Genetic Variabilities in Two Modified Opaque-2 Synthetics of Corn(*Zea mays* L.)

Yun Gyu Kang*, Keun Yong Park*, and Bong Ho Choe**

變更 오페이크-2 옥수수 合成品種의 遺傳變異

姜允圭 * · 朴根龍* · 崔鳳鎬 **

ABSTRACT

The genetic information was required to improve several plant characteristics of the two modified opaque-2 synthetics, which were synthesized in 1980 at the Chungnam National University. Genetic analysis to obtain the information was carried out by the method of Hallauer and Wright[11]. The information obtained from the analysis indicates that plant characteristics such as plant height, ear height, kernel weight and yield of the two synthetics can be improved by proper breeding procedures, since these characteristics were showing high estimates of genetic and additive variance. The study also shows that some characteristics such as ear length or kernel row number may be not improved effectively and with ease.

INTRODUCTION

Since the discovery of the effects of the opaque-2 gene on the protein quality of corn endosperm, many attempts have been made to incorporate the opaque-2 gene into normal corn. However, commercial production of opaque-2 corn varieties have been hampered by several disadvantageous plant characteristics associated with the opaque-2 corn. Opaque-2 gene was introduced in Korea soon after the report of the opaque-2 gene effects in 1960's and breeding works to use the opaque-2 gene have been done at the Crop Experiment Station, Rural Development Administration. Also new attempts were initiated in 1978 at the Agr. College of Chungnam National Univ., to improve the endosperm quality of the opaque-2 corn using modified opaque-2 gene(s). The main purpose of the breeding works were to increase the kernel weight of opaque-2 corn. In Chungnam National University two synthetic modified opaque-2 varieties were developed in 1980 through a series of breeding works[1,2,3]. The breeding works for the development of the synthetics were partly supported by the special research grant provided by the Ministry of Education from 1977 to 1979. The synthetics developed were tentatively named as Puyo #2 and Puyo #3. The kernel weight of the modified opaque-2 varieties has been improved. However, the total yield per the unit land area was much lower than the normal (non-opaque-2) corn varieties. New ways of improving the plant characteristics of the synthetics are required.

Importance of genetic variations in quantitative characters in plant population has been emphasized

* 作物試驗場 (Crop Experiment Station, RDA, Suwon 170, Korea)
** 忠南大學校 農科大學 (Agronomy Dept., College of Agriculture, Chungnam National Univ., Daejon 300, Korea)
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by many plant or animal breeders. Also various methods to estimate genetic variations in a population were reported. Wright[11] defined three types of hereditary or genetic variance: additive genetic variance, variance due to dominance deviations from the additive scheme, and variance due to deviations from the additive scheme resulting from the interaction of nonallelic genes. Wright[11] also outlined procedures for estimating genetic variances and discussed applications of the information. The relative magnitudes of genetic and environmental variances in certain plants have been studied by Hutchinson et al[7] and Powers.[9] Robinson et al[10] examined genetic variance among full-sib and half-sib families within two corn varieties and in crosses between them. Similar studies made by Compton et al[4] Robinson et al[10] also reported on the method of estimating heritability and the degree of dominance in corn. They found relatively high heritabilities in plant height, ear height, husk extension and husk score. But they failed to detect any sizable dominance variation among characters they studied. Hallauer and Wright[6] had estimated the additive portion of total genetic variances in openpollinated variety. Their estimates indicated that the greatest proportion of the total genetic variance was due to additive effects under the assumption of no epistasis. Hallauer and Wright[6] concluded that some form of intra-population selection should be effective, initially, for increasing the frequency of favorable factors determining yields.

Therefore, the objective of the present study was to find the genetic variabilities of the two modified opaque-2 synthetics.

MATERIALS AND METHODS

Two modified opaque-2 synthetics, Puyo #2 and Puyo #3, were used for the study. The original modified opaque-2 gene(s) for Puyo #2 was introduced from Dr. Bauman at the Purdue Univ. in the U.S. The modified opaque-2 gene(s) for the Puyo #3 was from Dr. Lambert at the Univ. of Illinois in the U.S. The introduced modified opaque-2 genes have been incorporated into various normal corn varieties by simple back crosses. From the segregating progenies phenotypic selection for the kernel type was made and the selected progenies were used in the subsequent crosses and selfing. The selected modified opaque-2 progenies were recombined for developing synthetic varieties by open pollination at the isolated farm of the university located at Puyo. The synthesized varieties were examined for their nutritional superiority by feeding experiments on chicken and Puyo #2 was superior to the Puyo #3 in increasing body weight of the chicken.[3] Analysis of lysine content of the two varieties was done and their average lysine level was 0.4% for Puyo #2 and 0.34% for Pyuo #3. The two modified corn varieties have been maintained by simple recurrent selection schemes. The only disadventageous plant characteristics associated with modified opaque-2 synthetics was their low yields per unit area compared with any leading normal hybrids grown in Korea.

