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Studies on the Inheritance of Agronomic Characteristics in Upland Cotton Varieties (*Gossypium hirsutum L.*) in Korea

Bang-Myung Kae
Mokpo Branch Station, Crop Experiment Station, Mokpo, Korea.

陸地綿品種의 有用形質의 遺傳에 關한 研究

桂 鳳 明
作物試驗場 木浦支場

I. Introduction

Upland cotton, introduced to Korea from the United States of America in 1904, was cultivated on a large area in Korea prior to the Second World War. Since then the cotton area has decreased yearly due to the large amount of cotton lint imported yearly from foreign countries especially the United States of America.

Since the Korean War, cotton acreage has decreased markedly while the textile industries have expanded yearly. Large amounts of American lint have been imported to meet the cotton fiber demand resulting in a loss of valuable foreign exchange. Staple food crops self-sufficiency is more ergently required in Korea than self-supply of cotton lint.

Cotton is one of the most important cash crops in Korea. The current area planted to cotton is 13,000 ha. Once food self-sufficiency is reached, cotton will become an important crop. It is firmly believed requiring continued experiments on varietal improvement and improved cultural practices of Upland cotton.

Accordingly genetic analyses for yield component and fiber quality of cotton should be done. Genotypic and phenotypic correlatonships between economic and agronomic characteristics must be clearly investigated to efficiently improve cotton varieties and cultural practices suitable for Korea. These findings could be utilized in making cross combinations and progeny selections thus promoting cotton breeding efficiency in developing desirable varieties.

Korea needs early-maturing, long-staple and high-yielding cotton varieties. To breed these desirable cotton varieties, combining ability, inheritance mode, heritability and genetic correlations for days to flowering, number of bolls per plant, boll weight, lint percent, staple length, 100 seeds weight and lint yield per plant were investigated. Analyses on segregating mode and genetic components, heritability, and phenotypic and genotypic correlations by using the F_2 and F_3 populations of Paymaster x Heujueusseo Trice combination were provided to solve basic problems of cotton breeding in Korea.

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II. Review of Literature

Studies on earliness and lateness of cotton varieties have been investigated because of their great effects on lint yield and quality.

Christidis · Harrison[10] and Nishikawa[54] showed that earliness and lateness of cotton could be classified by percent first harvest, 50% opening date, mean maturing date, opening date, days to open boll and boll period.

In Greece earliness of cotton is closely correlated with early flowering and short boll period. Also, in Korea Lee[42] confirmed significant positive correlation between flowering and boll opening dates(r=0.746) and Kae[34,36] indicated that there were significant correlations between flowering date and boll opening date (r=0.859~0.921), and between flowering date and percent September harvest(r=0.887—0.861). Thus flowering and boll opening date are considered as indexes of earliness.

Ray et al[60] reported that NFB (node of first fruiting branch) is highly heritability with low variability and is closely related with earliness. NFB is believed to be a morphological measure for earliness of cotton.

Richmond · Ray[63] reported that mean maturing date by number of bolls per plant was highly heritable in the F_2 population and it was confirmed to clearly identify earliness as a geno-statistical parameter.

Percent first and second harvest of total seed cotton yield were one of the practical measures to estimate earliness of cotton.

Concerning relationships between earliness and other characteristics, Duggar[12] reported that earliness was negatively correlated with big boll and that earliness was not correlated with lint yield. Kae[35] reported that flowering date had a positive significant correlation with boll weight, lint percent and fiber length, with late varieties having generally big boll, high lint percent and long staple.

Harland [5,22] reported that earliness was dominant. Hintz · Green [30] noted that heritability of mean boll period in F_1 and F_2 populations was high, 50.6%, they noted in addition many dominant genes for earliness and for lateness that countered each other. White[74] confirmed multiple alleles for earliness, lint percent and boll size in diallel analysis. Kohel at al [39] reported that in interspecific crosses between Upland and Sea-Island cotton, flowering date was not controlled by the simple inheritance of Sea-Island cotton but was render complex genetic control.

Flowering date of Latifolium strains was quantitatively inherited showing partial dominant as shown in the 48% dominance ratio. Estimates of the heritability were 57% and 70% for narrow and broad senses heritabilities respectively.

In further studies on early-maturing cotton varieties, Marray[52] confirmed that the lines resulting from cross populations of an early-maturing Yugoslavian variety and Acala 44 were earlier than the standard variety Paymaster 101-A, and had longer fibers than Acala 44, giving increased lint yields. Miller · Marani[49] reported that in diallel crosses with 8 Upland cotton varieties, yields of first harvest relative to earliness were increased 12% and boll weight was increased 9% showing heterosis. General combining ability was apparent for all the characteristics but specific combining ability was limited to yield and boll size.

Jones · Andries[33] reported that OKRA leaf reduced the occurrence of anthracnose while promoting earlinization. Tabrah[68] reported that early-maturing lines performed well when planted late. Hosfield[31] found that the glandlessness character was associated with late maturity, lint percent and boll size.

Christidis・Harrison[10] noted that the number of bolls per plant depended on number of flowers per plant and the numbers of squares and bolls shed. Boll number varied with environmental conditions but was highly correlated with lint yield.

Kae[35] confirmed that number of bolls per plant was significantly correlated with the number of fruiting branches per plant but bolls per plant were negatively correlated with flowering period. Harland[22] reported medium and large bolled varieties bore bolls from 26-28% of the open flowers while small bolled varieties produced bolls from 39-42% of the open flowers.

White・Kohel[75] examined and confirmed additive genetic variation for lint yield, boll size, number of bolls per plant and vegetative weight. Partial dominance was detected in a diallel analysis for all the above traits. F_1 hybrids produced 30% more than mid-parent due to number of bolls per plant and boll size. On the other hand, Miletello[47] certified that in the F_3 population lint yield was significantly correlated with number of bolls per plot but was negatively correlated with staple length, indicating fiber characteristics were generally related independently to each other.

In studies on boll weight, Dunlavy[15] reported that boll size was positively correlated with staple length, lint index and percent 5-lock bolls per plant but was negatively correlated with lint percent. Kae[35] confirmed that boll weight was positively correlated with percent 5-lock bolls per plant, staple length and 100-kernel weight. Miller et al[51] siudied genotypic and environmental variation and their covariance. Environmental variances were significant for lint yield, number of seeds per boll and boll weight while being small for lint percent. Boll weight was negatively correlated with seed index. Ramey・Miller[59] examined inter-specific hybrid populations. Dominant genetic variation was significant for lint percent, boll weight and fiber length. The means were located at the part of partial dominance being similar to the findings of White[74] in his studies on diallel crosses.

Dunlavy[15] reported negative correlation between fiber length with lint percent, and between seed weight and lint percent. Turner[70] confirmed significant negative correlation between lint percent and seed weight in Egyptian and Indian cotton, Christidis・Harrison[10] indicated that there were significant, positive correlations between boll・seed weights with lint percent in Greek varieties while negative correlations were found between fiber length and lint percent. They concluded due to the opposite relationship between earliness and lint percent, breeders should omit these combinations. Using different stock, kae[35] noted that lint percent, was significantly, positively correlated with boll weight and seed weight but negatively correlated with percent 5-lock bolls. William・Bridge[77] confirmed high correlations between the F_2 and F_3 populations consisting of 10 combinations with five varieties for lint percent, seed index, and fiber length, strength and elongation. The performance of the F_2 population was a particulary good indicator of these traits. Shephered[64,65] found negative correlations between lint percent and staple length in the 95 lines of the inter-specific hybrid cross Deltapine 15 times Sea Island. These negative correlations were not found in populations having high lint percent and adequate fiber strength.

Ramey[58] reported that the lint index inheritance was either dominant or epistatic. Ware・Harrell[73] reported combinatons showing F_1 hybrids expressed complete and incomplete dominance. Ferrer・Monge[16] reported that heritabilities were high for seed index, fiber density index and lint percent in the F_3 lines of Deltapine 15 times Sea Island. Richmond[61] noted that the amount of lint per seed was regulated by two genetic systems, one showing pleiotropic effects for lint and fuzz production. The second was a compound composition of supplementary minor genes behaving independently in producing lint.

Christidis・Harrison[10] found that high lint percent was dominant in the F_2 populations of Upland cotton times Sea Island cotton, being a single dominant gene in Upland cotton varieties. Partial dominance in the case of narrow difference between two parents' lint percents was found.

Christidis · Harrison found that staple length was positively correlated with boll opening date, yield, numder of bolls, boll weight and number of flowers within variety, but the positive correlation existed only with boll weight and boll opening date between varieties. Staple length was negatively correlated with number of bolls per plant between varieties. Balls[7] reported that the seed weight of Egyptian cotton was regulated by several simple allelic genes. Limaye[44] reported that there was no relationship between seed index and fiber density index in the F_1 and F_2 populations of Upland cotton times Sea Island cotton.

In the studies on lint yield, Grifee et al[19] noted that seed cotton yield was negatively correlated with internode length, largest leaf area and number of vegetative branches per plant but positively correlated with lint percent and lint yield. Al-Jibouri et al[4] confirmed that lint yield was significantly, positively correlated with lint percent while both characteristics were negatively correlated with tensile strength of fiber.

Christidis · Harrison[20] reported that lint yield was closely related with seed yield. Jones · Loden[32] reported yields of the F_1 hybrids from 9 combinations 16.9-47.0% greater than mid-parent yields. These F_1 hybrids were earlier in percent first harvest, and had large boll. Combinatons with significant SCA effects were selected. Barnes · Staten[8] found that 20% of all intervarietal · interspecific crosses (Pima 32 × Acala 1517C) were superior in yield and fiber quality. Lee et al[43] reported that the 26% heterotic effects on lint yields were caused by larger boll size, lint percent, fiber characteristics, and especially superior effects of GCA for lint characteristics. Hawkins et al[23] found the average lint yields of F_1 hybrids of Upland cotton varieties were 19.0% higher than the high parent. Superior varieties and superior combinations for GCA and SCA in lint yield, number of flowers per plant and percent 5-lock bolls per plant were identified.

White · Richmond[76] reported that F_1 hybrids gave 30% higher yield than high parent in diallel analysis among 5 varieties. GCA effects were significant for all of traits while SCA effects were estimated only for boll size and yield.

In the studies on breeding methods for improving yield and fiber quality of Upland cotton, Ramey[57] investigated additive-genetic variance, dominance variance and average degree of dominance for yield and fiber characteristics. Abou-El-Fittough[2] suggested that because yield was affected by genotypic, environmental interactions, regional breeding systems should be established to reduce large interactions between variety and region. Abou-El-Fittough et al[3] found significant varietal differences in seedling responses to minimum temperatures and ripening responses to maximum temperatures. Tempertures were estimated to account for 30% of environmental variations. Miller · Lee[48] reported that the top-cross hybrids generally had higher lint yields and larger bolls than the parent varieties. Lint percent and various fiber traits, were similar for both hybrid and mid-parent value. Certain individual top-cross hybrids were superior in lint yield to the better varieties included in the test. A conservative estimate of this superiority would be around 15 to 20%. Duncan et al[12,13] confirmed that a composite variety derived from various Upland cotton varieties was higher yielding due to heterosis. Galal et al[17,18] found that heterotic effects first appeared in seedling stage by giving an increased growth rate(6~9 weeks). This affect carried over to maturity by increasing number of bolls, and dry matter. Young et al[78] reported that heterotic effects of intervarietal crosses of Asiatic cottons and heterosis in tetraploid cotton was compounded by dominant growing characters.

