39	36.48	7.36	3.64	21.58	64.37
H-25	222.98	20.95	93.00	6.02	67.07	15.06	45.31	7.46	4.45	23.25	63.03
H-26	256.00	19.78	93.87	6.01	49.37	9.83	42.54	6.80	3.45	20.86	65.37
H-27	225.45	19.94	92.39	5.08	44.56	7.92	43.29	6.53	4.69	22.05	65.12
H-28	224.02	19.28	89.75	5.79	64.97	14.12	36.79	5.58	2.35	18.06	69.90
H-29	236.48	23.29	86.17	6.47	85.83	17.32	42.55	6.49	2.41	18.50	69.99
H-30	247.18	22.98	91.62	6.60	86.71	26.67	41.73	5.82	3.33	19.70	65.27
H-31	224.94	17.79	96.81	7.88	102.55	24.29	39.62	5.40	1.78	22.23	62.71
H-32	226.10	23.23	83.10	6.65	91.45	21.90	44.08	7.65	1.69	26.09	61.73

PH = Plant height (cm), HD = Head diameter (cm), FA = Percent filled achenes (%), HAW = 100-achene weight (g), AYPP = Achene yield per plant (g), HI = Harvest index (%), OC = Oil content (%), PA = Palmitic acid (%), SA = Stearic acid (%), OA = Oleic acid (%), LA = Linoleic acid (%)