The two synthetic varieties were planted at the experimental farm of the Crop Experiment Station, Office of Rural Development in 1983. The Design I experiment, described in detail by Comstock and Robinson[5] was the mating design used to develop the experimental material. Biparental crosses were made within each variety. One plant designated as male was used to pollinate three randomly chosen female plants in the same population. A total of seven male plants from each variety were used in crosses. Plants providing pollen and those bearing seed will be referred to as "male" and "female", respectively. Seven male groups (half-sib families) were obtained, and resulted in 21 full-sib families in each variety. The seed produced in 1983 was grown at the experimental farm of Heung Nong Breeding Farm located in Jochiwon in 1984. Male groups were randomly assigned within 21 full-sib families. The full-sib families were randomly allocated in three replicated plots designed as randomized complete block design. Each plot had three rows with 20 hills per row spaced 25 cm apart. The distance between rows was approximately 60 cm. Each plot was over-planted and later thinned to one plant per hill. All other managements including application of fertilizers followed standard cultural methods recommended by the RDA.

Data were obtained for eight competitive plants within each plot except for yield. The characters measured were plant and ear height, ear length and diameter, kernel row number, kernel number per ear, weight of 100 kernels, and grain yield. Plant height was measured three times at the interval of 20 days after emergence (DAE).

The analysis of variance for each trait was computed on plot means. The form of the analysis of variance was presented by Comstock and Robinson[5], and an example was given in Table 1. Because of the mating design used, the components of variance in Table 1, σ^2_m and σ^2_f, have the following genetic interpretations. The component of variance, σ^2_m, arises from the genetic differences among the male parents and is the covariance of half-sibs.

Table 1. Form of the analysis of variance.

S.V.	df*		M.S	Expected mean square**
Total	rmf	62		
Replication	r - 1	2		
Males	m - 1	6	M_1	$\sigma^2+3\sigma^2$ f/m$+9\sigma^2$ m
Females	m(f - 1)	14	M_2	$\sigma^2+3\sigma^2$ f/m
Error	(r - 1) (mf - 1)	40	M_3	σ^2

* : r, m, and f refer to replications, males, and females, respectively.

** ; σ^2_m = Variance due to genetic differences among males.

σ^2_f/m =Variance due to genetic difference among females mated to the same male.

σ^2 = Environmental variance among plants in the same plots.

The component of variance, σ^2_f, is due to the genetic differences among female parents mated to the same male parent and is the covariance of full-sibs minus the covariance of half-sibs. The assumptions made in deriving the mean square were that (1) parental plants used in making the crosses are non inbred, (2) regular diploid behavior, (3) no maternal effects, (4) equilibrium of repulsion and coupling phase linkages, (5) no selection of parental plants, and (6) no epistasis. Under the assumptions, the genetic interpretations were made by Hallauer and Wright[6] as follows:

σ^2_m = covariance half-sibs = (¼) σ^2_A ; and

$\sigma^2_{f/m}$ = covariance full sibs minus covariance half sibs = (¼) σ^2_A + (¼) σ^2_D . Then, 4 σ^2_m is the additive genetic variance (σ^2_A), and 4 $\sigma^2_{f/m}$ is the total genetic variance ($\sigma^2_G = \sigma^2_A + \sigma^2_D$) under the assumption of no epistasis. Dominance variance (σ^2_D) was estimated as 4 $\sigma^2_{f/m} - 4\ \sigma^2_m$.

Additive genetic and total genetic correlations were obtained for all pairs of traits observed. As indicated by Mode and Robinson[8] the expectations of the mean cross-products have the same forms as the expected mean squares. Therefore, the correlations among pairs of traits assuming absence of epistasis, were computed as follows:

Additive genetic correlation = $\bar{r}_A$ = Smm$'$ $/\sqrt{S^2 m \cdot S^2 m'}$; and total genetic correlation = $\bar{r}_G$ = Sf/m f$'$/m$'$$/\sqrt{S^2 f/m . S^2 f'/m'}$ where smm$'$ and sf/mf$'$/m$'$, are the estimated covariance components for males and females, respectively. The phenotypic correlation coefficients were calculated in usual ways from the total observations. Heritabilities in a broad sense for each trait were calculated as usual ways; $H_B{}^2 = \sigma^2_G / \sigma^2_P$, where σ^2_G and σ^2_P were variance due to genetic and phenotypes, respectively.