Pressley[56] and Koshal et al[41] confirmed that interspecific hybrids showed longer staple and were earlier maturing than were the midparent value. Kime · Tilley[38] reported that the yields of F_1 hybrids of 6 combinations of inter-varietal Upland cotton crosses were significantly higher than the higher yielding parent. The F_2 population showed increases in number of flowers, early maturing bolls and lint index. Simpson[66] and Turner[71] examined hybrid vigor effects from natural crosses by mixing varieties.

Studing selection for increased lint yield, Miller · Rawling[50] reported that recurrent selection from F_3 populations produced 29.7% higher lint yields while improving lint percent, number of seeds per boll, earliness, and fiber elongation and coarseness. Boll size, seed size and staple length and tensile strength were decreased. This suggested above characteristics were presented heterotically by additive-genetic effects.

Ⅲ. Materials and Methods

Experiment Ⅰ

Genetic studies on agronomic characteristics of Upland cotton were analysed by F_1 diallel crosses. The parents were the leading Korean varieties Suwon 1 and Mokpo 6, the American varieties Lockett 140, Paymaster, Acala 1517W, Delfos 9169, Arijona, the French variety Copt 6390, and the Manchurian variety Heujueusseo Trice[53]. Outlines for agronomic characteristics of the 11 parental varieties are given in Table 1.

Table 1. Parental mean values for seven agronomic characteristics in a 11-Parent diallel experiment with cultivated Upland cottons at Mokpo, Korea in 1972.

Variety	Original country	Days to flower -ing	Wt.of boll (g)	Lint %	Fiber length (mm)	100 Seeds weight (g)	No.of bolls per plant	Lint yield (g/plant)
1. Suwon #1	Korea	80.0	3.05	31.25	20.75	9.05	9.00	8.24
2. Mokpo #4	Korea	84.0	3.90	36.25	23.25	8.35	11.10	10.36
3. Mokpo #6	Korea	84.5	5.05	38.30	27.00	9.35	8.60	12.75
4. Copt 6390	France	84.5	4.75	34.65	25.90	9.45	9.10	9.70
5. Heujueusseo Trice	Manchu	82.5	4.65	33.20	25.55	11.20	7.00	6.45
6. Lockett 140	U.S.A	87.0	4.60	35.75	26.85	10.55	9.40	9.15
7. D.P.L.	U.S.A	87.0	4.30	33.95	25.85	9.65	8.40	8.03
8. Paymaster	U.S.A	87.0	6.05	39.45	27.25	9.90	8.35	8.53
9. Acala 1517w	U.S.A	87.0	5.00	30.30	26.85	11.50	8.05	6.96
10. Delfos 9169	U.S.A	87.0	4.30	36.60	29.25	9.45	9.55	10.93
11. Arijona	U.S.A	89.0	4.90	38.60	30.95	10.50	6.90	8.05

This data was collected at the experimental farm of Mokpo Branch Station, Crop Experiment Station, Mokpo, Korea in 1971 and 1972. This station is located at 34°48′N, 126°23′E and altitude of 10m above sea level.

The 11 varieties were planted at spacings of 70cm × 30cm on May 5th of 1971 and 55 combinations were made between the 11 varieties by diallel cross system. The hybrid seeds were treated with delinted sulfuric acid to promote germination. These crosses were seeded at 60cm × 30cm spacing on May 5th of 1972 along with the parents in a randomized complete block design with two replications; each plot containing 10 plants.

Eight hundred kgs of compost, 10kgs of ammonium sulfate, 9.4kgs of triple super phosphate and 8.8kgs of potassium chloride per 10a were applied at planting time and 10kgs of ammonium sulfate was top-dressed in late June of 1972.

Late emerging or missing hills were replanted with uniform seedlings of Mokpo 6 to reduce bias.

The following measurements were made on 13 individual plants per combination.

Days to flowering=days from seeding date to initial flowering date.

Number of bolls per plant=total open bolls just before the first heavy frost on November 20th.

Boll weight=grams of seed cotton per boll calculated by total seed cotton per plant divided by total number of bolls per plant.

Lint percent=ratio of lint weight to total seed cotton per plant, expressed as percentage.

Staple length=mean fibei length. The central-seed fiber was selected from each lock fiber length measurement.

Weight of 100 seeds=mean weight of 100 complete seeds selected randomly(2 times).

Lint weight=balanced after ginning

Experiment Ⅱ

Genetic studies on agronomic characteristics of the F_2 and F_3 populations of Upland cotton were conducted at the experimental fields of the Mokpo Branch Station, Crop Experiment Station, Mokpo, Korea for four years from 1969 through 1972.

The two parental varieties used in these experiments were Paymaster (p_1), a late maturing, big boll, highlint percent and long staple variety and Heujueusseo Trice (p_2), a early maturing, small boll, low lint percent and short staple length variety. Hybrid seeds from the cross Paymaster and Heujueusseo Trice were obtained in 1969. Bulk seeds from F_1 plants and new hybrid seeds were harvested in 1970. Five seeds from individual F_1 plants were bulked and bulk seeds from F_1 and new hybrid seeds were produced in 1971.

P_1, P_2 F_1, F_2 and F_3 populations were planted together in 1972 to reduce variation as the F_3 population was randomly selected the F_2 population.

Other cultural and investigating methods were the same as in Experiment I.

The climatic conditions during the cotton growing season of 1972 are compared with the average yearly data as shown in Fig 1.

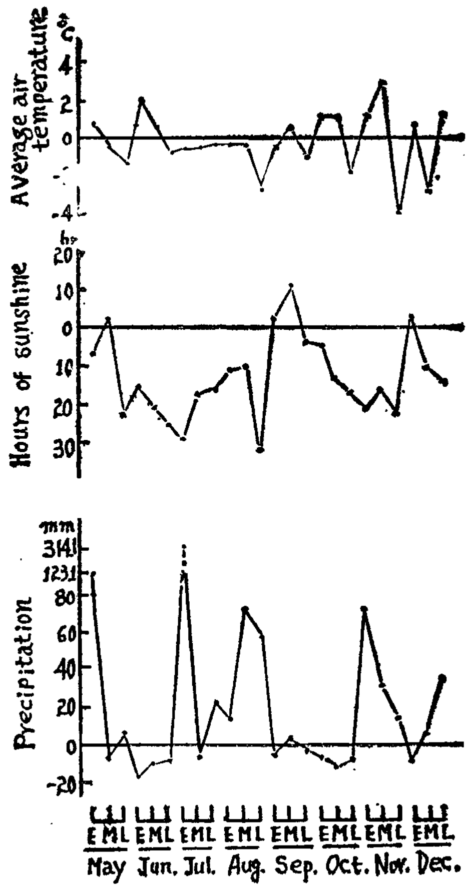


Fig 1. Some meteological factors during growing period of the cotton plant at Mokpo, Korea in 1972.

Continuous rainfall just after seeding caused differential germination and emergence. The growing conditions for young cotton seedlings were favorable from mid-May on allowing recovery.

During the quick growing periods from late June to early July, continuous rainfall delayed by one day the normal flowering date. Fields were carefully managed by drainage.

Relatively high temperatures and adequate sun shines during the boll opening period from September to October gave normal yields.

Table 2. Average parental values, direction of dominance and average F_1 heterosis for seven agronomic characteristics in 11-parent diallel cross of Upland cotton.

Characteristics	Average parent value	Direction of dominance	Average heterosis %
Days to flowering	85. 4	Early	-1.00^{ns}
Wt. of boll (g)	4.60	Large	3.06^{ns}
Line %	35.31	High	1.90^{ns}
Fiber length (mm)	26.31	Long	3.08^{ns}
100 seeds weight (g)	9.91	Heavy	2.42^{ns}
No. of bolls per plant	8.68	Many	27.84**
Lint yield (g/plant)	9.01	High yield	37.26**

The data obtained from the F_1 diallel crosses were analysed by Griffing's[20] and Hayman's[24, 25, 25,26,27,28,29] methods. Calculation was done by the Agricultural Research Bureau, Office of Rural Develoment.

Analyses of F_2 and F_3 genetic variation were made by Mather's[45] statistical method. The symbolism is that quoted by Mather and Hayman.

Ⅳ. Experimental Results

Experimnt Ⅰ: Inheritance of Agronomic Characteristics as calculated from F_1 Diallel Crosses of Upland Cotton.

A. Drection of dominance and heterosis.

Average parental values, direction of dominance and heterosis of the F_1 hybrids for seven agronomic characteristics of Upland cotton are given in Table 2.

In days to flowering, heterosis was directed toward earlier than average parental vaue.

Heteroses for weight of boll, lint percent, fiber length and 100 seeds weight were directed toward larger, higher, longer and heavier than average parental value, respectively.

The average degree of heterosis, expressed as percent deviation of the mean of the F_1 hybrids from the mean of parental values, was significant for number of bolls per plant and lint yield. Days to flowering weight of boll, lint percent, fiber length and 100—seed weight were non significant.

B. Effects of General Combining Ability and Specific Combining Ability.

With partial crosses, variance components for the estimates of general and specific combining

Table 3. F_1 mean squares for general, specific combining ability for seven agronomic characteristics in a 11-parent diallel experiment with cultivated Upland cottons.

Charateristics	Source of variation		
	GCA	SCA	Error
Days to flowering	18.5702*	3.7697**	0.6501
Weight of boll	1.8257**	0.0244	0.0240
Lint%	19.5960**	0.4659**	0.1279
Fiber length	17.3947**	0.4450**	0.0401
100 Seeds weight	1.6490**	0.1487**	0.0649
No. of bolls per plant	8.1132**	1.8208**	0.3204
Lint yield	10.3895**	2.8514**	0.4824

*, **: Significant at 5 and 1% level respectively.

Table 4. Estimates of GCA effect for seven agronomic characteristics in 11−parent diallel cross F_1.

Variety	Days to flowering	Weight of boll	Lint %	Fiber length	100 seeds weight	No. of bolls per plant	Lint yield
Suwon #1	−1.947	−0.711	−1.620	−1.813	−0.544	0.063	−0.329
Mokpo #4	−0.716	−0.330	0.044	−1.375	−0.397	0.771	0.480
Mokpo #6	−0.755	0.180	1.283	0.178	−0.205	0.075	1.329
Copt 6390	−1.024	0.065	−0.393	−0.290	−0.094	0.290	0.390
Heujueusseo Trice	−1.447	−0.023	−1.105	−0.479	0.529	−1.359	−1.759
Lockett 140	1.283	−0.030	0.260	0.063	0.271	0.410	0.667
D. P. L.	0.744	−0.146	−0.797	−0.302	−0.070	0.571	0.114
Paymaster	1.167	0.800	2.067	0.186	−0.082	0.156	0.140
Acala 1517w	0.629	0.203	−1.501	−0.025	0.586	−0.043	−0.612
Delfos 9169	0.744	−0.157	0.317	1.551	−0.519	0.702	0.758
Arijona	1.321	0.150	1.444	2.305	0.167	−1.639	−1.129
S. E.($\hat{g}i-\hat{g}i$)	0.1001	0.0037	0.0197	0.0062	0.010	0.0193	0.0742

ability were analysed for days to flowering, weight of boll, lint percent, staple length, 100 seeds weight, number of bolls per plant and lint yield.

The variance associated with general combining ability (GCA) was highly significant for all characteristics. Significant specific combining ability (SCA) variances for all characteristics except weight of boll were noted as shown in Table 3.

