Performance, Heterosis, and Combining Ability for Some Important Traits of Maize (*Zea mays* L.) Under Low Addition of Nitrogen

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Abstract

Seven inbred lines of maize were crossed in half diallel system (7×7) to give a set of 21 F_1 crosses following method 2 (parents and crosses), model 1 (fixed) of Griffing (1956) at the Scientific Agricultural Research Center in Raqqa, Syria. RCBD lay out was applied and arranged in split plot design where the main factor was the nitrogen level while the secondary factor was the genotypes with three replications during the growing seasons 2013 and 2014, to evaluate the performance of maize genotypes under three levels of nitrogen (40, 80, and 130 N kg/ha), to assess the general combining ability (GCA) and specific combining ability (SCA) effects, and to study heterosis (%) for days to tasseling, 100 kernels weight (g) and grain yield (ton/ha). Analyses of variance for combining ability (GCA and SCA) variance was significant for all studied traits, which indicated that these traits were controlled by additive and non-additive gene actions. P1, P3 and P4 were considered as desirable inbred lines for days to tasseling and grain yield, this is a clear indication that these parents have the largest number of genes that had additive effect which play an important role in the inheritance of these traits. The best crosses namely (P1xP3, P1xP2, P1xP4, P3xP4 and P2xP3) showed highest significant SCA effects and heterosis, this refers to the possession of these crosses largest number of genes that show dominance in inheritance those traits, which means deterioration of quality value due to continues genetic isolations under the influence of low nitrogen levels.

Key words: Maize, Heterosis, GCA, SCA, Low Nitrogen addition, Crosses.

Introduction:

Maize (*Zea mays* L.) is considered as the third most important cereal crop in the world, after wheat and rice. In Syria, maize is grown on 56231 ha with an annual production of 215309 tones with an average yield of 3829 kg/ha (Ministry of Agriculture and Agrarian Reform, 2019). Crop growth and grain yield of cereal crops vary widely in response to nitrogen (N) availability. Nitrogen deficiency is common where nitrogen (N) is applied at below-optimal levels because of high-cost relative to economic returns, or where there are significant risks of drought and frost or of excessive leaching of nitrate (Lafitte and Edmeades, 1994). Nitrogen is an essential component of all enzymes and therefore necessary for plant growth and development. There is a positive correlation among nitrogen uptake, biomass production, and grain yield. The application of N fertilizers and organic amendments can generally correct nitrogen deficiency, though these are often not available (Lafitte and Edmeades,

1994) or are beyond the farmer's capability (Paterniani, 1990). Nitrogen deficiency has been shown to reduce both leaf area and leaf N concentration, therefore reducing light capture and photosynthetic capacity (Vos *et al.*, 2005). Furthermore, low biomass accumulation during the vegetative growth may also limit grain yield as harvest index has been shown to be fairly stable in maize (Duvick, 2005). Lastly, limits in crop growth rate during the critical period may lower established kernel number (Andrade *et al.,* 1999) while N deficiency during the grain filling period causes reduction in kernel weight (Borrás and Otegui, 2001). One approach to reducing the impact of N deficiency of maize production may be to select cultivars that are superior in the utilization of available N, either due to enhanced uptake capacity or because of more efficient use of absorbed N in grain production (Lafitte and Edmeades, 1994). Selection for yield in the target environment has been suggested as an effective method rather than selection for yield potential alone (Blum, 1988). However, such environments are not favored by maize breeders due to increased environmental variability as soil fertility declines resulting in a decline in heritability for grain yield (Lafitte and Edmeades, 1994). Presterl *et al.*, (2003) reported a reduction of 37% in grain yield at low N compared to high N. Heterosis is important in maize breeding and is dependent on level of dominance and differences in gene frequency. The manifestation of heterosis depends on genetic divergence of the two parental varieties (Hallauer and Miranda, 1988). Genetic divergence of the parental varieties is inferred from the heterotic patterns manifested in a series of variety crosses. Heterosis in maize has been investigated extensively. In a study by Vasal *et al.*, (1992), high-parent heterosis ranged from -3.1% to 12.7% for grain yield, -7.7% to 4.5% for plant height, -4.7% to -0.1% for days to silk in pools and populations. In the United States of America, maize varietal improvement together with improved crop management, and crop need-based fertilizer N application resulted in grain yield increase, per kilogram of applied N, from 42 kg in 1980 to 57 kg in 2000 (Mosier *et al.,* 2004). According to (Mi *et al.,* 2005), growing N-efficient cultivars are an important prerequisite for integrated nutrient management strategies in both high and low-input agriculture. Crops that are efficient in N utilization use less N to yield more per kilogram N applied. With improved nitrogen use efficiency varieties, farmers will not only optimize their use of N fertilizers but also maintain sufficient production profit margins (IPNI, 2012). The current study was conducted to fulfill the following objectives: to evaluate performance of the genotypes for grain yield and for other economically important traits, to study heterosis and the ability of these hybrids to tolerate low nitrogen levels, and to determine the general combining ability (GCA), specific combining ability effects (SCA) among many inbred lines and their F1 crosses for important agronomic traits.

Materials and Methods:

Site of experiment: An experiment was conducted at Raqqa Research Center (8 km south-west of town center on right bank of Ephorates river), General Commission for Scientific Agricultural Research (GCSAR), Syria. Random composite soil samples were taken from the experiment site before adding fertilizers and planting (Table 1). It is evident from the results of physical and chemical soil analyses that the soil is sandy loam, poor in organic matter, mineral nitrogen, available phosphorous, available potassium, and moderate in content of calcium carbonate.

Table 1. Some chemical and physical properties of the site soil.

Mechanical analysis			K	P	N-m	$CaCO_3$	Organic matter
Clay (%)	Silt (%)	Sand (%)	mg/Kg			%	
18.7	34	47.3	132	3.3	6.6	15.96	0.50

Plant material: The material consisted of seven inbred lines of maize designated as (IL.189-09, IL.191-10, IL.1-10, IL.134-10, IL.356-10, IL.69-09, and IL.175-10). It was obtained from the genetic bank of Maize Research Department, GCSAR, Syria. The F_1s (21) were as a result of half diallel crossing system among 7 inbred lines of maize at Raqqa Research Center in July 2012. Also, the single cross Basel-1was used as a control to be compared with the studied genotypes.