RESULTS AND DISCUSSIONS

The mean values of the plant height measured at the three different dates and their standard errors are shown in Table 2. The mean plant height at 20 days after emergence for Puyo #2 and #3 were 46.3 cm and 54.2 cm, respectively. Puyo #3 was about 8 cm higher than the Puyo #2 in plant height. Differences of plant height due to male plants at the 20 DAE seems to exist in both synthetics. The mean plant height at 40 DAE of Puyo #2 was 141.4 cm, while the mean plant height of Puyo #3 at the 40 DAE was 171.0 cm. Again Puyo #3 was about 30 cm higher than the Puyo #2. Variation of plant height due to male plants was mostly apparent in both synthetics studied.

The mean plant height at 60 DAE of Puyo #2 was 238.8 cm and the plant height of Puyo #3 was

Table 2. Mean values and Standard errors of 10 characters of two synthetic varieties, Puyo #2 and Puyo #3.

Variety	Male \ Character	Plant Height (cm) 20DAE*	40DAE	60DAE	Ear (cm) Ht.	L'th.	Diam.	Kernel Row No.	No.	100K. Wt. (g)	Grain Yield (g/ear)
Puyo #2	I	48.0	156.0	253.1	118.5	15.3	3.86	14.77	385.5	18.0	52.9
	II	48.4	148.3	242.0	107.3	15.7	3.66	15.81	380.2	15.3	48.3
	III	48.5	143.7	245.9	107.6	13.2	3.56	14.79	292.0	16.8	37.7
	IV	44.8	133.8	239.5	108.7	15.4	3.42	14.84	330.1	12.6	38.4
	V	43.1	130.1	223.0	94.5	14.2	3.26	14.06	304.7	12.6	33.8
	VI	41.5	134.0	239.0	101.2	15.1	3.28	14.13	324.1	13.7	37.3
	VII	50.0	143.6	228.9	91.8	15.4	3.58	13.79	339.4	16.4	42.4
	$\bar{X}$	46.3	141.4	238.8	104.2	14.9	3.52	14.60	336.9	15.1	41.5
	$\sigma\bar{X}$	1.60	3.55	3.56	3.53	0.98	0.12	0.52	48.72	1.12	7.57
Puyo #3	I	60.7	180.2	281.6	140.0	17.6	3.98	14.67	395.5	20.9	62.3
	II	56.8	181.3	252.4	138.1	15.9	4.03	15.06	375.5	20.5	66.0
	III	54.1	172.4	257.7	137.0	15.9	3.80	14.40	372.1	17.6	56.2
	IV	49.5	166.1	264.7	128.8	16.5	3.65	13.95	288.9	17.5	51.3
	V	47.3	163.0	265.6	129.2	17.1	3.81	14.53	378.0	17.2	56.3
	VI	49.4	152.8	245.5	121.7	16.2	3.68	13.39	337.9	17.9	57.8
	VII	61.8	181.3	263.8	126.5	17.0	3.99	15.28	404.5	18.5	63.7
	$\bar{X}$	54.2	171.0	261.6	131.6	16.6	3.85	14.47	364.6	18.6	59.1
	$\sigma\bar{X}$	3.40	6.18	7.91	4.18	0.85	0.12	0.61	66.25	1.37	9.77

* ; Days after emergence.

261.6 cm, being Puyo #3 higher than Puyo #2. The plant height measured at three different dates during plant growth of the two synthetics indicates that there seems to exist some differences in manifestation of heterosis between the two synthetics. In other words, Puyo #3 was showing faster growth in early part of vegetative growth than the Puyo #2. The standard errors calculated for plant height of both synthetics indicate that Puyo #3 was more variable than the Puyo #2.