Listed in Table 4 are the estimated general combining ability (GCA) effects for each characteristic in the 11-parent diallel cross F_1. Those parents showing high GCA effects for days to flowering were Suwon 1 and Heujueusseo Trice (early) and Arijona, Lockett 140 and Delfos 9169 (late).

In the GCA effects for boll weight, big bolled Paymaster tended toward large bolled progeny while Suwon 1 and Mokpo 4 with small boll directed crosses toward small boll effects.

Paymaster is expected to be a useful parent in breeding for big boll varieties. Suwon 1 will be useful when building for small boll varieties.

In lint percent Suwon 1 gave the lowest GCA estimates for lint percent, while the GCA effects for Paymaster, Arijona and Mokpo 6 were relatively high. The GCA effects of staple length for Arijona and Delfos 9169 were high while Suwon 1 and Mokpo 4, short staple length varieties gave low GCA effects.

The GCA effects of 100 seeds weight were small especially for Suwon 1 and Delfos 9169. The highest GCA effects of 100 seeds weight were for Acala 1517, Heujueusseo Trice, both heavy in 100−seed weight, and for Arijona.

In number of bolls per plant, the GCA effect of Mokpo 4, a many bolled plant, was the largest while Arijona and Heujueusseo Trice were relatively low in GCA.

The GCA effect for lint percent for Mokpo 6 was highest with 1.329 followed by Delfos 9169 and Lockett 140 in that order. Because the GCA effects for lint percent of Mokpo 6 and Delfos 9169, were high, these varieties are considered promising parented material to increase lint yields.

Since the GCA effects for lint percent of Heujueusseo Trice, Arijona, ect, were low, these varieties could be considered causing yield reduction when used parental material to improve staple length and to introduce early−maturing gene.

The SCA of Suwon 1 and Lockett 140, of Mokpo 6 and Lockett 140, and of Paymaster and Arijona for days to flowering were high and late while the SCA between Mokpo 4 and Acala 1517W and between Mokpo 6 and Acala 1517W were high and early(Table 1).

The SCA effects on boll weight showed little variation, giving small, non significant effects.

The SCA effects on lint percent were largest for Arijona times Suwon 1(1.257)and Mokpo 6 times Suwon 1(0.969), Mokpo 4 times Lockett 140 and Suwon 1 times Heujueusseo Trice gave the lowest SCA estimates.

SCA effects on staple length gave different responses though the estimates were similar to the GCA effect for percent.

The SCA effects on staple length showed a range of 1.080−1.192. The SCA effects of crosses between Paymaster, Delfos 9169, Mokpo 6 and Copt 6390 with Suwon 1 were high.

The SCA estimates on number of bolls per plant showed over-dominance because more bolls were produced on the F_1 plants than on either parents. High SCA estimates were found for the combinations of Mokpo 4 and Delfols 9169, of Mokpo 6 and Paymaster, and of Lockett 140 and D.P.L.. There were large variations of the SCA effects in the crosses Mokpo 4 times Copt 6390 and Mokpo 6 times Copt 6390.

SCA estimates for lint yields gave large variations for crosses with Mokpo 4 and Mokpo 6 this being similar to the SCA effects of number of bolls per plant, relatively large SCA effects were found in crosses with Heujueusseo Trice.

Combinations showing large SCA effects for high lint yield potential were Mokpo 4 and Acala 1517W, Mokpo 4 and D.P.I., Heujueusseo Trice and Paymaster, and Lockett 140 × Acala 1517W. The SCA effects of these combinations were larger than the GCA effects.

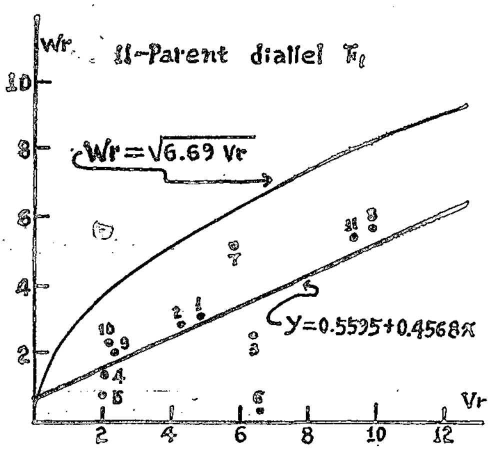
C. Diallel graph and genetic components

1). Days to flowering

A diallel graph for days to flowering for F_1 hybrid from the 11 parents is shown in Fig 2. The linear regression line passes above the zero point of Wr axis suggesting that days to flowering is partially dominant. Because the linear regression coefficient, b=0.4568, is far from b=1, there is a large interactions between cotton varieties for days to flowering.

These interactions were assumed as complementary gene interactions in the varieties Lockett 140, Mokpo 4 and Paymaster. The F_1 hybrids between these varieties were excluded in the second diallel graph for days to flowering shown in Fig 2.

In the second graph b=0.8388, b approaches



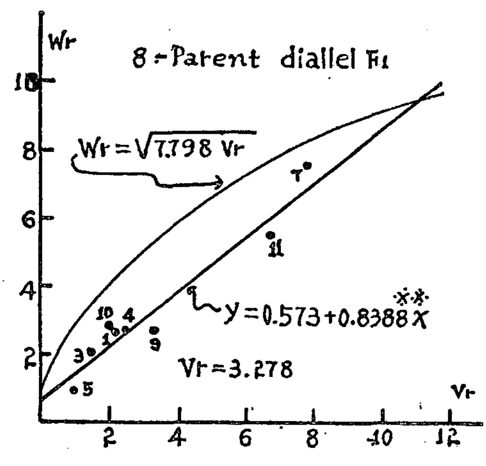


Fig 2. Wr, Vr graph for days to flowering in 11 and 8 parent diallel cross F1. (2, 6, 8 were excluded in the 8-parent diallel).
1:Sowon #1 2:Mokpo #4 3:Mokpo #6 4:Copt 6390 5:Heujueusseo Trice 6:Lockett 140 7:D.P.L. 8:Paymaster 9:Acala 1517w 10:Delfos 9169 11:Arijona

and is not significantly different from b=1. Because this line passes above zero point of Wr axis, earliness can be concluded to be partially dominant to lateness. D.P.L. and Arijona, which are late maturing, were shown to be the most recessive. Other varieties were shown to be dominant because of near approach to the zero point. The early-maturing varieties Suwon 1, Mokpo 6 and Heujueusseo Trice showed strong dominance as compared with other varieties while the late-maturing varieties Acala 1517w and Delfos 9169 showed dominance. The variance components for days to flowering in the 11-and 8-parent diallel cross F_1 are shown in Table 5. In the 11-parent diallel cross for days to flowering, intensity of dominance was large because H_1 is larger than D. F is of nagative value and $H_2/4H_1$ is 0.5608 these effect of recessive genes is large.

Table 5. Variance component for days to flowering in 11-and-8-parent diallel cross F_1.

Component of variance	Estimated value	
	11-parent diallel	*8-parent diallel
D	2.0465	4.9701
F	−5.6783	−1.5759
H_1	2.3271	−1.3822
H_2	5.2207	0.5031
H_1/D	1.1307	−0.2781
$(H_1/D)^{\frac{1}{2}}$	1.0663	0.5273
$H_2/4H_1$	0.5608	−0.0909
$\pm r(Wr+Vr/Yr)$	0.4249	0.6205
K	−0.6332	−8.8821
E	4.6443	3.5253

*: Mokpo #4, Lockett 140 and Paymaster were excluded in the 8-parent diallel analysis.

In the 8-parent diallel cross for days to flowering, additive gene action was greater than heterosis as D was 4.9701 and presented partial dominance due to $(H_1/D)^{\frac{1}{2}}$ of 0.5273. Minor gene action greatly influenced early maturity because of K=−8.8821.

2) Weight of Boll(weight of seed cotton per boll)

The variance component and diallel graph for weight of boll in the 11-parent diallel cross F_1 are shown in Table 6 and Figure 3, respectively.

In the diallel graph for weight of boll in the 11-parent diallel cross F_1, the linear regression line is passing above the zero point of the Wr axis and D is bigger than H_1 indicating that the weight of boll showed partial dominance or a very low in degree of dominance. This can be concluded because of H_1 located between $\frac{1}{2}D-\frac{1}{4}D$. Although recessive genes were highly evaluated due to the negative F value, it was considered that this resulted due to small dominance intensity.

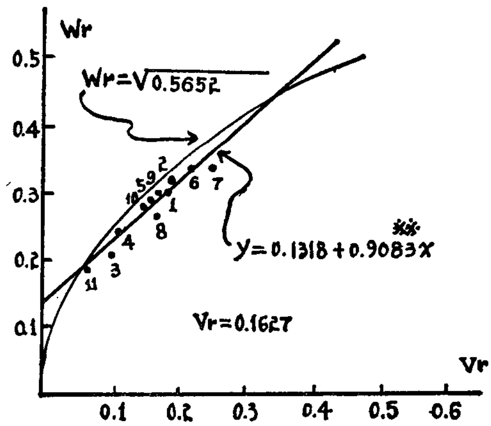


Fig 3. Wr, Vr graph for weight of boll in 11-parent diallel cross F_1.
1: Suwon #1 2:Mokpo #4
3: Mokpo #6 4: Copt 6390
5: Heujueusseo Trice
6: Lockett 140 7: D.P.L.
8: Paymaster 9: Acala 1517W
10: Delfos 9169 11: Arijona

Table 6. Variance component for weight of boll in the 11-parent diallel cross F_1.

Component of variance	Estimated value
D	0.4703
F	−0.1439
H_1	−0.1702
H_2	−0.1011
H_1/D	−0.3619
$(H_1/D)^{\frac{1}{2}}$	0.6015
$H_2/4H_1$	0.1485
±r (Wr+Vr/Yr)	−0.3643
K	−5.2303
E	0.0949

In comparing dominance among varieties, Arijona, Mokpo 6 and Copt 6390 were the most dominant while Lockett 140 and D.P.L. were located at the recessive region.

Relationships of boll size dominance should not be equated and genetic analysis should not be significant because Paymaster with big boll and Suwon 1 and Mokpo 4 with small boll are located in the central region.

3) Lint percent

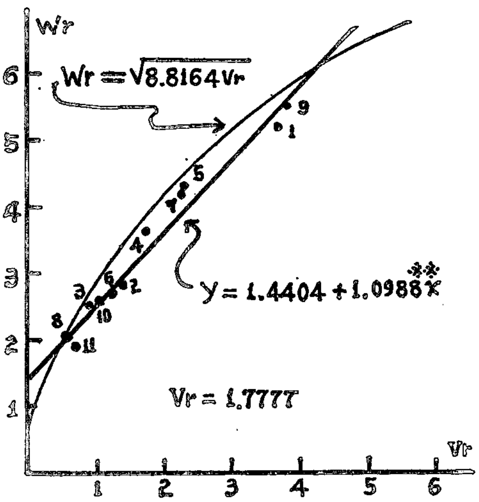


Fig 4. Wr, Vr graph for lint percent in the 11-parent diallel cross F_1.
1: Suwon #1 2: Mokpo #4
3: Mokpo #6 4: Copt 6390
5: Heujueusseo Trice 6: Lockett 140
7: D.P.L. 8: Paymaster
9: Acala 1517W 10: Delfos 9169
11: Arijona

Variance component and diallel graph for lint percent in the 11-parent diallel cross F_1 are shown in Table 7 and Fig 4, respectively.

Because the linear regression line is passing above the zero point of Wr axis, lint percent represents partial dominance. It is recognized that there was allelic gene interaction for lint percent.

