

General and Specific Combining Ability and Heterosis for Yield in Lettuce Lines

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Abstract

This research was conducted to estimate general and specific combining ability and heterosis in lettuce inbred lines using 5×5 diallel crosses. The varieties used were (P1) “Aviflora 2680”, (P2) “Aviflora 2643”, (P3) “Paris Island”, (P4) “Baboli”, and (P5) “Jahromi”. Analysis of variance indicated responses for all measured traits were differed. The highest plant length at flowering stage was related to P1 line and its hybrids. The highest plant width and weight were recorded in the crosses, P3×P5 and P5×P3, respectively. The highest plant length at flowering Stage For Specific Combining Ability (SCA) and General Combining Ability (GCA) were in the P1×P4 and P3×P1 crosses and P1 line; lines P3, P4 and P5 had negative GCA and the cross P5×P1 had the highest negative SCA. Lines P4 and P5 had the highest positive GCA, and line P1 had the highest negative GCA, and crosses P5×P1 and P5×P3 had the highest positive head width SCA while P5×P4 cross had the highest negative head width SCA. Line P1 had positive head weight GCA. The highest positive and negative parent heterosis for head width was from cross P5×P2 and P3×P4 respectively. The highest parent heterosis for head weight was from the crosses P4×P2 and P2×P4 while the highest negative parent heterosis was from the cross P3×P4. Lines P1 and P4 are proposed for high yield hybrid production and their hybrid in next generation are suitable for introducing new high yielding lines.

Keywords: Breeding, Head weight, Lettuce, Yield

Introduction

Lettuce is a cool-season crop that grows best on well-drained soils. Most lettuces [1] cultivars have a growing season of about three months [2].

Estimates of combining ability are useful in determining the breeding value of horticultural crop lines by suggesting the appropriate use in a breeding program [3]. In studying combining ability, the most commonly utilized experimental approach is the diallel design. In the diallel analysis, [4] introduced the concepts of General Combining Ability (GCA) and Specific Combining Ability (SCA). The GCA is a measure of the additive genic action, while the SCA is assumed to be a deviation from additivity.

Crossing a line to several others provides the mean performance of the line in all its crosses. This mean performance, when expressed as a deviation from the mean of all crosses, is called the general combining ability of the line. Any particular cross, then, has an expected value which is the sum of the general combining abilities of its two parental lines. The cross may, however, deviate from this expected value to a greater or lesser extent. This deviation is called the specific combining ability of the two lines in combination. In statistical terms, the general combining abilities are main effects and the specific combining ability is an interaction. [5] defines diallel crosses in terms of genotypic values where the sum of general combining abilities for the two gametes is the breeding value of the cross (i, j). Similarly, specific combining ability represents the dominance deviation value in the simplest case ignoring epistatic deviation ; see [6,7] for details.

Complete diallel cross designs involve equal numbers of occurrences of each of the distinct crosses among p inbred lines. [8-10] investigated the issue of optimality of complete diallel crosses. Heterosis has been utilized to exploit dominance variance through production of hybrids [11]. General and specific combining ability have been investigated to help breeders in breeding scheme for each trait in horticultural crops [12,13]. However, there are differences between reports. The different results means for any breeding program and for breeding each population the general and specific combining ability had to estimate. This research was conducted to estimate general and specific combining ability and heterosis in lettuce inbred lines and hybrids proposed for breeding program using MANOVA analysis like PCA and cluster analysis in reason to produce hybrids or recombinant inbred lines with high yield and quality.

Material and Methods

The experiment was conducted at a research center in Fars province, Ab Barik (latitude 29°56' N; longitude 52°02' E; 1810 m altitude) during spring and summer 2014. The soil was a sandy clay loam, pH 7.1, containing total N (1.5 %), total C (1 %), a C/N ratio of 0.67; there were 4500, 1900, and 4000 mg Ca, P, and K per kg of soil dry matter, respectively, and an electrolytic conductivity (EC) of 0.08 ds·cm⁻¹. Soil was prepared by plowing and disking. Seeds of varieties or hybrids were sown into greenhouse trays containing sand and peat (1:1 v/v). After sowing, seedlings were transferred to potting medium containing peat and cattle manure (1:1 v/v) and irrigated when it was necessary. Seedlings were transplanted with a distance of 0.25 × 0.25 m between rows and plants. Each plot area was 5 m² and contained 25 plants. There was a pre-planting application of nitrogen (urea) at 50 kg·ha⁻¹ and 100 kg·ha⁻¹ of phosphorus (muriate of potash). Nitrogen, 25 kg·ha⁻¹ of KNO₃, was applied by irrigation during the season. No pesticide was used during cultivation. Plants were harvested manually and for yield estimation all plants were weighted and to determine other factors 3 heads of lettuce of each plot were measured.