Planting method: Experiments were conducted under irrigation, where water was applied when needed. Each genotype was represented by a plot of 2 rows, 3 meters long with a spacing of 25×80 cm between holes and rows, respectively, giving a total plot area of 4.8 m^2. At physiological maturity, when the leaves and husks of the plant started to turn yellow and dry, each plot was harvested separately. Nitrogen fertilizer was applied at three levels (40-80-control 130 N/ha) and urea equivalent amount (87-174-283) kg/ha, respectively. These amounts were applied at two doses, half amount at sowing and repeat the same dose after 45 days from sowing. Hand weeding was done frequently to maintain a clean field.

Studied traits: Data collected were days to tasseling, 100-kernels weight (g), and grain yield (when the leaves and husks of the plant started to turn yellow and dry; each plot was harvested separately and then air dried and threshed. The dry weight of grains from all the harvested ears per plot was recorded. The grain yield was obtained by converting the yield of the actual harvested area into (kg/ha).

Experiment design and statistical analysis:

RCBD arranged in split plot design was used, where the main factor is the nitrogen level (40-80-control 130 N/ha) and secondary factor is the 29 genotypes with three replications during the growing seasons 2013 and 2014. The collected data were subjected to analysis of variance procedure using SAS (2004), and least significant difference test (L.S.D.) was used to compare means. The hybrids and hybrid interaction sum of squares were partitioned into general combining ability (GCA) and specific combining ability (SCA) effects according to Griffing′s (1956) Method-II (parents and set of F1s crosses), Model I (Fixed). The value of heterosis estimated over the mid- parent (average of the parents) as: Average heterosis (h') = $[(F_1\text{-MP})/\text{MP}] \times 100$ Where: F_1=is the mean of F_1 hybrids; MP= is the mean value of two parents involved in the cross, calculated as $(P_1+P_2)/2$. Test of significance of heterosis was done according to Singh and Naraynan, (1993).

Results and Discussion:

Variability: The analysis of variance showed highly significant differences among genotypes for all traits at three nitrogen levels (Table 2). The significant differences were observed in mean square at three nitrogen levels for all traits studied. These findings indicated the presence of a wide range of genetic variability in the studied crosses that could be utilized in the maize breeding program to produce new hybrids possessing desired traits. The value of variability observed in the material used in this study may lay a foundation for developing synthetic hybrids that would help in increasing maize production. Grzesiak, (2001) observed considerable genotypic variability among various maize genotypes for 100 kernels weight and grain yield.

GCA and SCA variance components:

The mean squares due to GCA and SCA were highly significant ($P<0.01$) for studied traits, which indicated that these traits were controlled by additive and non-additive gene action (Table 2). Sujiprihati *et al.*, (2001) concluded the importance of GCA effects for days to tasseling in eight early maturing composites of maize. The ratio of GCA to SCA was less than one for all traits measured in this study (Table 2), suggesting that the inheritance of these traits was due to non-additive gene action. These results indicate that dominance and epistatic interactions seemed to be predominant for these traits and therefore, heterosis breeding may be rewarding. Nanda and Gupta, (1967) reported the predominant role of non-additive gene action for grain yield in pearl millet that may be similar in maize since the two species are C4 cereals. As a basic principle in breeding hybrid maize. However, SCA is an indicator for the predominance of genes having dominance and epistatic effects, while GCA as indicative for predominance of genes having largely additive effects. The importance of non-additive gene action was also emphasized by Alika, (1994) and Beck *et al.*, (1991). In Sudan, Elali Elkhalf *et al.*, (2011) made a combining ability analysis in a set of half diallel cross of 6 yellow maize inbred lines for grain yield and other related traits. Its results showed that both GCA and SCA mean squares were significant for grain yield.

Table 2. Mean squares for combining ability and ratio of GCA to SCA of some agronomic traits of 7 maize inbred lines and their 21 crosses evaluated at Raqqa research center for the average seasons 2013 and 2014.

Source of variation	**d.f**	**Days to tasseling**			**100 kernels weight (g)**			**Grain yield (ton/ha)**		
		40N	**80N**	**130N**	**40N**	**80N**	**130N**	**40N**	**80N**	**130N**
Block	**2**	0.08	0.38	2.28*	4.51	8.05*	2.16	0.24	0.12	0.21
Genotype	**28**	220.9**	207.1**	221.6**	99. 1**	131.1**	175.5**	5.03**	6.97**	9.75^{NS}
GCA	**6**	7.24**	3.89**	5.73**	11.77**	2.46**	6.75**	0.45**	0.69**	1.18**
SCA	**21**	1.77**	1.15**	1.35**	8.87**	5.86**	8.03**	0.80**	0.78**	1.19**
Error	**224**	0.24	0.46	0.33	2.80	2.12	2.03	0.11	0.09	9.75
GCA:SCA		0.47	0.41	0.50	0.15	0.04	0.09	0.06	0.10	0.11

***, ** Significant at 0.05 and 0.01 levels of probability, respectively.**

d.f=degree of freedom. GCA:SCA= ratio of general to specific combining ability.

Days to 50% tasseling:

Results indicate that there are significant differences among the parents and their F_1 crosses, and the different nitrogen levels on the other hand for this trait (Table 2). The parents varied in their response to low nitrogen rates, as most of the parents were early tasseling, and the three parents P1, P6, and P4 ranked first and record significance differences compared to the control (Basil-1) (48.8 days) with an average tasseling of (44.6, 44.7, and 44.9 days), respectively (Table 3a). Samanci, (1996) emphasized the importance of optimum flowering dates during inbred development as a useful selection criterion for prediction of hybrid performance. Crosses differed in their tasseling under the influence of low nitrogen. The hybrids (P4×P6), (P3×P4) and (P3×P5) were early tasseling with a number of days (42.0, 42.0 and 42.1), respectively, (Table 3b). Number of days to tasseling were close under the influence of low nitrogen, as they averaged (43.4 and 44.2 days) for nitrogen levels 80N and 40N, respectively, with significance differences compared with the control 13N (44.4 days). (Table 3b). Crosses were affected by low nitrogen rates and led to early flowering period of the tasseling in different proportions, superior to the control Basil-1 and to the parents at low nitrogen levels 40N, 80N except P2×P4. The best early tasseling hybrids was P3×P4 with flowering period (41.3 and 41.8 days) with earliness of (16.2 and 15.9)% compared with the control (Basil-1) at levels of 80N and 40N, respectively.