Table 7. Variance component for lint percent in the 11-parent diallel cross F_1.

Component of variance	Estimated value
D	7.5769
F	2.0331
H_1	-1.1337
H_2	-1.0239
H_1/D	-0.1495
$(H_1/D)^{\frac{1}{2}}$	0.3867
$H_2/4H_1$	0.2257
±r(Wr+Vr/Yr)	-0.9785**
K	-2.3826
E	1.1267

Paymaster, Arijona and Mokpo 6 all having high lint percent are located in the region of dominance near the zero point, while Suwon 1 and Acala 1517W with low lint percent are located at the recessive region far from zero point. This suggests that the F_1 hybrids between varieties of high and low lint percents should be located near to the varieties with high lint percent. As shown in Table 7, partial dominance of high lint percent more highly dependent on additive genetic effects than on heterosis. The ratio of dominant genes vs recessive genes was considered 1:1 because $H_2/4H_1$ (0.2257) closely approximated. The effects of dominant genes were considered over-evaluated because F is a possitive value.

Although the value k=-3826 shows that relatively few genes were related, the F_2 population supposedly would segregate more complicatedly because $(H_1/D)^{\frac{1}{2}}$ equalled o.3867.

4) Staple length

Variance component and diallel graph for staple length in the 11-parent diallel cross F_1 are presented in Table 8 and Fig 5, respectively. These data showed similar trends to those of lint percent. There is not nonallelic gene actions because the coefficient of linear regression is 1.008. Partial dominance additively affected was shown for staple length.

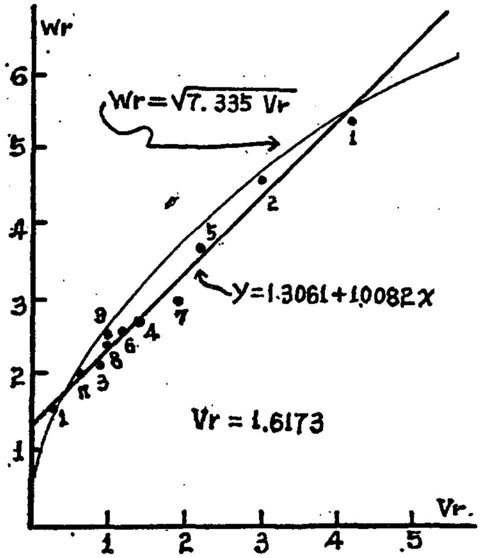


Fig 5. Wr, Vr graph for fiber length in the 11-Parent diallel cross F_1.
1: Suwon #1 2: Mokpo #4
3: Mokpo #6 4: Copt 6390
5: Heujueusseo Trice
6: Lockett 140 7: D.P.L.
8 Paymaster 9: Acala 1517W
10: Delfos 9169 11: Aijona

Table 8. Variance component for fiber length in the 11-Parent diallel cross F_1

Component of variance	Estimated value
D	6.3206
F	1.2625
H_1	-0.8016
H_2	-0.6561
H_1/D	-0.1268
$(H_1/D)^{\frac{1}{2}}$	0.3561
$H_2/4H_1$	0.2046
$\pm r(Wr+Vr/Yr)$	-0.9344**
K	-4.4688
E	1.0143

The varietal responses for staple len_ h were not similar to those for lint percent. Short staple varieties like Suwon 1, Mokpo 4 and Heujueusseo Trice were located far from the zero point. The linear regression line showed extreme recessive gene action whereas the long staple varieties of Arijona, Delfos 9169 and Lockett 140 showed dominance. General trends for the genetic components were similar to those of lint percent but the inheritance of staple length was governed more or less by multi-gene actions.

5) 100 seeds weight

Variance component and diallel for 100 seeds weight in the 11-parent diallel cross F_1 are presented in table 9 and Fig 6. The linear regression coefficient is passing near the zero point of the Wr axis, while D is significantly larger than H, indicating complete dominance for 100 seeds weight. There is no non-allelic gene action because the b value of 1.1397 nearly equals b=1.

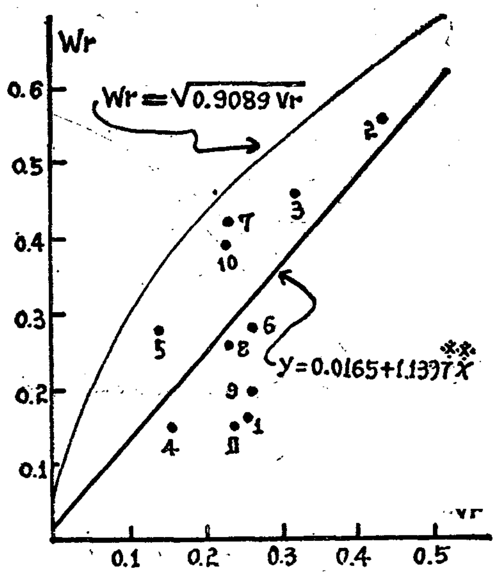


Fig 6. Wr, Vr graph for 100 Seeds weight in the 11-parent diallel cross F_1
1: Suwon #1 2: Mokpo #4
3: Mokpo #6 4: Copt 6390
5: Heujueusseo Trice
6: Lockett 140 7: D.P.L.
8: Paymaster 9: Acala 1517W
10: Delfos 9169 11: Arijona

Table 9. Variance component for 100 Seeds weight in the 11-parent diallel cross F_1

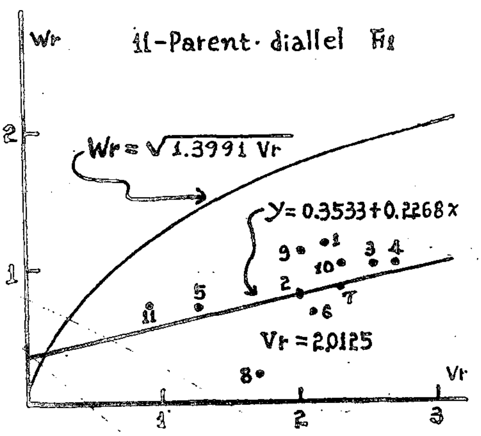
Component of variance	Estimated value
D	0.6378
F	0.1651
H_2	-0.0612
H_3	0.0018
H_1/D	-0.0960
$(H_1/D)^{\frac{1}{2}}$	0.3099
$H_2/4H_1$	-0.2046
$\pm r(Wr+Vr/Yr)$	-0.5620
K	150.1218
E	0.2710

In varietal responses, the genetic composition of each variety was diverse because of the scattered distribution of varieties along the line. Arijona with big seed and Suwon 1 with small seed showed over-dominance as compared with other varieties while Mokpo 6 with big seed and Mokpo 4 with small seed were shown to be recessive. The inheritance of 100 seeds weight showed irregular trends.

The ratio of dominant genes to recessive genes was considered nearly 1:1 because $H_2/4H_1$ equalled 0.2046. Expression of the dominant genes was probably over-evaluated due to the positive value of F.

6) Number of bolls per plant.

As shown in Fig 7, the diallel graph for number of bolls per plant indicated a large interaction of complementary genes as shown by a linear regressien coefficient of 0.2268. This interaction was estimated as occurring in particular varieties. Fig 7 was regraphed after omitting the small-seed varieties Arijona, Heujueusseo Trice and Suwon 1.



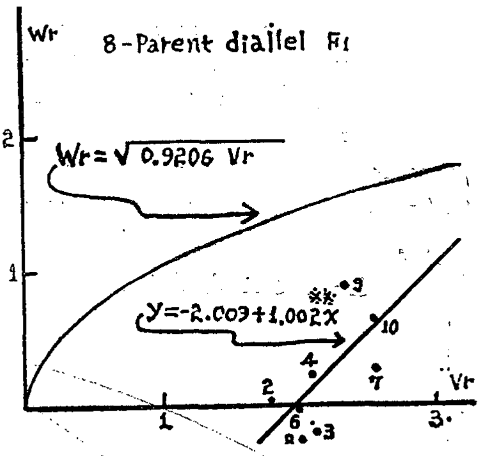


Fig 7. Wr, Vr graph for number of bolls per plant in the 11-and-8-parent diallel cross F_1 (1,5,11 were excluded in the 8 parent diallel). 1:Suwon #1 2:Mokdo #4 3:Mokpo #6 4:Copt 6390 5:Heujueusseo Trice 6:Lockett 140 7:D.P.L. 8:Paymaster 9:Acala 1517W 10:Delfos 9169 11:Arijona

In the second graph there is no nonallelic gene interaction as the coefficient of linear regression is b=1.002. This regression line crosses the Wr axis giving a negative value showing a significant value for over-dominance.

The relatively small-boll varieties Paymaster and Mokpo 6 were strongly influenced by overdominance. Mokpo 4 and Lockett 140 many bolls varieties were located at the region of dominance.

Table 10. Variance component for number of bolls per plant in 11-and-8-diallel cross F_1.

Component of variance	Estimated value	
	11-parent diallel	*8-parent diallel
D	—0.6623	—2.2267
F	—3.8143	—3.6099
H_1	0.4004	0.2897
H_2	1.0757	2.0900
H_1/D	—0.6045	—0.1301
$(H_1/D)^{\frac{1}{2}}$	0.7775	0.3607
$H_2/4H_1$	0.6716	1.8031
$\pm r(Wr+Vr/Yr)$	0.5458	—0.4267
K	8.1771	4.9564
E	2.0615	3.1474

*: Suwon #1, Heujueusseo Trice and Arijona were excluded in the 8 parent diallel.

Varietal differences in dominance for number of bolls per plant were variable.

Variance component for number of bolls per plant in the 11-and-8-diallel cross F_1 as shown in Table 10. Additive effects were small and heterotic effects were significant as shown by a negative D value and the smaller H_1 value.

These phenomena are more apparent in the 8-parent diallel cross than in the 11-parent diallel cross. K is relatively small at 2.0615 and 3.1474 indicating that dominant gene action was under as stated because recessive genes were over-evaluated as shown by the 0.0716 and 1.8031 value of $H_2/4H_1$.

7) Lint yield

The diallel graph for lint yield (Fig 8) shows over-dominance similar to that of number of bolls per plant. Complementary gene interaction is indicated because the linear regression coefficient is b=0.6854

High-lint yielding varieties, Mokpo 4, Mokpo 6 and Delfos 9169 showed dominance over low-yielding varieties Acala 1517W and D.P.L.. Suwon 1 and Arijona, both low yield, were located in the region of dominance. This makes it difficult to conclude that high-yield dominant to

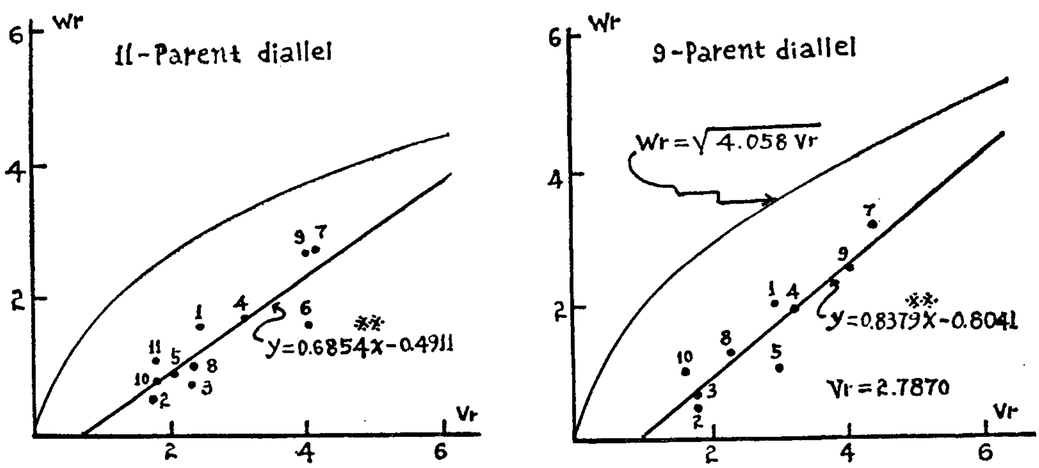


Fig 8. Wr, Vr graph for lint yield in the 11-and-9 parent diallel cross F_1 (Lockett 140 and Arijona were excluded in 9 parent diallel). 1:Suwon #1 2:Mokpo #4 3:Mokpo #6 4:Copt 6390 5:Heujueusseo Trice 6:Lockett 140 7:D.P.L. 8:Paymaster 9:Acala 1517W 10:Delfos 9169 11:Arijona

low- yield.