The work was started by 5×5 diallel crosses. The varieties used were (P1) "Aviflora 2680", (P2) "Aviflora 2643", (P3) "Paris Island", (P4) "Baboli", and (P5) "Jahromi". Flowers emasculated by spraying 200 ppm gibberellins and the clip and wash method [1]. These crosses, along with their parents, were evaluated in a randomized complete block design with three replications. The head length, width and weight were recorded. The data were analyzed using Griffing's model I(i) Method 1: $X_{ij} = u + g_i + g_j + s_{ij} + r_{ij} + (1/b) \sum_k e_{ijk}$

($i = j = 1 \dots p$; $k = 1 \dots b$), where u = the population mean; g_i = the general combining ability effect of the i^{th} parent; g_j = the general combining ability effect of the j^{th} parent; S_{ij} = the specific

combining ability effect of the cross between i^{th} and j^{th} parents such that $s_{ij} = s_{ji}$; r_{ij} = the reciprocal effect of the cross between i^{th} and j^{th} parents such that $s_{ij} = s_{ji}$; e_{ijk} = the environmental effect associated with ijk^{th} observation.

Analyses Of Variance (ANOVA) of data were performed. For the GCA, measurements within plots were averaged and analyzed in the computer program Diallel [14]. The parents were considered fixed effects because they were specifically selected and of limited number. The model used was based on [5] and assumes that epistasis is not significant [15].

Result and Discussion

Analysis of variance indicated responses for all measured traits were differed (Table 1). The highest plant length at flowering stage was related to P1 line and its hybrids (Table 2). The highest plant width and weight were recorded in the crosses, P3×P5 and P5×P3 respectively (Table 2).

In Griffing's method 1, variances due to GCA effects were significant for plant length at flowering stage and head width but GCA effects was not significant for head weight (Table 3). Variances due to SCA effects were significant for plant length at flowering stage and head weight and variances due to reciprocal effects were significant for head width and weight (Table 3). Combining ability analysis is used in selection of parents in formulations of a crossing plan. The diallel study provided evidence for existence of significant additive variation through large GCA values for plant height at flowering stage and head width. The GCA of a parental line provides an assessment of its breeding value, as judged by mean performance of its progenies from crosses with other clones [12]. These traits were controlled additively, additive variance is important for this trait, and breeders are able to produce suitable materials via selection. The highest plant length at flowering stage for SCA and GCA were in the P1×P4 and P3×P1 crosses and P1 line ; lines P3, P4 and P5 had negative GCA and the cross P5×P1 had the highest negative SCA (Table 4). Lines P4 and P5 had the highest positive GCA, and line P1 had the highest negative GCA, and crosses P5×P1 and P5×P3 had the highest positive head width for SCA while P5×P4 cross had the highest negative head width for SCA (Table 5). Line P1 had positive head weight GCA (Table 6).

The highest mid parent heterosis for plant height, were from the crosses P3×P2 and P2×P3 at flowering stage while cross P3×P4 had the highest negative heterosis for plant height at flowering stage ; the highest positive and negative parent heterosis for head width was from cross P5×P2 and P3×P4 for head width respectively (Table 7). The highest high parent heterosis was from the crosses P4×P2 and P2×P4 for head weight while the highest negative parent heterosis was from the cross P3×P4 (Table 7).

Source of variation	d.f.	Mean of square		
		head length	Head width	Head weight
Replication	2	0.07**	117.8**	0.089**
Genotypes	24	2.82**	1955.25**	1915.42**
Error	48	0.09	56.54	111.09
C.V. (%)		3.76	17.32	14

** significant at P<0.01.

Table 1: ANOVA table effect of genotype on length, width and weight of lettuce head.

Genotypes	Plant length at flowering stage (cm)	Head width (cm)	Head weight (g)
P1	130.00a	13.000g	330.0g
P1×P2	81.67abc	17.000fg	447.3efg
P1×P3	121.00ab	17.333efg	446.7efg
P1×P4	94.67abc	23.000b-g	531.0c-g
P1×P5	125.00ab	18.667d-g	686.7a-e
P2	81.67abc	16.667fg	492.0d-g
P2×P1	82.00abc	19.333d-g	487.3d-g
P2×P3	111.33ab	32.00a-f	681.3a-e
P2×P4	101.67ab	30.667a-f	664.3a-e
P2×P5	93.33abc	30.333a-f	711.0a-e
P3	113.33ab	19.000d-g	624.7a-f
P3×P1	115.00ab	28.667a-g	775.7abc
P3×P2	102.00ab	37.000ab	867.3ab
P3×P4	51.67c	17.333efg	374.8g
P3×P5	113.33ab	39.333a	825.0ab
P4	114.00ab	20.000c-g	461.7efg
P4×P1	76.67bc	31.667a-f	677.7a-e
P4×P2	118.83ab	33.667a-e	655.5a-e

P4×P3	109.17ab	34.333a-d	595.3b-g
P4×P5	107.00ab	23.000 b-g	655.5a-e
P5	100.00ab	27.000a-g	646.0a-f
P5×P1	91.67abc	33.667a-e	826.7ab
P5×P2	103.33ab	36.000abc	735.0a-d
P5×P3	116.90ab	34.667a-d	876.0a
P5×P4	108.00ab	23.000 b-g	655.5a-e

In each column numbers followed by same letters are not significantly different.