The majority of the crosses showed negative and highly significant heterosis in the desired direction under the influence of different nitrogen levels, which indicates the earliness of all the crosses compared to the average of the parents included in their composition. Nineteen crosses had negative value and high significance (desirable) heterosis for the tasseling trait, as the heterosis varied from (**1.6-) % for (P3×P6) and (-6.9**)% for both crosses (P1×P3) and (P3×P5) at the level of 130N, while mid-parent heterosis percentage ranged between (-1.8*)% for both crosses (P5×P6), (P1×P7), and (-9.2**)% for (P3×P5) at the nitrogen level 40N (Table 5).

The best combiners were P1 and P4 showing negative and highly significant (desirable) GCA effects under low nitrogen levels, where the highest value (-**0.97 and -**0.88) recorded at the 40N level, also P3 was negative and highly significant (desirable) GCA (-0.54**) at the 80N level and a negative and non-significant (-0.15) at the 40N level (Table 4). This leads us to the fact these parents possess the largest number of additive gene action that contribute to an increase in early flowering and therefore will transfer them to the crosses that participate in their formation and are considered high GCA genotypes.

The crosses (P1×P3) and (P3×P4) showed a negative and significant (desirable) SCA under the influence of 40N and 130N nitrogen levels, (Table 5). which resulted from parents, each of which had a negative and highly significant GCA, and a genetic interaction of the type (additive × additive), it is expected that the value of the trait will be stable in later solitary generations, crosses are considered promising to improve primordial character. The hybrid (P3×P5) showed a negative and highly significant (desirable) SCA. As a result, parent's negative GCA value at nitrogen rates (80N, 130N) and the genetic interaction has a type (additive×additive). It is expected that the value of the trait will be stable. In the subsequent solitary generations, therefore, crosses are considered promising to improve the primordial character under the influence of low nitrogen levels.

Table 3a. Means for days to tasseling of seven maize parents evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Parents	Nitrogen Level					Mean
	130N (Control)	80N	R.R. %	0N4	R.R. %	
P1	45.8^{bc}	43.5^{efg}	5.0	44.3^{ghi}	3.3	44.6^{efg}
P2	46.7^{ab}	44.8^{cd}	4.1	46.3^{cd}	0.9	45.9^{bcd}
P3	45.8^{bc}	42.7^{fgh}	6.8	46.5^{cd}	-1.5	45.0^{cdef}
P4	44.8^{cdef}	44.6^{cde}	0.4	45.3^{ef}	-1.1	44.9^{cdef}
P5	45.5^{cd}	45.4^{bc}	0.2	45.7^{def}	-0.4	45.5^{bcde}
P6	45.3^{cd}	43^{fgh}	5.1	45.7^{def}	-0.9	44.7^{def}
P7	47.7^{a}	45.1^{bc}	5.5	47.7^{b}	0.0	46.8^{b}
Mean	**45.9**	**44.2**		**45.9**		**45.3**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %.

Table 3b. Means for days to tasseling of 22 maize crosses evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Crosses	Nitrogen Level					Mean
	130N (Control)	80N	R.R. %	40N	R.R. %	
P1×P2	43.8^{fghi}	42.0^{hi}	4.1	42.8^{jk}	2.3	**42.9^{ijk}**
P1×P3	42.7^{jk}	42.2^{hi}	1.2	42.3^{kl}	0.9	**42.4^{ijkl}**
P1×P4	43.2^{ghijk}	42^{hi}	2.8	41.8^{l}	3.2	**42.3^{jkl}**
P1×P5	43^{hijk}	42.5^{ghi}	1.2	42.3^{kl}	1.6	**42.6^{ijk}**
P1×P6	44^{fgh}	42.8^{fgh}	2.7	43.5^{ij}	1.1	**43.4^{hij}**
P1×P7	45.8^{bc}	43.8^{def}	4.4	45.2 ^{fg}	1.3	**44.9^{cdef}**
P2×P3	44.2^{efg}	43F^{gh}	2.7	44 ^{hi}	0.5	**43.7^{ghi}**
P2×P4	42.8^{ijk}	43.5^{efg}	-1.6	43.5^{ij}	-1.6	**43.3^{hij}**
P2×P5	44.7^{def}	41.8^{hi}	6.5	44.3 ^{ghi}	0.9	**43.6^{ghi}**
P2×P6	43.8^{fghi}	42.8^{fgh}	2.3	44 ^{hi}	-0.5	**43.6^{ghi}**
P2×P7	45.8^{bc}	44.5^{cde}	2.8	45.7^{def}	0.2	**45.3^{cde}**
P3×P4	42.8^{ijk}	41.3^{i}	3.5	41.8^{l}	2.3	**42^{l}**
P3×P5	42.5^{jk}	41.8^{hi}	1.6	41.8^{l}	1.6	**42.1^{kl}**
P3×P6	44.8^{cdef}	42.2^{hi}	5.8	44.8 ^{fgh}	0.0	**43.9^{fgh}**
P3×P7	46.7^{ab}	46.2^{b}	1.1	46.2^{cde}	1.1	**46.3^{bc}**
P4×P5	43.5^{ghij}	43^{fgh}	1.1	42.7^{jkl}	1.8	**43.1^{hijk}**
P4×P6	42.2^{k}	41.8^{hi}	0.9	42^{kl}	0.5	**42^{l}**
P4×P7	44.8^{cdef}	43.5^{efg}	2.9	45 ^{fg}	-0.4	**44.4^{efg}**
P5×P6	45.2^{cde}	43.2^{fgh}	4.4	44.8 ^{fgh}	0.9	**44.4^{efg}**
P5×P7	46.8^{ab}	45.7^{bc}	2.4	47^{bc}	-0.4	**46.5^{b}**
P6×P7	47^{a}	45.2^{bc}	3.8	46.7^{c}	0.6	**46.3^{bc}**
(Control) Basel-1	47.3^{a}	49.3^{a}	-4.2	49.7^{a}	-5.1	**48.8^{a}**
Mean	**44.4**	**43.4**		**44.2**		**44.0**
C.V.%	**1.3**	**1.6**		**1.1**		**1.3**
L.S.D$_{0.05}$	**0.94**	**1.1**		**0.81**		**0.55**
L.S.D$_{0.05}$ for N levels		**0.18**	**L.S.D$_{0.05}$ for N levels× genotypes**			**0.95**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %

Table 4. Estimates of GCA effects for days to tasseling of 7 maize inbred lines evaluated at Raqqa Research Center for the average seasons 2013 and 2014.

Parents	Nitrogen Level		
	130N (Control)	80N	40N
P1	0.39**+	0.50**+	0.97**+
P2	0.09	0.06	0.18*
P3	0.26*+	0.54**+	+0.15
P4	0.96**+	0.28*+	+0.88**
P5	0.11+	0.22	+ 0.12
P6	0.00	0.31*+	0.20*
P7	1.63**	1.35**	1.74**
L.S.D$_{0.05}$	0.20	0.24	0.18
L.S.D$_{0.01}$	0.27	0.32	0.24

***,** Significant at 0.05 and 0.01 levels of probability, respectively. + negative GCA effects.**

Table 5. Heterosis and SCA values for days to tasseling of the maize crosses evaluated at Raqqa research center for the average seasons 2013 and 2014.

Crosses	SCA values			Heterosis		
	130N (Control)	80N	40N	130N (Control)	80N	40N
P1×P2	+++0.58*	+++0.91**	+++0.80**	-5.2**	-4.9**	-5.5**
P1×P3	++1.39**	++0.15	++0.97**	-6.9**	-2.1**	-6.8**
P1×P4	++0.19	++0.58	++0.75**	-4.8**	-4.6**	-6.7**
P1×P5	++1.21**	++0.58	++1.00**	-5.8**	-4.4**	-5.9**
P1×P6	+++0.32	0.29	+++-0.15	-3.5**	-1.0*	-3.3**
P1×P7	+++0.12	+++0.37	+++0.02	-2.0**	-1.0*	-1.8**
P2×P3	+++0.37	0.13	+++0.45*	-4.5**	-1.7**	-5.2**
P2×P4	+++1.00**	0.37	+++0.23	-6.4**	-2.7**	-5.1**
P2×P5	+++0.02	++++1.80**	+++0.15	-3.1**	-7.3**	-3.6**
P2×P6	++++0.97**	+++0.26	++++0.80**	-4.7**	-2.5**	-4.3**
P2×P7	++++0.60*	++++0.26	++++0.67**	-2.8**	-1.0*	-2.8**
P3×P4	++0.65*	++1.21**	++1.56**	-5.5**	-5.3**	-8.9**
P3×P5	++1.84**	+++1.21**	++2.32**	-6.9**	-5.0**	-9.2**
P3×P6	0.38	++0.34	0.37	-1.6**	-1.6**	-2.7**
P3×P7	0.59*	2.00**	0.16	-0.2	5.2**	-1.9**
P4×P5	++0.13	+++0.30	++0.76**	-3.7**	-4.4**	-6.2**
P4×P6	+++1.58**	++0.93**	+++1.75**	-6.5**	-4.5**	-7.7**
P4×P7	+++0.54*	+++0.93**	+++0.28	-3.1**	-3.0**	-3.2**
P5×P6	0.57*	+++0.09	0.33	-0.6	-2.4**	-1.8**
P5×P7	0.61*	0.74*	0.96**	0.5	0.9	0.7*
P6×P7	0.66*	0.78*	0.31	1.1**	2.6**	0.0
L.S.D$_{0.05}$	**0.50**	**0.60**	**0.44**	**0.8**	**1.0**	**0.7**
L.S.D$_{0.01}$	**0.67**	**0.80**	**0.58**	**1.1**	**1.3**	**0.9**

***,** Significant at 0.05 and 0.01 levels of probability, respectively. ++negative SCA effects resulting from cross of two parents, each of which is negative GCA. +++ negative SCA effects resulting from cross of two parents, one positive and other negative GCA. ++++ negative SCA effects resulting from cross of two parents, each of which is positive GCA.**

100 kernels weight (g):

The results showed that there were significant differences between the parents and their F$_1$ crosses for 100 kernels weight under the influence of different nitrogen levels as shown in Table (2). Parents differed by the reduction ratio (%) resulting from the low nitrogen rate compared to the control level 130N, where the weight of 100 kernels of the P4 reached (38.6 g) at 130N level and decreased to (31.3 g) with a decrease of (18.9%) at the 80N level, while it decreased by (41.5)% at the 40N level compared to the control 130N (Table 6a). The hybrids did not record any superiority with the average 100 kernels weight over the check Basel-1, and their values ranged from the highest value (36.8 g) for the hybrid P3XP4 to the lowest value (29.1) for the hybrid P6×P7 without significance differences. The hybrid P3×P4 with a weight of 100 grains (45.6 g) showed significant differences compare the control (Basel-1) and the other hybrids at 130N level with a percentage greater (12.06)%, while the hybrids did not record any superiority at the rest of the other low levels of nitrogen (Table 6b).