Complmentary gene interaction was estimated for particular varieties, thus Lockett 140 and Arijona were excluded in the 9-parent diallel graph. As shown in the second graph in Fig 8, general varietal responses were simlar to the 11—parent diallel graph, though complementary gene interaction was reduced as indicated by the value of 0.8379 approaching 1. Except for Heujueusseo Trice, high-yielding varieties were dominant to low-yielding varieties. Suwon 1 was located in the region of dominance on the 11-parent diallel graph while being located at the recessive region on the 9-parent diallel graph.

Variance component for lint yield in the 11-and-9-parent diallel cross F_1 are shown in Table 11. D was 0.0122 in the 11-parent diallel cross F_1, indicating small additive effects H_1 and H_2 were large at 0.6317 and 0.9755. H_1/D was 51.5686 and $(H_1/D)^{\frac{1}{2}}$ was 7.1811, suggesting strong over-dominance.

Table 11. Variance component for lint yield in the 11 and 9 parent diallel cross F_1.

Component of variancce	Estimated value	
	11—parent diallel	*9—parent diallel
D	0.0122	0.4788 F
F	−4.3303	−3.8327
H_1	−0.6317	−1.0351
H_2	0.9755	1.0818
H_1/D	−51.5686	−2.1618
$(H_1/D)^{\frac{1}{2}}$	7.1811	1.4703
$H_2/4H_1$	−0.3860	−0.2612
$\pm r(Wr+Vr/Yr)$	−0.4485	−0.6693
K	12.5071	11.1283
E	3.3362	3.5793

* : Lockett 140 and Arijona were exculuded in the 9—parent diallel cross.

In excluding Lockett 140 and Arijona, D increased to 0.4788 while H_1/D was substantially reduced to 2.1618. This suggests over-dominance with increased additive gene effects and a reduction of dominance effects. The effective number or genes as shown by 12.5071—11.1283, showing multigene action.

D. Heritability

Heritabilities for each characteristic, estimated by the formula $\dfrac{\frac{1}{2}D}{\frac{1}{2}D-\frac{1}{2}F+\frac{1}{2}H_1-\frac{1}{4}H_2+\frac{r(n+1)}{2n}E}$, are presented Table 12.

Heritability of days to flowering was 11.64% in the 11—parent diallel cross though increasing to 39.4% in a 8—parent diallel cross

Heritabilities of weight of boll and 100 seeds weight were considerably higher at 67.03 and 63.66%, respectively.

Heritabilities of lint percent and staple length were very high at 99.43—92.98%.

Heritability for number of bolls per plant was low(8.82%) in the 11-parent diallel cross though considerably high(29.7%) in an 8-parent diallel cross.

Heritability of lint yield was extremely low in both the 11-parent and 9-parent diallel cross.

E. Correlations between agronomic characteiristics

Phenotypic and genotypic correlation coefficients for seven agronomic characteristics were calculated by the following formulas

$$rph = \frac{phij}{\sqrt{(ph\,i^2)\,(ph\,j^2)}} \quad rg = \frac{gij}{\sqrt{(gi^2)\quad(gj^2)}}$$

Results are shown in Table 13.

There were highly significant positive correl-

Table 12 Estimates of heritability for seven agronomic characteristics in diallel cross F_1 of Upland cotton.

characteristics	Heritability(%)		Remark
	11-parents diallel set.	9 or 8 parents diallel set.	
Days to flowering	11.64	39.43	Mokpo #4, Lockett 140 Paymaster excluded
Wt. of boll	67.03	—	
Lint %	99.43	—	
Fiber length	92.98	—	
100 seeds weight	63.66	—	
No. of bolls per plant	8.82	29.71	Suwon #1, Heujueusseo Trice, Arijona excluded
Lint yield	0.12	0.57	Lockett 140, Arijona excluded

ations between days to flowering, weight of boll, lint percent and staple length.

Those varieties with large bolls, high lint percent and long fiber showed late maturity on the whole as did their F_1 hybrids. As boll weight, lint percent and staple length were correlated with each other, when one characteristics was increased, the other characteristics was also increased.

There was significant positive correlation between lint yield and lint percent and a highly significant correlation between number of bolls per plant and lint yield.

Consequently, lint yield can be increased by relating for increased lint percent and number of bolls per plant.

It is interesting that the yield components of staple length, weight of boll and days to flowering influenced cotton fiber quality but did not directly influence lint yield.

Genotypic correlations were found to be higher than phenotypic correlations. The highest genotypic correlation were between number of bolls per plant and lint yield (0.8574), between

Table 13. Phenotypic and genotypic correlation coefficients for seven agronomic characteristics.

Characteristics.	Correlation coefficients						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Days to flowering	—	0.3272**	0.2797**	0.4030**	0.1084	−0.0658	0.0093
(2) Wt. of boll	0.3661	—	0.5896**	0.4340**	0.2960**	−0.0371	0.1026
(3) Lint %	0.3524	0.6630	—	0.5218**	−0.1517	0.0458	0.3229*
(4) Fiber length	0.4573	0.4746	0.5553	—	0.2688*	−0.1510	0.0534
(5) 100 seeds weight	0.1177	0.3685	−0.2193	0.3091	—	−0.2251	−0.2268
(6) No. of bolls per plant	−0.1433	−0.1106	0.0608	−0.1740	−0.2912	—	0.7216**
(7) Lint yield	0.0355	0.0590	0.3422	0.0667	−0.3134	0.8574	—

Phenotypic correlation showed in upper side and genotypic correlation in lower side.

*, **: Significant at 5% and 1% level.

weight of boll and lint percent (0.6630) and between staple length and lint percent (0.5530). Significant negative genotypic correlations between 100 seeds weight and lint yield were found.

These high genotypic correlations suggest that there is a greater genetic effect than environmental effect.

Experiment Ⅱ. Inheritance of Agronomic Characteristics in the F_2 and F_3 Populations of Upland cotton.

A. Mean, standard error and dominance in succeeding generations of Upland cotton.

In order to investigate segregation patterns for days to flowering, boll weight, lint percent, staple length and number of bolls per plant in the F_2 and F_3 populations of Upland cotton, Paymaster (P_1) which is a late maturing, big bolled high lint percent and long staple variety, was crossed with Heujueusseo Trice (P_2) which is an early maturing, small bolled, low lint percent and short staple variety.

As shown in Table 14, early maturity tended to be dominant in the F_1, F_2 and F_3 populations when parental maturity difference was about 6 days.

For boll weight there was no significant difference in the F_1 hybrids.

Table 14. Mean values ($\overline{X}$), standard errors ($s\overline{X}$) and degree of dominance (D) for seven characters in different generation of Paymaster (P_1) and Heujueusseo Trice.

Population	Days to flowering	Wt. of boll (g)	Lint %	Fiber length (mm)	100 Seeds wt. (g)	No. of bolls per plant	Lint yield (g/plant)
Paymaster (P_1)	86.43±0.24	6.39±0.129	42.12±0.203	28.02±0.145	11.39±0.103	8.17±0.165	18.93±1.041
Heujueusseo Trice (P_2)	80.77±0.33	4.62±0.089	33.22±0.201	23.10±0.098	12.59±0.122	7.04±0.284	11.16±0.515
F_1	83.06±0.28	5.40±0.161	37.64±0.201	27.08±0.141	10.71±0.107	10.45±0.346	19.25±1.031
F_2	82.23±0.18	5.83±0.065	37.60±0.186	26.04±0.146	10.48±0.059	9.97±0.250	16.63±0.548
F_3	83.18±0.14	5.82±0.060	37.17±0.156	25.95±0.138	10.72±0.053	9.14±0.203	15.54±0.478
DF_1	−0.1908	−0.1186	−0.0067	0.6179**	−2.000**	5.0354**	1.0824
DF_2	−0.4841	0.3672**	−0.0157	0.1951	−2.3594**	4.1858**	0.4080
DF_3	−0.1484	0.3559**	−0.1056	0.1585	−1.9844**	2.7168**	0.1274

Lint percent did not show any dominance.

Long fiber was completely or partially dominant to short fiber in the F_1's.

No segregation for 100 seeds weight was expected as the difference between parent was small.

Over-dominance was observed for number of bolls per plant. An increase of three bolls per plant above the mid-parent value was noted.

In the F_2 to F_3 generation, this over-dominance gradually disappeared.

In lint yield, some over-dominace was found in F_1 hybrids. In the F_2 and F_3 populations partial dominance was indicated but there were no significant differences.

Table 15. Estimates of variance component and number of genes for days to flowering in the cross between Paymaster (P_1) and Heujueusseo Trice (P_2).

Component	Observed value
VF_2 $(\frac{1}{2}D+\frac{1}{4}+E_1)$	5.1700
VF_3 $(\frac{3}{4}D+\frac{3}{16}H+E_1)$	5.1687
E_1	3.3975
D	1.1782
H	4.7336
Number of gene $\frac{(\bar{P}_1-\bar{P}_2)^2}{4D}$	6.7976

$E_1=\frac{1}{3}(VP_1+VP_2+VF_1)$

B. Segregation mode and genetic components for agronomic characteristics

1. Days to flowering

The frequency distribution of parents, F_1, F_2 and F_3 populations, and their variance components for days to flowering as shown in Fig 9 and Table 15. Days to flowering varied from 75 days to 88 days. In the F_2 population many plants were earlier than the parents.

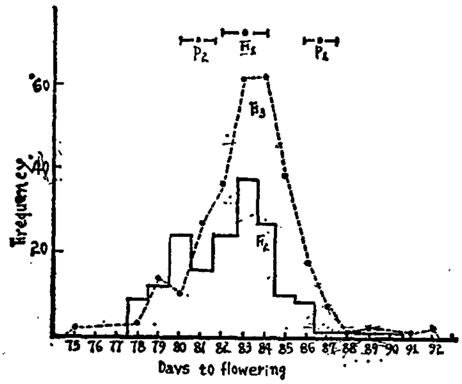


Fig 9. Frequency distribution of parents, F_1, F_2 and F_3 for days to flowering in the cross between Paymaster (P_1) and Heujueusseo Trice (P_2).
Solid horizontal lines show the standard deviation of the parents and F_1 and dots show the mean values.

Most F_3 plants were distributed around the mid-parent value having a similar distribution as did the F_2 population.

In the F_2 and F_3 populations extremely late-maturing individuals requiring over 89 days were created.

For the genetic components for days to flowering, H was relatively large while D was relatively small indicating that days to flowering was governed by many genes.