The mean ear height for the Puyo #2 and #3 are shown in Table 2. The mean ear height was 104 cm for Puyo #2 and 132 cm for Puyo #3. Variation of ear height due to male groups was also apparent in both synthetic varieties. The mean ear length was 15 cm for Puyo #2 and 16.6 cm for Puyo #3. The mean ear diameter was 3.5 cm for Puyo #2 and 3.9 cm for Puyo #3. Variation of ear length or diameter was not so great as the plant height or ear height. Ear length and diameter shows that Puyo #2 is smaller than Puyo #3 in ear size.

Kernel row number and kernel number per a ear are presented in Table 2. The average row number was 14.6 for Puyo #2 and 14.5 for Puyo #3. The average kernel number per ear was 337 for Puyo #2 and 364 for Puyo #3. The two synthetic varieties have the same row number, while Puyo #3 had more kernels per ear. The weight of 100 kernel was 15.1 grams for Puyo #2 and 18.6 grams for the Puyo #3. The kernel size (not shown) of Puyo #2 was samller than that of Puyo #3. However, Puyo #2 had more endosperm with vitrous starch (not shown) than the Puyo #3[1,2,3]. Yields per ear were 41.5 grams for Puyo #2 and 59.1 grams for the Puyo #3, being higher for Puyo #3. Our previous report on the lysine content of the whole endosperm basis shows that Puyo #2 was higher in lysine level than the Puyo #3[3].

Table 3 and 4 show that mean squares for characters of the two synthetic varieties. Except for a few characters such as ear length, ear diameter or kernel number, male or female groups showed a greater contribution to significant mean square values. The significant mean square values associated with the male or female groups indicate variation due to environmental and genetic causes. Mean square

Table 3. Mean squares of 10 characters of Puyo #2.

S.V.	df	Plant height 20DAE	Plant height 40DAE	Plant height 60DAE	Ear Height	Ear Length	Ear Diam.	Kernel row No.	Kernel No.	100K. Wt.	Grain yield
		Mean Squares									
Total	62										
Reps.	2	70.77**	479.71**	56.00	23.33	4.62	.03	.22	176.19	4.07	105.19
Treatment	20	47.79**	300.49**	364.05**	298.88**	5.14	.16**	2.63**	7893.30	15.06**	292.10
Male	6	93.21**	766.21**	923.36**	751.06**	7.18*	.43**	4.10**	11575.07	41.37**	538.09*
Female	14	28.33**	100.90**	124.34	105.09**	4.27	.05	1.99*	6315.40	3.79	186.68
Error	40	7.67	37.87	92.93	37.30	2.89	.04	.81	7120.47	3.77	171.94
Male	12	7.90	22.77	106.62	75.31	4.60	.03	.68	11672.20	3.49	173.35
Female	28	7.58	43.35	87.06	22.00	2.16	.05	.87	5169.73	3.88	171.34
C.V.		5.98%	4.35%	4.04%	5.86%	11.44%	6.02%	6.18%	25.05%	12.89%	31.78%

*, ** ; Significant at the 5 and 1% probability levels, respectively.

Table 4. Mean squares of 10 characters of Puyo #3.

S.V.	df	Plant height 20DAE	Plant height 40DAE	Plant height 60DAE	Ear Height	Ear Length	Ear Diam.	Kernel row No.	Kernel No.	100K. Wt.	Grain yield.
		Mean Squares									
Total	62										
Reps.	2	194.49**	502.52*	1733.23**	412.41**	7.36*	.09*	4.37*	36341.98	3.52	3431.02**
Treatment	20	124.54**	486.16**	568.06**	249.33**	4.07*	.16**	2.56*	15740.84	11.41*	416.75
Male	6	298.26**	1078.68**	1182.42**	418.37**	1.59	.23**	3.73**	14022.78	20.79**	568.15
Female	14	50.09**	232.23*	304.77	176.89**	5.13*	.14**	2.05*	16477.15	7.39	351.86
Error	40	17.20	114.48	187.84	52.44	2.16	.04	1.12	13165.54	5.60	286.55
Male	12	37.84	216.73	141.84	51.97	2.10	.03	1.04	14448.82	6.88	212.08
Female	28	8.36	70.66	207.55	52.65	2.19	.04	1.16	12615.56	5.06	318.46
C.V.		7.65%	6.26%	5.24%	5.50%	8.65%	5.17%	7.32%	31.47%	12.73%	28.42%

Table 5. Estimates of additive genetic variance, dominance variance, total genetic variance, and heritability of broad sense for nine characters of Puyo #2.