Most of the crosses showed positive and highly significant (desirable) heterosis under the influence of different nitrogen levels, which indicates an increase in the 100 kernels weight for the most of the crosses compared to the average of the two parents entering their composition. Fourteen crosses showed positive and highly significant (desirable) heterosis with ranged between (0.8)% in the P3×P5 and (**18.1)% in P3×P4 at the level of 130N. Table (8). While the value of the heterosis ranged between (1.9%) for P2×P6, P4×P6, and (24.6**)% for P1×P5 at the 80N level, while heterosis at the level of low nitrogen of 40N ranged between (0.5)% for the hybrid P2×P4 and (**36.7%) for the P4×P5, while the crosses had a negative heterosis, which is undesirable to improve the 100 kernels weight (Table 8).

P1 and P4 were the best parents for 100 kernels weight, which had a positive GCA under low nitrogen levels, where the highest value for them was positive and significant (*0.73 and **1.15) at the 40N level and a positive and non-significant (0.38, 0.33) GCA under the influence of the 8N level, respectively, which indicates that the two parental lines possess the largest number of genes with additive effect that contribute to the increase in the 100 kernels weight and thus will transfer them to the crosses that participate in their formation (Table 9).

The hybrid P1×P3 showed a positive and highly significant (**2.21) SCA effects at the 40N level, and it resulted from two parents that have positive GCA, and therefore the interaction of genetic factors for it is of the type (additive × additive), so it's considered a promising hybrid under low nitrogen level 40N. Likewise, for the hybrids P1×P5, P2×P5, P2×P4, and P4×P5, they were characterized by a positively SCA effects at the level of nitrogen 80N, which resulted from parents, each of which possesses positive GCA, and the genetic interaction of type (additive × additive). Table (10). The P3×P4 hybrid also showed a positive and highly significant SCA ability (**2.39,**5.89) under the 40N and 130N, respectively, and it resulted in two parents, each of whom had a positive and significant GCA, and the genetic interaction was of the type (additive × additive). The P3×P4 is considered promising to improve this characteristic under the influence of these two levels of nitrogen, 40N and 130N (Table 10).

Grain yield (tons/ha):

Nitrogen (N), after water, is the single most important input for maize production. It plays a major role in establishing optimal photosynthetic capacity during key growth stages for crops to achieve high yields (Nebiker *et al.*, 2008). The results showed that there are significant differences between the parent lines and their F1 crosses for the grain yield under the influence of low nitrogen levels and interaction effect between the two factors together (Table 2).

The parent lines differed in the average grain yield under the influence of different nitrogen levels, P4 has the best grain yield (5.622) ton/ha, followed by P3 with an average of (5.489) ton/ha without significant differences compared with the check Basel-1 (7.237) ton/ha. The parental lines varied in their response to low nitrogen levels, where the grain yield of the P5 decreased to (5.219) tons/ha under the influence of the 8N level with a decrease of (22.1 %), while it decreased to (33.8)% under the influence of the 4N level compared with 13N (Table 7a). One hybrid (P1×P2) with an average grain yield of (7.597) tons/ha had significantly higher grain yield than the check (Basel-1) and the parents included in its formation. Also in the effect of the interaction between the genotypes and the nitrogen levels, none of the hybrids recorded superiority to the control (Basel-1) in grain yield at the rates of nitrogen 8N and 13N, while only the P4×P6 outperformed the control Basil-1 with a grain yield of (6.511) tons/ha under the influence of the low level of nitrogen 4N with a percentage of more than (9.4%) on the control (Table 7b).

Table 6a. Means for 100 kernel weight (g) of seven maize parents evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Parents	Nitrogen Levels					Mean
	130N (Control)	80N	R.R. %	40N	R.R. %	
P1	35.5^{hijk}	29.8^{jklmn}	16.1	24.5 ^{fghijk}	31.0	**29.9^{efghij}**
P2	34.2^{jk}	29.7^{klmn}	13.2	24.6 ^{fghijk}	28.1	**29.5^{fghij}**
P3	38.6^{cdef}	29.3^{lmn}	24.1	25.2 ^{fghi}	34.7	**31.0^{cdefgh}**
P4	38.6^{cdef}	31.3^{hijklm}	18.9	22.6 ^{ijkl}	41.5	**30.8^{cdefghi}**
P5	37.7^{cdefgh}	28.5^{n}	24.4	21.5^{kl}	43.0	**29.2^{hij}**
P6	36.9^{efghi}	31.5^{ghijkl}	14.6	21.5^{kl}	41.7	**30.0^{efghij}**
P7	34.9^{ijk}	28.7^{mn}	17.8	19.9^{l}	43.0	**27.8^{J}**
Mean	**36.6**	**29.8**		**22.8**		**29.7**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %

Table 6b. Means for 100 kernel weight (g) of 22 maize crosses evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Crosses	Nitrogen Levels					Mean
	130N (Control)	80N	R.R.%	40N	R.R.%	
P1×P2	37.5^{cdefghi}	34.3^{bcdef}	8.5	30.9^{b}	17.6	**34.3^{bc}**
P1×P3	35.6^{ghijk}	32.5^{efghij}	8.7	29.8 ^{bc}	16.3	**32.7^{bcde}**
P1×P4	40^{bc}	35.8^{abc}	10.5	25.8 ^{efgh}	35.5	**33.9^{bcd}**
P1×P5	38.3^{cdefg}	36.3^{ab}	5.2	25.1 ^{fghij}	34.5	**33.2^{bcd}**
P1×P6	41.9^{b}	35.7^{abc}	14.8	27.7 ^{cdef}	33.9	**35.1^{ab}**
P1×P7	38.4^{cdef}	31.2^{ijklmn}	18.8	21.9^{klj}	43.0	**30.5^{defghi}**
P2×P3	37.1^{defghi}	36.3^{ab}	2.2	25.1 ^{fghij}	32.3	**32.8^{bcde}**
P2×P4	39.3^{bcdef}	34.2^{bcdefg}	13.0	23.7 ^{ghijk}	39.7	**32.4^{bcde}**
P2×P5	37.4^{cdefghi}	35.5^{abcd}	5.1	22.7 ^{hijkl}	39.3	**31.9^{bcdef}**
P2×P6	36.8^{efghij}	31.2^{ijklmn}	15.2	22.4 ^{ijkl}	39.1	**30.1^{efghij}**
P2×P7	35.5^{hijk}	34.0^{bcdefh}	4.2	24.6 ^{fghijk}	30.7	**31.4^{cdefg}**
P3×P4	45.6^{a}	34.5^{bcdef}	24.3	30.4^{bc}	33.3	**36.8^{ab}**
P3×P5	38.4^{cdef}	33.8^{bcdefghi}	12.0	28.8 ^{bcde}	25.0	**33.7^{bcd}**
P3×P6	40.0^{bc}	32.8^{cdefghi}	18.0	25.8 ^{efgh}	35.5	**32.9^{bcde}**
P3×P7	39.8^{bcd}	32.3^{efghijk}	18.8	26.2 ^{defg}	34.2	**32.8^{bcde}**
P4×P5	33.8^{k}	33.5^{cdefghi}	0.9	30.1 ^{bc}	10.9	**32.5^{bcde}**
P4×P6	31.1^{l}	32.0^{fghijkl}	-2.9	30.0 ^{bc}	3.5	**31^{cdefgh}**
P4×P7	39.5^{bcde}	32.3^{efghijk}	18.2	28.9 ^{bcd}	26.8	**33.6^{bcd}**
P5×P6	38.9^{cdef}	34.8^{bcde}	10.5	26.8 ^{defg}	31.1	**33.5^{bcd}**
P5×P7	36.7^{fghij}	33.8^{bcdefghi}	7.9	24.2 ^{ghijk}	34.1	**31.6^{cdefg}**
P6×P7	33.8^{k}	31.3^{hijklm}	7.4	22.2 ^{ijkl}	34.3	**29.1^{ij}**
(Control) Basel-1	40.1^{bc}	37.7^{A}	6.0	34.3^{a}	14.5	**37.4^{a}**
Mean	**38.0**	**33.9**		**26.7**		**32.9**
C.V.%	**3.8**	**4.4**		**6.5**		**4.7**
L.S.D$_{0.05}$	**2.4**	**2.3**		**2.7**		**1.4**
L.S.D$_{0.05}$ for N levels		**0.45**	**L.S.D$_{0.05}$ for N levels× genotypes**			**2.4**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %

N deficiency reduces leaf chlorophyll content, soluble protein content, photosynthetic rate, and related enzyme activities of the maize plant during grain filling (Uribelarrea *et al.*, 2009). For that reason, the GY of all the 64 genotypes was assumed to have been strongly affected by the lack of nitrogen in low conditions.

All crosses showed positive and highly significant (desirable) heterosis under the influence of all nitrogen levels for grain yield, which indicates an increase in grain yield for all crosses compared with the average of the two parents entering their composition. Where heterosis ranged between the lowest positive and highly significant value (**11.9)% for the hybrid group P6×P7 and the highest positive and highly significant value (**53.9)% for the group P1×P6 at the level 13N, while at the nitrogen level 8N it ranged the heterosis between the lowest positive and highly significant value (**7.2)% in the hybrid group P6×P7 and the highest positive and highly significant value (**49.0)% in the P2×P7. Table (8). While the heterosis ranged between (**2.4)% in the hybrid P2×P4 and (**64.3)% in the hybrid P4×P7 at the low nitrogen level 4N, all in the desired direction to increase the grain yield compared with the parents included in its formation (Table 8). These results are in agreement with the findings of (Shafey, 1998) using the full diallel cross between six inbred lines of maize, the heterosis values reached 66.08% for the 100 kernels weight and 83.32% for the grain yield trait compared to the average of the parents.

The best parents of grain yield for GCA effects are P3 and P4, which had a positive and highly significant (desirable) GCA under the influence of different nitrogen levels 4N, 8N, and 13N (Table 9). The highest value for them reached (**0.25, **0.28), respectively under the influence of low nitrogen level 4N, followed by the parent P1, which had a positive and non-significant (0.04) GCA under the influence of low nitrogen level 4N, and a positive and significant (**0.39 and *0.12) GCA under the influence of nitrogen levels 13N and 8N, respectively, which indicates that these three parent lines possess the largest number of genes with the additive effect that contribute to increasing the grain yield and thus will transfer them to the crosses that participate in their formation (Table 9).

Three hybrids P1×P3, P1×P4, and P3×P4 showed positive SCA effects under the influence of low nitrogen levels, and its highest value was (**0.79) in the P1×P4 at the low nitrogen level 4N, which resulted from parents with positive GCA, and therefore the interaction of gene action has a type (additive x additive), so it is considered a promising cross to improve grain yield. P1×P2 and P2×P3 showed positive SCA effects under the influence of nitrogen levels (8N, 13 N) and the highest value of them (0.86**) in the P1×P2 at the nitrogen level 8N, which resulted from the parents of the effects of its positive GCA, and therefore the interaction of genetic factors has a type (additive × additive), so the hybrid P1×P2 is considered promising to improve grain yield under the influence of nitrogen modifiers 8N, and 13N (Table 10).

Table 7a. Means for grain yield (ton/ha) of seven maize parents evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Parents	Nitrogen Levels					Mean
	130N (Control)	80N	R.R.%	40N	R.R.%	
P1	6.254^{ij}	5.397^{ij}	13.7	3.814^{l}	39.0	**5.155^{IJ}**
P2	6.185^{ij}	5.270^{j}	14.8	4.165^{jkl}	32.7	**5.207^{IJ}**
P3	6.336^{hij}	5.473^{ij}	13.6	4.657^{ghij}	26.5	**5.489^{HIJ}**
P4	6.349^{hij}	6.17^{gfh}	2.8	4.345^{ijkl}	31.6	**5.622^{HI}**
P5	6.696^{hi}	5.219^{j}	22.1	4.430^{hijk}	33.8	**5.448^{HIJ}**
P6	5.123^{k}	5.373^{ij}	-4.9	4.005^{jkl}	21.8	**4.834^{JK}**
P7	5.137^{k}	5.397^{ij}	8.6	3.224^{m}	37.2	**4.353^{K}**
Mean	**6.011**	**5.371**		**4.091**		**5.158**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %

Table 7b. Means for grain yield (ton/ha) of 22 maize crosses evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Crosses	**Nitrogen Levels**					**Mean**
	130N (Control)	**80N**	**R.R.%**	**40N**	**R.R.%**	
P1×P2	8.685^{abc}	4.697^{k}	11.1	6.383^{ab}	26.5	**7.597^{a}**
P1×P3	8.844^{a}	7.722^{a}	14.7	5.843^{bcde}	33.9	**7.409^{abc}**
P1×P4	8.637^{abc}	7.541^{ab}	13.0	6.202^{abc}	28.2	**7.451^{ab}**
P1×P5	8.259^{abcde}	7.513^{ab}	19.2	4.802^{fghi}	41.9	**6.578^{defg}**
P1×P6	8.754^{ab}	6.672^{def}	15.6	5.821^{bcde}	33.5	**7.321^{abcde}**
P1×P7	8.000^{cdef}	7.389^{abc}	26.2	4.386^{ijkl}	45.2	**6.097^{gh}**
P2×P3	8.221^{abcde}	5.906^{hi}	9.7	5.317^{def}	35.3	**6.988^{abcdef}**
P2×P4	8.099^{bcdef}	7.427^{abc}	17.8	4.358^{ijkl}	46.2	**6.372^{fg}**
P2×P5	7.843^{def}	6.66^{def}	8.1	4.583^{hijk}	41.6	**6.544^{efg}**
P2×P6	7.985^{cdef}	7.207^{abcd}	10.6	4.819^{fghi}	39.6	**6.647^{cdefg}**
P2×P7	7.986^{cdef}	7.136^{bcd}	7.0	5.332^{def}	33.2	**6.915^{abcdef}**
P3×P4	8.568^{abc}	7.428^{abc}	14.2	5.620^{cde}	34.4	**7.180^{abcde}**
P3×P5	7.992^{cdef}	7.353^{abc}	13.5	5.653^{cde}	29.3	**6.853^{abcdef}**
P3×P6	7.835^{def}	6.913^{cde}	9.4	5.230^{efg}	33.2	**6.721^{bcdefg}**
P3×P7	8.414A^{bcd}	7.097^{bcd}	15.4	5.961^{abc}	29.2	**7.163^{abcde}**
P4×P5	8.217^{abcde}	7.115^{bcd}	14.2	5.662^{cde}	31.1	**6.976^{abcdef}**
P4×P6	8.340^{abcde}	7.048^{bcd}	13.9	6.511^{a}	21.9	**7.343^{abcd}**
P4×P7	7.671^{ef}	7.179^{abcd}	12.7	6.217^{abc}	19.0	**6.862^{abcdef}**
P5×P6	7.495^{fg}	6.698^{def}	13.8	5.874^{bcd}	21.6	**6.609^{defg}**
P5×P7	6.962^{gh}	6.457^{efg}	13.5	5.009^{fgh}	28.1	**5.997^{gh}**
P6×P7	5.741^{jk}	6.022^{gh}	6.0	4.215^{ijkl}	26.6	**5.11^{ij}**
(Control) Basel-1	8.367^{abcde}	5.398^{ij}	11.0	5.899^{bcd}	29.5	**7.237^{abcde}**
Mean	**8.042**	**6.969**		**5.441**		**6.817**
C.V.%	**4.9**	**4.6**		**6.3**		**5.3**
L.S.D$_{0.05}$	**0.60**	**0.49**		**0.53**		**0.31**
L.S.D$_{0.05}$ for N levels		**0.10**	**L.S.D$_{0.05}$ for N levels× genotypes**			**0.54**

Means within the same column followed by the same letter(s) are not significantly different at the probability level of 0.05. R.R.%= Reduction Ratio %

Table 8. Average mid-parents heterosis (%) of maize crosses evaluated under three nitrogen levels at Raqqa Research Center for the average seasons 2013 and 2014.

Crosses	100 Kernel weight (g)			Grain yield (ton/ha)		
	130N (Control)	80N	40N	130N (Control)	80N	40N
P1×P2	7.6**	15.4**	26.2**	39.6**	44.8**	60.0**
P1×P3	-3.8**	9.9**	20.1**	40.5**	38.8**	37.9**
P1×P4	8.0**	17.2**	9.8**	37.1**	29.9**	52.0**
P1×P5	4.8**	24.6**	8.9**	27.6**	25.7**	16.5**
P1×P6	15.8**	16.3**	20.5**	53.9**	37.2**	48.9**
P1×P7	9.2**	6.6**	-1.5	40.5**	17.0**	24.6**
P2×P3	1.9	23.2**	1.0	31.3**	38.2**	20.5**
P2×P4	7.9**	12.0**	0.5	29.2**	16.4**	2.4**
P2×P5	4.0**	22.1**	-1.3	21.8**	37.4**	6.7**
P2×P6	3.4**	1.9	-2.8*	41.2**	34.1**	18.0**
P2×P7	2.8**	16.6**	10.6**	41.1**	49.0**	44.3**
P3×P4	18.1**	13.7**	27.6**	35.1**	26.3**	24.9**
P3×P5	0.8	17.0**	23.6**	22.7**	29.3**	24.4**
P3×P6	5.9**	7.9**	10.7**	36.7**	30.9**	20.8**
P3×P7	8.4**	11.5**	16.3**	46.7**	39.9**	51.3**
P4×P5	-11.3**	12.0**	36.7**	26.0**	23.8**	29.0**
P4×P6	-17.7**	1.9	36.2**	45.4**	24.4**	55.9**
P4×P7	7.6**	7.8**	36.2**	33.6**	23.3**	64.3**
P5×P6	4.2**	16.1**	24.5**	26.8**	21.9**	39.3**
P5×P7	1.1	18.4**	16.9**	17.7**	21.5**	30.9**
P6×P7	-5.9**	4.2**	7.0**	11.9**	7.2**	16.6**
L.S.D$_{0.05}$	**2.0**	**2.1**	**2.4**	**0.5**	**0.4**	**0.5**
L.S.D$_{0.01}$	**2.7**	**2.7**	**3.2**	**0.7**	**0.6**	**0.6**

***,** Significant at 0.05 and 0.01 levels of probability, respectively.**

Table 9. Estimates of GCA effects for 100 kernel weight (g) and grain yield (ton/ha) of 7 maize inbred lines evaluated at Raqqa Research Center for the average seasons 2013 and 2014.