Table 2: Effect of genotypes on lettuce characteristics.

S.O.V	d.f.	Mean of square		
		head length	Head width	Head weight
Gca	4	1.08**	1630.31**	108.103ns
Sca	10	0.94**	73.66ns	800.12**
Reciprocal	10	0.14ns	289.76**	904.77**
M _e		0.03	18.85	0.36

ns, ** non-significant and significant at P≤0.01, respectively.

Table 3: Mean squares from diallel analysis for various characters in lettuce (Griffing's model I Method 1).

Parent	P1	P2	P3	P4	P5
P1	-9.03	0.86	-5.76	1.14	-3.29
P2	-4.55	-2.36	2.24	2.14	1.71
P3	-14.67	-4.79	4.59	-0.81	3.76
P4	1.54	16.54	10.69	3.35	-2.67
P5	15.81	18.00	7.88	-70.62	3.45

Table 5 : General and Specific combining ability of lines (on diagonal) and hybrids (out of diagonal) for head width according to Griffing's method 1.

Parent	P1	P2	P3	P4	P5
P1	-149.13	8.67	-128.95	49.91	85.71
P2	-58.11	-48.13	4.71	82.24	9.05
P3	-15.56	55.63	88.82	30.62	-13.91
P4	136.94	174.53	60.38	-5.71	-104.38
P5	151.65	198.79	-86.88	-144.78	114.15

Table 6 : General and Specific combining ability of lines (on diagonal) and hybrids (out of diagonal) for head weight according to Griffing's method 1.

Hybrid	Plant height at flowering stage		Head width		Head weight	
	High parent heterosis	Mid parent heterosis	High parent heterosis	Mid parent heterosis	High parent heterosis	Mid parent heterosis
P1×P2	-37.18	-22.9528	.12-05	5.1557	-8.21	9.4539
P1×P3	-6.92	4.3105	-53.16	-30.668	-48.50	-25.3839
P1×P4	-27.18	-20.8335	-32.35	-2.8165	-10.80	18.6155
P1×P5	-3.85	1.2555	-46.15	-21.6774	-21.61	13.8805
P2×P1	-37.18	-22.9528	-13.79	0.0120	0.96	20.3925
P2×P3	9.15	21.0108	-13.51	13.6105	-21.45	0.5865
P2×P4	-6.87	6.3677	-10/68	14.2885	11.59	26.2135
P2×P5	-20.16	-6.1538	5012.-	12.3444	-18.84	4.3035
P3×P1	-12.82	-2.3017	-48.65	-24	-27.97	4.3488
P3×P2	12.75	25	22.52-	1.7769	-10.56	14.5232
P3×P4	-52.67	-51.0625	-53.15	-51.4025	-56.78	-47.6777
P3×P5	-3/05	3.5445	6.31	9.7665	-5.82	-5.3537
P4×P1	-12.31	-4.6695	-15.49	-15.4925	-22.44	3.1355
P4×P2	-29.77	-19.7874	-41.74	18.0155	13.84	28.7595
P4×P3	8.85	12.5459	-9.01	-5.6065	-24.42	-8.4918
P4×P5	4.081	7.644	-8.65	-8.20	-26.94	-11.193
P5×P1	-23.08	-18.9955	-20.58	13.2859	-26.26	7.1315
P5×P2	-21.58	-7.8235	-2.88	24.6925	-5.63	21.2765
P5×P3	-11.61	-5.5915	-2.70	0.4646	-16.10	-15.6788
P5×P4	4.081	7.644	-8.65	-8.20	-26.94	-11.193

Table 7: High and mid parent heterosis for plant length, head width and weight.

Conclusion

Although yield related traits like head weight, heterosis is the primary target for increasing productivity, the biological complexity of yield as a trait frequently makes it difficult to draw meaningful conclusions in order to track individual causal elements involved in heterosis. Lettuce breeders might develop high yielding cultivars based on high GCA for their traits. Lines P1 and P4 are proposed for high yield hybrid production and their hybrid in next generation are suitable for releasing new high yielding lines.

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