2. Weight of boll (weight of seed cotton per boll)

Frequency distribution and variance components of parents, F_1, F_2 and F_3 populations for boll weight from crosses between Paymaster (P_1) and Heujueusseo Trice (P_2) are presented in Fig 10 and Table 16. The frequency distribution of the F_2 population for boll weight was normal.

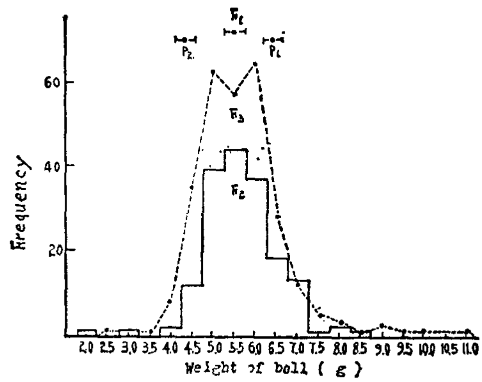


Fig 10. Frequency distribution of parents, F_1, F_2 and F_3 for weight of boll in the cross between Paymaster(P_1) and Heujueusseo Trice (P_2).
Solid horizontal lines show the standard deviation of the parents and F_1 and dots show the mean values.

Table 16. Estimates of variance component and number of genes for weight of boll in the cross between Paymaster (P_1) and Heujueusseo Trice (P_2)

Component	Observed value
$VF_2(\frac{1}{2}D+\frac{1}{4}+E_1)$	0.9201
$VF_3(\frac{3}{4}D+\frac{3}{16}H+E_1)$	1.0009
E_1	0.6455
D	0.3986
H	0.3012
Number of gene $(\frac{(\bar{P}_1-\bar{P}_2)^2}{4D})$	0.0424

$E_1=\frac{1}{3}(VP_1+VP_2+VF_1)$

Most of the individuals of the F_2 population lay between P_1 and P_2. Most of individuals of the F_3 population were distributed around to mid-parent as in the F_2 population.

Because the nongenetic component was relatively larger than the genetic component, there were very little genetic effects.

3. Lint percent.

The frequency distribution and variance component for parents, F_1, F_2 and F_3 populations for lint percent in the cross Paymaster (P_1) and

Heujueusseo Trice (P_2) are shown in Fig 11 and Table 17. Lint percent varied in the F_2 population from 28% to 45%. Most of the F_2 individuals were distributed around 38% that being a little higher than mid-parent value. The F_3 population varied between P_1 and P_2 averaging 37%.

In the F_1 hybrids lint percent averaged 39 %. This showed partial to complete dominance for Paymaster. Succeeding generations approached mid-parent value.

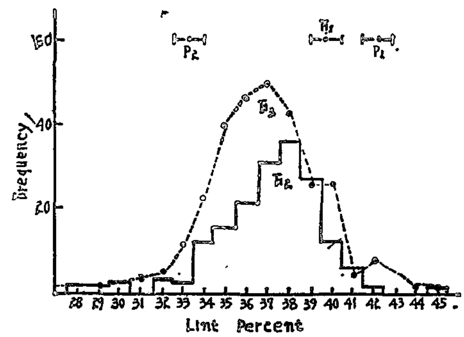


Fig 11. Frequency distribution of parents, F_1, F_2 and F_3 for lint percent in the cross between Paymaster (P_1) and Heujueusseo Trice (P_2).
Solid horizontal lines show the standard deviation of the parents and F_1 and dots show the mean values.

Table 17. Estimates of variance component and number of genes for lint percent in the cross between Paymaster(P_1) and Heujweusseo Trice (P_2).

Component	Observed value
$VF_2(\frac{1}{2}D+\frac{1}{4}+E_1)$	5.7887
$VF_3(\frac{3}{4}D+\frac{3}{16}H+E_1)$	6.8206
E_1	1.6697
D	5.4978
H	5.4804
Number of gene $(\frac{(\bar{P}_1-\bar{P}_2)^2}{4D})$	3.6019

$E_1=\frac{1}{3}(VP_1+VP_2+VF_1)$

In analysing genetic components, D and H were considerably larger than E_1. This indicated that lint percent is inherited by poli-gene because the value for number of genes is 3. 6019.

4. Staple length.

Frequency distribution, variance component and number of genes of parents, F_1, F_2 and f_3 populations for fiber length in the cross Paymaster (P_1) and Heujueusseo Trice (P_2) are shown in Figure 12 and Table 18.

The F_2 population varied around 26mm. Most F_2 values fell between P_1 and P_2.

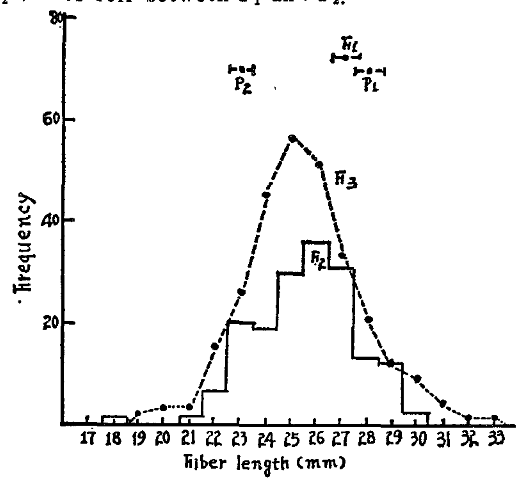


Fig 12. Frequency distribution of parents, F_1, F_2 and F_3 for fiber length in the cross between Paymaster (P_1) and Heujueusseo Trice (P_2).
Solid horizontal lines show the standard deviation of parents and F_1 and dots show the mean values.

Table 18. Estimates of variance component and number of genes for fiber length in the cross between Paymaster(P_1) and Heujueusseo Trice(P_2).

Component	Observed value
$VF_2(\frac{1}{2}D+\frac{1}{4}+E_1)$	3.5914
$VF_3(\frac{3}{4}D+\frac{3}{16}H+E_1)$	5.3492
E_1	0.6652
D	6.6380
H	−1.5712
Number of gene $(\frac{(\bar{P}_1-\bar{P}_2)^2}{4D})$	0.9117

$E_1=\frac{1}{3}(VP_1+VP_2+VF_1)$

Some F_2 fiber length values of 29-30㎜ frequently occurred. These values are greater than the high parent. The F_3 population was similar to the F_2 population in distribution of fiber length values. Some F_3 fiber length values exceeded F_2 values.

Additive genetic action was large while a negative heterotic response was small. Staple length appears to be governed by a simple major gene.

5. Number of bolls per plant

The frequency distributions of parents, F_1, F_2, and F_3 populations, variance component and number of genes for boll number per Plant in the cross Paymaster (P_1) times Heujueusseo Trice (P_2) are presented in Fig 13 and Table 19.

Boll numbers per P_1 and P_2 plant were similar. Number of bolls per F_1 plant was 10.45 bolls indicating over-dominance. The F_2 population showed over-dominance with selected plants producing an average of 10 bolles per plant.

The F_3 population segregated similar to the F_2 population. The mean number of bolls per plant was near tbe mid-parent value though some plants gave up to 19 bolls per plant.

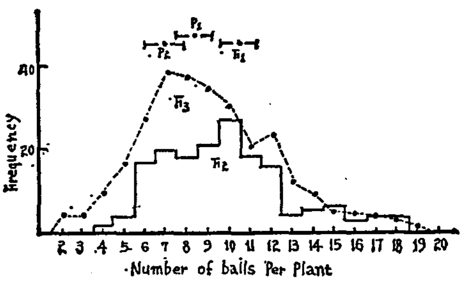


Fig 13. Frequeucy distribution of parents, F_1, $F_2$and F_3 for number of bolls Per plant in the cross between Paymaster (P_1) aud Heujueusseo Trice (P_2). Solid horizontal lines show the standard deviation of parents and F_1 and dots show the mean values

The variance components for boll number per plant showed that heterosis was larger than the additive component but number of gene was 0.0424 presenting no genic effects. 100 seeds weight and lint yield were not considered due to a large variance error and no significant difference

Table 19. Estimats of variance component and number of genes for No. of bolls per plant in the cross between Paymaster (P_1) aud Heujueusseo Trice(P_2).

Component	Observed value
$VF_2(\frac{1}{2}D+\frac{1}{4}+El)$	10.52
$VF_3(\frac{3}{4}D+\frac{3}{61}H+El)$	11.5786
E_1	3.4650
D	7.5262
H	13.1675
Number of geue $\left(\frac{(\bar{P}_1-\bar{P}_2)2}{4D}\right)$	0.0424

$E_1=\frac{1}{3}(VP_1+VP_2+VF_1)$

between P_1 and P_2.

C. Heritability

Estimates of broad and narrow sense heritabilities for seven agronomic characteristics in the F_2 population of Paymaster times Heujueusseo Trice are shown in Table 20. Broad and narrow sense heritabilities for days to flowering were 34.28% and 11.39%, respectively. Heritabilities for boll weight was 29.84—21.66%, broad and narrow sense respectively. Broad sense heritabilities for lint percent and staple length were 71.16% and 81.48%, respectively, while their narrow sense heritabilities were 47.48% and 92.42%, respectively.

Broad and narrow sense heritabilities for number of bolls per plant were 35.77% and 67.06% respectively.

The narrow sense heritabilities for staple length and lint yield were higher than broad sense heritabilities because heterosis value of fiber length showed short in length while additive portion value showed long in length.

D. Phenotypic and genotypic correlations

Phenotypic and genotypic correlations between the seven measured agronomic characteristics, in the cross Paymaster and Heujueusseo Trice were calculated in F_2 and F_3 by following formulas and shown in Table 21

$$rp=\frac{WF_2\ A\cdot B}{\sqrt{VF_2A\cdot VF_2B}}$$

$$rg=\frac{WF_2\ A\cdot B-WE\ A\cdot B}{\sqrt{(VF_2A-VEA)\ (VF_2B-VEB)}}$$

Table 20. Estimates of broad and narrow sense heritability for seven agronomic characteristics in the F_2 population of Paymaster × Heujueusseo Trice combination.

Character	*Heritability (%)	
	Broad sense	Narrow sense
Days to first flowering	34.28	11.39
Weight of boll	29.84	21.66
Lint percent	71.16	47.49
Fiber length	81.48	92.42
**100 Seeds wt.	—	—
No. of bolls per plant	67.06	35.77
Lint yield	38.44	49.82

*Using method are as fallow:

$$\text{Broad sense heritability} = \frac{VF_2 - \frac{1}{3}(VF_1 + VP_1 + VP_2)}{VF_2}$$

$$\text{Narrow sense heritability} = \frac{\frac{1}{2}D}{VF_2\ (\frac{1}{2}D + \frac{1}{4}H + E)}$$

** Because of error variance are large them F_2 variance heritability of 100 seeds wt. could'nt calculate.

$$rp = \frac{WF_3\ A \cdot B}{\sqrt{VF_3A \cdot VF_3B}}$$

$$rg = \frac{WF_3A \cdot B - WEA \cdot B}{(VF_3A - VEA)\ (VF_3 - VEB)}$$

$$VE = \frac{1}{3}(VP_1 + VP_2 + VF_1)$$

$$WE\ A \cdot B = \frac{1}{3}(WP_1A \cdot B + WP_2A \cdot B + WF_1A \cdot B)$$

High positive phenotypic correlations between lint percent and days to flowering and with staple length and days to flowering in the F_2 and F_3 populations.