Character		σ^2_A	σ^2_D	σ^2_G	h^2_B
Plant height	20DAE	28.835	−1.296	27.539	0.782
	40DAE	295.694	−211.663	84.031	0.689
	60DAE	355.122	−313.244	41.878	0.311
Ear height		287.099	−196.707	90.392	0.708
Ear length		1.292	0.546	1.838	0.388
Ear diameter		0.168	−0.164	0.004	0.074
Kernel row No.		0.936	0.642	1.577	0.659
100K. Wt.		16.703	−16.676	0.027	0.007
Grain yield		156.179	−136.522	19.657	0.103

values of male component were much higher than those of female component in both varieties. The genetic components of variance for the characters in both synthetics are shown in Table 5 and 6. The additive variance for the plant height measured at the three different growing dates of Puyo #2 was very high compared to the dominance variance and they seemed to increase as plants grow. The ear height of the Puyo #2 showed also large estimates of additive variance. The additive variance of yield of Puyo #2 was estimated very high compared to the dominance variance. However, characters such as ear length, ear diameter and kernel row number were showing relatively small estimates of additive variance. The 100 kernel weight of Puyo #2 was one of the characters that was showing relatively large values of additive variance. The characters showing high values of additive variance had large heritabilities in a broad sense except for yield. The high estimates of additive variance for the plant height, ear height, and yield of Puyo #2 were quite agreed upon with the previous reports by Hallauer and Wright[6] on an open pollinated corn variety they used.

The estimates of additive variance was consistently larger than variance due to dominant gene action for plant height, ear height, 100 kernel weight and yield of Puyo #3. The additive variances of ear length, ear diameter and kernel row number of Puyo #3 were not much greater than the dominance

Table 6. Estimates of additive genetic variance, dominamce variance, total genetic variance, and heritability of broad sense for nine characters of Puyo #3.

Character		σ^2_A	σ^2_D	σ^2_G	h^2_B
Plant height	20 DAE	110.298	−66.446	43.852	0.718
	40 DAE	376.200	−219.201	156.999	0.578
	60 DAE	390.070	−234.162	155.908	0.454
Ear height		107.324	58.599	165.923	0.760
Ear length		−1.570	5.520	3.950	0.646
Ear diameter		0.040	0.089	0.127	0.765
Kernel row No.		0.748	0.492	1.240	0.525
100K. Wt.		5.960	−3.584	2.375	0.298
Grain yield		96.127	−9.040	87.087	0.233

Table 7. Additive genetic, genotypic, and phenotypic correlation among 10 characters of Puyo #2.

Character		Plant height 40 DAE	Plant height 60 DAE	Ear height	Ear leight	Ear diam.	Kernel row No.	Kernel No.	100 K. Wt.	Grain Yield
Plant height 20DAE	a)	.254	.099	.057	.014	.264	.098	.125	.264	.195
	g)	.769**	.263	.190	-.145	.830**	.275	–	.888**	.609*
	p)	.787**	.263	.129	.278	.702**	.306	.359	.646*	.564*
Plant height 40DAE			.236	.204	.073	.324	.155	.243	.305	.286
			.716**	.645*	.271	.997**	.478	–	.996**	.984**
			.583*	.515	.300	.830**	.432	.473	.769**	.699**
Plant height 60DAE				.311	.016	.228	.198	.155	.202	.171
				.980**	-.229	.721**	.622*	–	.742**	.475
				.845**	.195	.629*	.533*	.467	.375	.542*
Ear height					.033	.210	.222	.169	.139	.154
					-.072	.665**	.774**	–	.502	.475
					.218	.563*	.516	.425	.280	.433
Ear length						.087	.068	.261	.020	.228
						.201	.045	–	.057	.766**
						.349	.315	.664**	.093	.667**
Ear diam.							.158	.244	.287	.272
							.466	–	.967**	.958**
							.471	.563*	.708**	.773**
Kernel row. No.								.165	.056	.134
								–	.267	.372
								.391	.039	.414
Kernel No.									.145	.317
									–	–
									.045	.907**
100K. Wt.										.220
										.982**
										.323

a), g), and p) refer to the additive genetic, genotypic, and phenotypic correlation, respectively.

variance. The higher estimates of additive variance of plant height, ear height, 100 kernel weight and yield of the Puyo #3 were very much alike similar with those estimates obtained from the Puyo #2 variety. The heritabilities in the broad sense were high for the plant height, ear height, ear length, and ear diameter. The heritabilities of yield of Puyo # 2 and Puyo #3 were very low.