Parents	100 Kernel weight (g)			Grain yield (ton/ha)		
	130N (Control)	80N	40N	130N (Control)	80N	40N
P1	+0.26	+0.38	+0.73*	+0.39**	+0.12*	+0.04
P2	-0.97**	+0.31	-0.57	+0.11	+0.19**	-0.17**
P3	+1.48**	-0.12	+1.43**	+0.26**	+0.22**	+0.25**
P4	+0.67*	+0.33	+1.15**	+0.23**	+0.26**	+0.28**
P5	-0.18	+0.31	-0.33	+0.00	-0.19**	-0.03
P6	-0.47	-0.13	-0.65*	-0.42**	-0.11*	-0.02
P7	-0.78**	-1.08**	-1.75**	-0.57**	-0.50**	-0.35**
L.S.D$_{0.05}$	**0.51**	**0.52**	**0.60**	**0.13**	**0.11**	**0.12**
L.S.D$_{0.01}$	**0.68**	**0.69**	**0.80**	**0.18**	**0.15**	**0.16**

***,** Significant at 0.05 and 0.01 levels of probability, respectively. + positive GCA effects, - negative GCA effects.**

Table 10. SCA values for 100 kernel weight (g) and grain yield (ton/ha) of the maize crosses evaluated at Raqqa Research Center for the average seasons 2013 and 2014.

Crosses	100 kernel weight (g)			Grain yield (ton/ha)		
	130N (Control)	80N	40N	130N (Control)	80N	40N
P1×P2	+++0.64	++0.88	+++5.33**	++0.66**	++0.86**	+++1.43**
P1×P3	-3.67**	-0.52	++2.21**	++0.67**	++0.65**	++0.47**
P1×P4	++1.54*	++2.37**	-1.51*	++0.50**	++0.57**	++0.79**
P1×P5	+++0.70	++2.88**	-0.80	++0.35*	+++0.18	-0.30*
P1×P6	+++4.58**	+++2.66**	+++2.18**	+++1.26**	+++0.83**	+++0.72**
P1×P7	+++1.38*	-0.89	-2.55**	+++0.66**	-0.27*	-0.39**
P2×P3	-1.00	+++3.38**	-1.21	++0.32	++0.47**	+++0.16
P2×P4	+++2.00**	++0.77	-2.38**	++0.24	-0.34*	-0.84**
P2×P5	++++0.95	++2.13**	-1.83*	++0.21	+++0.65**	-0.30*
P2×P6	++++0.64	-1.76**	-1.85*	+++0.77**	+++0.51**	-0.07
P2×P7	-0.33	+++2.01**	++++1.47	+++0.92**	+++1.18**	++++0.77**
P3×P4	++5.89**	+++1.53*	++2.39**	++0.55**	++0.32*	++0.00
P3×P5	-0.41	+++0.88	+++2.27**	++0.21	+++0.33*	+++0.35*
P3×P6	+++1.43*	++++0.33	-0.42	+++0.47**	+++0.44**	-0.08
P3×P7	+++1.59*	++++0.77	+++1.08	+++1.20**	+++0.84**	+++0.97**
P4×P5	-4.21**	++0.11	+++3.83**	++0.47**	+++0.42**	+++0.32*
P4×P6	-6.69**	-0.95	+++4.03**	+++1.01**	+++0.48**	+++1.16**
P4×P7	+++2.07**	+++0.33	+++4.08**	+++0.49**	+++0.38**	+++1.19**
P5×P6	++++1.96**	+++1.90**	++++2.29**	+++0.39*	++++0.20	++++0.84**
P5×P7	++++0.07	+++1.85**	++++0.84	+++0.01	++++0.15	++++0.30*
P6×P7	-2.53**	-0.21	-0.90	-0.79**	-0.55**	-0.50**
L.S.D 0.05	1.26	1.28	1.48	0.33	0.27	0.29
L.S.D 0.01	1.68	1.71	1.97	0.44	0.36	0.39

***,** Significant at 0.05 and 0.01 levels of probability, respectively. - negative SCA effects. ++Positive SCA effects resulting from cross of two parents, each of which is positive GCA. +++Positive SCA effects resulting from cross of two parents, one positive and other negative GCA. ++++Positive SCA effects resulting from cross of two parents, each of which is negative GCA.**

Conclusions:

- Most of the crosses showed negative heterosis for days to tasseling, which can be relied on these crosses by selection for earliness trait.
- The grain yield decreased due to a decrease in nitrogen levels, and the hybrids varied in their sensitivity to nitrogen deficiency.
- P1 and P4 were characterized by positively and highly significant GCA for 100 kernel weight and the grain yield under the influence of low nitrogen levels, which indicates the possibility of improving these traits through hybridization and selection under the influence of low nitrogen levels.

Suggestions:

- Selecting hybrids that possessed positive and significant SCA, for the grain yield and its components, resulting from the cross of two parents, each of whom has a positive GCA for injection in the breeding program and continue in individual selection under the influence of low levels of nitrogen.
- The interest in promising crosses have positive and highly significant SCA, resulting from parents with high GCA to expect the stability of the trait value of these crosses in the isolated generations under the influence of low levels of nitrogen.
- The use of hybridization and then selection to improve the productive traits under the influence of low levels of nitrogen.
- Introducing P1 and P5 genotypes in breeding programs to improve early tasseling, and introducing P6 and P7 in breeding programs aimed at improving grain yield under the influence of low levels of nitrogen.
- Taking care of crosses P1×P2, P4×P7, and P4×P6 because they have the highest grain yield under the influence of low nitrogen levels.

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