Significant positive correlations between lint percent and boll weight and between staple length and weigth of boll in the F_2 and F_3 populations were found. Late-maturing individ-

Tabel 21. Phenotypic and genotypic correlations between all pairs of seven agronomic charater in the F_2 and F_3 population of Paymaster × Heujueusseo Trice.

Character	Generation	Correlation coefficient						
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Days to flowering	F_2	—	0.0329	0.2102**	0.2100**	0.0292	−0.0616	−0.0096
	F_3	—	0.0387	0.1529*	0.0514	−0.0193	−0.1271*	−0.0226
(2) Wt. of boll	F_2	0.5319	—	0.2013**	0.2818**	0.1864*	−0.0762	0.1098
	F_3	0.1761	—	0.0954	0.1451*	0.4106**	−0.3030**	0.0717
(3) Lint percent	F_2	0.2418	0.7496	—	0.2136**	−0.1726*	−0.0835	0.0647
	F_3	0.1362	0.1466	—	0.1195*	−0.1286	−0.0062	0.2507**
(4) Fiber length	F_2	0.3476	1.0957	0.3338	—	0.1503	0.1702*	0.2218**
	F_3	0.0545	0.2525	−0.1094	—	0.0295	0.1153	0.1555**
(5) 100 seeds wt.	F_2	0.2271	—	−0.5852	0.7601	—	−0.1379	−0.0844
	F_3	0.0061	1.2639	−0.2377	0.1527	—	−0.1733**	0.0063
(6) No. of bolls per plant	F_2	0.0571	−0.3538	−0.1890	0.2338	−0.6197	—	0.7085
	F_3	−0.0862	−0.6147	−0.0654	0.1498	−0.4007	—	0.7926**
(7) Lint yield	F_2	0.0686	0.3450	−0.0712	0.3747	−0.0186	1.1490	—
	F_3	0.0189	0.0806	0.2681	0.2181	0.1573	1.1411	—

* Phenotypic correlation show in the upper side and genotypic correlation in the lower side.
**Levels of significance for the phenotypic correlation coefficient at 5% and 1% are 0.155 and 0.199 in the F_2 or 0.118 and 0.155 in the F_3.

uals were of high lint and longer fiber.

Significant positive correlations between weight of boll and 100 seeds weight were found in the F_2 and F_3 populations. There was a negative correlation between weight of boll and number of bolls per plant. Big-bolled varieties tend to be heavy in seed weight while varieties with many bolls tend to have light seed.

There was a positive correlation between lint percent and staple length in the F_2 and F_3 populations. A significant positive correlation between lint percent and lint yield in the F_3 population was found. Lint percent is influenced by staple length, while lint yield is positively influenced by lint percent.

There was a significant positive correlation between staple length and lint yield in the F_2 and F_3 populations. This suggests that long-staple individuals will show high-yielding potential.

Significant negative correlations in the F_3 population between days to flowering, weight of boll and 100 seeds weight each with number of bolls per plant were found. Early maturing, small boll and Light seeded individuals tended to have many bolls per plant. There was a highly significant positive correlation between numer of bolls per plant and lint yield.

Genotypic correlations were similar to or higher than the observed phenotypic correlations. One conspicous expample was the elevated genotypic correlation coefficient between days to flowering and weight of boll.

Genotypic correlation coefficients between staple length, weight of boll and number of bolls per plant each with lint yield were higher than rg=1. These values were supposedly influenced by the environmental variances of F_1, P_1 and P_2.

The phenotypic correlations of the F_2 and F_3 populations were similar. The genotypic correlations, however, showed significant differences for some charaetcristics.

V. Discussion

Yield and fiber quality in Upland cotton are known to be compound quantitative characteristics. The interrelation of these characteristics makes the breeding of high-yielding, good quality Upland cotton difficult. The breeding problem becomes even more complicated in breeding for early-maturing, high-yielding, good-quality Upland cottons for Korea.

These breeding goals can be more efficiently approached if individual genetic phencmenon heritabilities and interrelationships can be determined in the early generations.

To this end, fundamental information concerning heterosis, combining ability, inheritance mode and genetic interrelationships between several agronomic characteristics of Upland cotton varieties are needed.

A. Heterosis and combining ability in the diallel cross F_1 hybrids

Heterosis in Upland cotton has been studied by the many researchers. Jones·Loden[32], Barnes·Staten[8], Lee et al[43], Hawkins et al[23], White·Richmond[76], and Miller·Lee[48] have reported that cotton F_1 hybbrid yields were increased above mid-parent by 16.9-47.0%, 20%, 26%, 19%, 30%, and 15-20%, respectively.

In addition there have been reports of other heterosis. This research has shown that F_1 hybrids yielded 37.3% higher than mid-parent, and that the number of bolls per F_1 plant were 27.8% more than mid-parent. Other characteristics did not show any significant heterosis.

GCA effects were found to be significant for all studied crahacteristics. SCA effects were found to be lower than GCA effects, which were similarly reported by Lee et al [43], Miller·Marani [49], and White·Richmond [76].

GCA effects for days to flowering were high, directed toward early-maturing in the early varieties and toward late-maturing in the late varieties. These results suggest that earliness and lateness are affected simultaneously by interacting dominant genes as indicated by Hintz.

Green[30].

GCA effects for boll weight were directed toward large boll. Paymaster, a large bolled variety had the highest GCA for boll weight while Suwon 1 and Mokpo 4 both small bolled varieties showed low GCA effects.

GCA effects for lint percent and for staple length were directed toward long fiber, by high-lint, long-fiber varieties and toward low-lint and short-fiber varieties because Suwon 1 and Heujueusseo Trice were low in lint percent while Paymaster and Arijona were high for these GCA effects. These results were similar to those reported by Lee et al [43] and Barnes·Staten[8]

Varieties with many bolls per plant, Mokpo 4 and Delfos 9169, gave a high GCA while varieties bearing few bolls per plant, Arijona and Heujueusseo Trice, gave a low GCA.

This high GCA effects for many bolled varieties will assist in breeding high-yielding varieties. As the GCA effects for lint yield were high in the varieties with large bolls, Mokpo 6, Delfos 9169 and Lockett 140, it is supposed that other yield components including number of bolls per plant directly affect lint yields. White·Richmond[76], Hawkins et al[23] and Miller·Marani[49] reported that the GCA effects of many bolled or large bolled varieties were high.

In this report Mokpo 6 and Delfos 9169, varieties with many bolls and Lockett 140, a variety with large bolls, had high GCA values for lint yield.

SCA effects for lint yield were high in crosses between many-bolled variety and late-maturing, large-boll varieties. Additive genetic effects supposedly caused the yield increase of many-bolled times large-boll crosses.

B. Inheritance and genetic component for the agronomic characteristics

1. Days to flowering

Early-maturing varieties not only affect lint yield and fiber quality, but they are important for multiple cropping.

Earliness and lateness are generally measured by days to flowering, days to open boll, average maturing date, boll period and percent first harvest.[9,10,30,60,62,63]

There are highly significant correlations between all these characteristics.[10,12,34,42]

Generally one or two characteristics for maturity in addition to days to flowering were recorded for this study.

Using diallel cross F_1 hybrids, early maturing varieties were shown to have partial to complete dominance over late-maturing varieties. The results were the same as reported by Harland[22], Kohel et al[39], White[74] and Murray.[52]

However, late-maturing varieties like Acala 1517w and Delfos 9169 were dominant over D.P.L. and Arijona. Segregation in the F_2 and F_3 populations of the cross Paymaster times Heujueusseo Trice distribution was centered mainly around the mid-parent. It is probable that maturity is governed by many genes due to unclear dominance relationships. These conclusions are similar to those reported by White[74] and Hintz·Green[30] and Kohel et al.[39]

Some crosses showed earliness comletely dominant to lateness while other combinations gave intermediate phenotypes indicating multi-gene or additive genetic action. It is considered that eary-maturing varieties such as Suwon 1 and Heujueusseo Trice have different early gene from Mokpo 4, while the lateness of Acala 1517w and Delfos 9169 is different from that of D.P.L. and Arjona.

2. Weight of boll (weight of seed cotton per boll)

The genetic analysis for boll weight in the diallel cross F_1 hybride showed large-bolled varieties dominant to small-bolled varieties. The dominance pressure from low and/or intermediate-maturing varieties showed irregularity in dominance.

Segregation of the F_2's and F_3's of the cross Paymaster times Heujueusseo Trice did not gave a clear dominance relationship.

These findings were different from the results of Ramay·Miller[59] and White[74]. The Korean climate during the cotton growing season is favorable to early-maturing varieties but it is not favorable to late-maturing varieties. In this experiment late maturing were not favored causing a wide variation in boll weight of late maturing varieties.

3. Staple length

The inheritance of staple length as shown by the diallel cross F_1 hybrids, indicated allelic gene interaction, additive gene action and complete or partial dominance according to cross. Long staple was dominat to short staple.

The F_2 and F_3 segregation for staple length in the Paymaster, Heujueusseo Trice cross fell within the range of parental variation for staple length. F_2 segregation tended toward long.

The number of genes as calculated by the partition of variance components in the F_2 and F_3 populations approached 1. This suggests that fiber length,was inherited by complete-or partial-dominant single gene.

This F_1 data agreed with the results of a diallel cross reported by Verhalen · Murray[72]. This F_2 and F^3 data also agreed with the analysis of variance component of a back cross F_1 population reported by Ramey and Miller.[59]

It is believed that long fiber is governed by a single partially dominant to dominant gene, though other modifying factors were present.

4. Lint percent

F_1 genetic components analysis for lint percent showed that high lint percent was partially dominant to low lint percent. High additive gene action without nonallelic genes action was found. The analysis of variance components for lint percent in the F_2 and F_3 populations of Paymaster times Heujueusseo Trice showed partial dominance with decreasing dominance in advancing generations. The number of genes for lint percent was three. These results did not completely agreed with the complete dominance found by Ramey,[58] · Ware · Harrell[73] · Christidis · Harrison[20] and William · Bridge[77] found single gene dominance for lint percent in diallel crosses while Ferrer · Monge[16] found the some results in F_2 populations.

Suggested causes of these dffferent findings were different test varieties and environmental cultivation condtions. As fiber length affects lint percent, more investigations are needed on the interrelationships between fiber length and lint percent.

5. Number of bolls per plant.

Analyses of the number of bolls per plant in the diallel cross F_1 hybrids showed over-dominance of allelic genes. Small-boll varieties such as Arijona, Heujueusseo Trice and Suwon 1 were governed for number of bolls per plant by non-alleles. Early varieties with many small bolls showed epistatic gene action.

It is suggested that the number of bolls per plant is related in certain varieties because early-maturing, small-boll varieties are different in shedding rate bolls from other varieties. Continuing studies on nonallelic gene action should be made to see if these varieties have other characteristics related to the boll shedding rate.

The inheritance of boll number per plant calculated by diallel-cross-analysis by White · Kohel[75] indicated partial dominance. This report differs from these findings, for small-bolled varieties were low in shedding rate due to the limited cultural period in Korea. Earliness was found to be partial dominant to lateness. Early times late crosses increased the numer of fruiting branches per plant thus increasing the number of bolls per plant by over-dominance. More detailed studies on the characterics should be continued.

Over-dominance for bolls per plant were found in the F_1, F_2 and F_3 segregating populations of Paymaster times Heujueusseo Trice. The averages of the advancing generations moved closer to mid-parent while the distribution of individual many bolled plants remained high.

6. Lint Yield.

Lint yield is dependent on the number of bolls per plant, boll weight and lint percent.