Throughout the analysis of variance components, one particular thing was that the magnitude of the genetic variances for several plant characters of both varieties was smaller than the estimates of additive variance under the assumption of no epistasis. For instance, plant height measure at 20 DAE, 40 DAE and 60 DAE, 100 kernel weight, and yield of Puyo #2 and #3 showed smaller genetic variance than the additive variance. The smaller genetic variance was, therefore, responsible for the negative values of some dominance variance for some characters studied.

The additive genetic, genotypic, and phenotyp correlations among the plant characters are show in Table 7 and 8. Except for additive genetic corı lation, plant height of Puyo #2 tended to have positive correlations with ear height, ear diamet and grain yield. Ear height was correlated with e diameter except for additive correlations. Ear leng of the Puyo #2 was highly correlated with gra yield in genetic and phenotypic aspects. Kernel rc number had a high phenotypic correlation wi grain yield.

As in Puyo #2, no additive genetic correlati(was high enough to be significant in the Puyo # The genotypic and phenotypic correlations amoı plant characters of the Puyo #3 showed the san tendencies as shown in the Puyo #2. In geneı plant height measured at 20 DAE and 40 DA tended to show more positive correlations wi other plant characters compared with the pla: height measured at 60 DAE. It should be point(

Table 8. Additive genetic, genotypic, and phenotypic correlation among 10 characters of Puyo #3.

Character	Plant height 40DAE	Plant height 60DAE	Ear height	Ear length	Ear diam	Kernel row No.	Kernel No.	100K. Wt.	Grain yield
Plant height 20DAE	a) .291 g) .903** p) .838**	.133 .400 .493	.156 .550* .444	.162 .650* .320	.268 .871** .793**	.243 .900** .611*	.225 – .445	.242 .842** .554*	.017 .985** .506
Plant height 40DAE		.155 .440 .569*	.223 .802** .624*	.107 .381 .302	.281 .984** .752**	.298 .988** .741**	.201 – .428	.231 .825** .558*	.108 .970** .579*
Plant height 60DAE			.154 .446 .605*	.427 .622* .625*	.105 .333 .406	.125 .478 .432	.101 – .494	.112 .400 .271	-.002 -.435 .475
Ear height				.011 .411 .336	.184 .669** .498	.165 .688** .423	.126 – .490	.221 .858** .443	.011 .427 .594*
Ear length					.148 .248 .372	.141 .435 .165	.201 – .736**	.124 -.045 .065	-.002 .790** .461
Ear Diam.						.290 .989** .673**	.269 – .649*	.251 .870** .659*	.023 .986** .668**
Kernel row No.							.248 – .441.	.165 .741** .269	.021 .569* .583*
Kernel No.								.156 – .169	.020 – .796**
100K. Wt.									.016 .952** .372

a), g), and p) refer to the additive genetic, genotypic, and phenotypic correlation, respectively.

out that the plant height of either Puyo #2 or Puyo #3 was highly depressed because of a black streaked dwarf virus incurred during the later part of the growth.

In conclusion high estimates of genetic, additive, variance of some characters indicate that plant characters such as plant height, ear height, kernel weight and grain yield of the two modified opaque-2 synthetics may be improved by proper breeding procedures such as recurrent selection. However, some plant characters like ear length, ear diameter or kernel row number may be not improved with ease. It was also indicated that yields of the two synthetics could be increased by increasing plant height or ear diameter.

摘　　要

보통 옥수수의 胚乳에서 缺乏되어 있는 라이신 등 必須 아미노산의 양을 增加시키기 위해 變更 오페이크－2 遺傳因子를 도입하여 부여 #2와 부여 #3 (가칭)의 두 合成品種을 충남대 농대에서 育成(1980)하여 이들의 두 품종이 가지고 있는 遺傳變異를 알고져 Hallauer와 Wright[11]의 分析方法에 따라 알아본 결과는 다음과 같다. 우선 두 품종이 다 같이 草長, 이삭높이, 이삭의 크기, 100립중, 수량／이삭 등에 있어서 優性因子效果 보다도 相加的 效果가 큼을 확인하였는데 이로 미루어 보아 이들 주요 식물 특성이 循環選拔과 같은 적당한 育種方法에 의해 改良될 수 있다는 것이고 이삭當 列數나, 이삭의 直徑 등은 優性效果가 相加的 效果(分散)보다 커서 두 품종 모두 育種的 改良이 어려울 것이라는 것을 확인하였다.

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