Some scientists believe that lint yield should not be treated as a genetic characteristics [9,10]. Other researchers believe lint yield to be a most important characteristics because it is the primary objective of cotton cultivation[2, 4, 9, 13, 14, 23, 32, 43, 50, 57]

Lint yield showed over-dominance in the diallel cross F_1 hybrid as previously reported by Barnes et al [8], Lee et al[43], Ramey[57] and Jones · Loden.[32]

Delfos 9169, Mokpo 4 and Mokpo 6 showed dominance for yield while D.P.L. and Acala 1517W showed recessive yield inheritance. This indicates that high-yield is over-dominant to low-yield. The genetic yield effects will be difficult to predict because of little additive gene actions and environmeital variation.

The diallel graph for lint yield was similar to the one for number of bolls per plant. The order of varieties by lint yield was different from the order for number of bolls per plant because numerous factors affect yield.

C. Heritability

High heritabilities for staple length and lint percent were found in F_1 hybrids, F_2 and F_3 populations of Paymaster times Heujueusseo Trice. These results agree with reports by Ferre-Monge[16], Tipton[69] and William · Bridge[77], the selection efficiencies for staple length and lint percent are expected to be very high.

The heritability for days to flowering was found to be 39% in the F_1 hybrid. In F_2 broad sense heritability was estimated at 34% while narrow sense heritability was estimated at 11%. Kohel · Richmond[40] reported from F_2 and F_3 populations narrow sense heritabilities for days to flowering at 57% while broad sense heritability was estimated at 70%. Hintz · Green [30] reported heritabilities of 50.6% for days to flowering.

The low herilabilities found in this study were caused by large error variance in the F_1 hybrids and large environmental effects in the cross Paymaster times Heujueusseo.

Heritability estimate for weight of boll was 67% for the F_1 hybrids. Estimates of 30% for broad sense and 22% for narrow sense heritabilities were found in the F_2 populations. william · Bridge[77] reported that heritability for boll size was generally low.

Heritability estimate for number of bolls per plant was 30% in the F_1 hybrids. In the F_2 populations narrow sense estimate was 36%, this being similar to the reports of Williiam · Bridge[77] and Richmond · Ray.[63] The heritability for number of bolls per plant showed over-dominance. This suggests that selection will be efficient for individual plants with many bolls.

The heritability estimates for lint yield were very low in the F_1 hybrids, substanciating the findings of Lee et al[43]. Heritabilities in the F_2 and F_3 popuiations were higher, 38% and 50%, respectively. This finding corresponds with the report of Miller · Lee[48]. but differs with the report of William · Bridge[88]. It is believed that the heritability figures for lint yield given in this report are over-evaluated in the additive estimate because individual plants showing large heterotic effect increased the variance of the F_2 and F_3 populations.

D. Correlations between agronomic characteristics

There were high phenotypic correlations between days to flowering and staple length and between lint percent and staple length in the F_1, F_2 and F_3 populations. Late-maturing individuals generally had long staple length and high lint percent. Christidis · Harrison[10] and Kae[35] reported highly significant positive correlations between flowering period and staple length.

This report has shown that correlation between days to flowering and lint yield is extremely low substanciating Duggar's results[12].

Phenotypic correlations between lint percent and staple length were so high in the F_1, F_2 and F_3 populations that the two traits were considered a nearly the same. Christidis · Harrison[10] and Kae[35] indicate the same results. It is noted that lines with shorter staple length will probably appear in early-maturing varieties, as indicated by the negative correlation between these characteristics found by Christidis · Harrison.[10]

The phenotypic and genotypic correlations showed that the number of bolls per plant had the largest affect on lint yields. Christidis · Harrison,[10] White · Kohel[75] and Miletello[47] reported the same results.

There were highly significant positive phenotypic correlations between lint percent and lint yield and between staple length and lint yield. This suggests that high-yielding lines would be closely related to lines with high lint percent and/or lcng staple length. Genetic correlations were similar to the above phenotypic correlations.

These data suggest that many bolled individuals be selected to increase yield, and that plants with high lint percent and long staple be selected to improve quality. However, there are problems in selecting early-maturing, good-quality and high-yielding lines in Korea.

To solve these problems, good-quality and high-yielding individuals should first be selected in early generations and then back crossed to early-maturing lines. O.her breeding methods including recurrent selenction should be reviewed.

Ⅵ. Summary

To obtain fundamental informations on cotton breeding efficiences for Korea, individual genetic relationships and interrelationships between the agronomic characteristics of Upland cotton were investigated. These experiments were ccuducted at the Mokpo Branch Station (34°48′N, 126°23′E and altitude of 10m above sea level) from 1969 through 1972.

Heterosis, combining ability, dominance and recessive gene action, genetic variance, and phenotypic and genotypic correlation were investigated by F_1's frcm an 11-parent partial diallel cross and the segregating F_2 and F_3 populations of the cross Paymaster times Heujueusseo Trice. The following points resulted from this study.

1. Heteroses for number of bolls per plant and lint yield were significant at 27.84% and 37.26%, respectively. No other character had significant heteroses.
2. The GCA estimates for all studied characteristics were higher than the SCA estimates. Varieties with high GCA effects were Suwon 1 for earliness, Paymaster and Arijona for high lint percent, and Arijona for long fiber, etc.
3. SCA estimates for lint yield varied widely in crosses with Mokpo 4, Mokpo 6 and Heujueusseo Trice. Those crosses with the highest SCA effects were combinations with large characteristics differences. Example of these crosses are Mokpo 4 times Acala 1517W, Mokpo 4 times D.P.L. and Heujueusseo Trice aud Paymaster.
4. Early-maturing varieties were completely dominant to late-maturing varieties in some combinations while other crosses gave intermediate phenotypes·These results suggest additive genetic action by multi-genes.

   Heujueusseo Trice, Mokpo 6, and Suwon 1 showed highest degree of dominance for earliness.
5. There were no significant trends for inheritance of weight of boll and 100 seeds weight.
6. Long staple was partially to completely dominant to short staple. Though there were single gene ratios the rate of dominance decreased in the F_2 and F_3 populations in the cross between the long staple variety Paymaster and the short staple variety Heujueusseo Trice. Diallel cross F_1 hybrids showed complicated allelic gene action for staple length.Various dominance degree were shown by varieties.
7. Number of bolls per plant indicated strong over-dominance and small non-allelic additive gene action.
8. Lint yield was characterized by over-dom-

inance and by multiple non-allelic-gene action. High-yielding varieties were dominant to low-yielding ones. However, the low-yielding variety Heujueusseo Trice showed over-dominance, indicating different reactions according to the varieties and combinations.

9. Broad sense heritability for days to flowering was 34-39% while narrow sense heritability was 11%. Large variations of individual plants caused by Korean climatic conditions cause this situation. Heritability estimates for weight of boll was 30% for broad sense and 22% for narrow sense.
10. Heritability estimates for staple length and lint percent were very high suggesting strong selection effects.
11. Narrow sense heritability estimates for number of bolls per plant was 30% in the diallel cross F_1 hybrids and 36% in the F_2 population of the special cross. Broad sense heritability was estimated at 67% suggesting that.
12. Heritability estimates for lint yield was low due to high over-dominance in the diallel cross F_1 hybrids. Heritability estimates for yield was low in the F_1 hybrids but high in the F_2 and F_3 populations.
13. Phenotypic and genotypic correlations between lint percent and days to flowering and between staple length and days to flowering were high in the F_1, F_2 and F_3 populations. Late-maturing varieties and individuals had long staple and high lint percent in general. As the correlation between days to flowering and lint yield was extremely low, the two traits were considered independent of each other. Days to flowering and number of bolls per plant were negatively correlated in the F_3 population, indicating early-maturing individual plants with many bolls may be readily selected.
14. Phenotypic and genotypic correlations between lint percent and staple length were high in F_1, F_2 and F_3 populations. Accordingly, long staple varieties were high in lint percent.
It was recognized that lint yield and lint percent were positively correlated in the diallel cross F_1 hybrids, and lint percent and staple length were positively correlated in the F_2 population, indicating that lint percent and staple length affect lint yield.
15. Lint yield was significantly and positively phenotypically correlated with number of bolls per plant in F_1, F_2 and F_3 populations. A high genotypic correlation was also noted indicating a close genetic relationship.

The selection efficiencies for a high-yielding variety can be increased when individual plants with many bolls are selected in later generations. The selection efficiencies for good fiber quality can be enhanced when individuals with long staple and high lint percent are selected in early generations.

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摘　要

棉花의 有用形質의 個別的 遺傳關係를 早期에 檢定하고 이들의 相互關聯性을 育種事業에 效率的으로 利用할 수 있는 基礎資料를 얻고저 1969年부터 1972年까지 作物試驗場木浦支場實驗圃場(北緯 34°47′, 東經 126°20′, 標高 1.5m)에서 陸地棉品種間의 Partial Diallel Cross F_1 및 Paymaster×Heujueusseo Trice의 F_2, F_3 分離集團을 供試하여 Hetesosis, Combining Ability, 品種別優劣性, 遺傳分散의 分割, 表現型 및 遺傳相關等을 調査한 結果를 要約하면 다음과 같다.

1. Heterosis는 株當莢數와 繰綿收量에서 兩親平均보다 各各 27.84%, 37.26%의 增加傾向을 보였고 其他 形質에서는 有意性이 없었다.

2. GCA에 있어서는 모든 形質에서 有意性이 있었고, SCA보다 GCA 效果가 컸으며, 品種別 GCA 效果는 Suwon #1이 早熟으로, Paymaster 및 Arijona는 高繰綿으로, Arijona는 長纖維의 方向으로 컸다.

3. 繰綿收量의 SCA는 Mokpo #4, Mokpo #6, Heujueusseo Trice等을 片親으로 한 組合이 變異가 컸고, 其中 SCA效果가 가장 큰 組合은 Mokpo #4×Acala 1517W, Mokpo #4×D.P.L, Heujueusseo Trice×Paymaster 組合等으로서 比較的 對立形質이 많은 組合이였다.

4. 早晩性의 遺傳은 早熟이 晩熟에 對하여 完全優性組合 또는 早熟과 晩熟의 相互間의 優性을 나타내지 못하는 中間性組合이 있었음에 따라 이것은 相加的遺傳成分이 큰 Multi gene의 支配를받는 것으로推察되였다. 早熟性의 優性强度가 가장 큰 品種으로서는 Heujueusseo Trice, Mokpo #6, Suwon #1 等이였다.

5. 莢重 및 種子 100粒重의 遺傳은 뚜렷한 傾向이 없었다.

6. 長纖維性인 Paymaster와 短纖維性인 Heujueusseo Trice間의 交雜組合의 F_2, F_3에 있어서의 纖維長分離는 長纖維가 短纖維에 對하여 完全 또는 部分優性의 單因子支配에 依하여 分離되였으며 世代가 進展됨에 따라 優性個體發現率이 減少되는 傾向이였다. 또한 Diallel Cross F_1으로 同時에 數個品種을 比較할 境遇는 各品種의 纖維長의 幅이 다르고 優性의 程度가 다르기 때문에 多少 複雜한 對立因子作用으로 나타났다.

7. 株當莢數는 大體로 超越優性이 强하게 나타났으며 따라서 相加的部分이 적게 表現되여 非對立遺傳子의 作用도 存在하는 것으로 보였다.

8. 繰綿收量도 超越優性이 强하게 나타내여 非對立遺傳子의 作用도 存在하는 Multi gene에 依하여 支配되는 것으로 보였으며 大體로 多收性品種이 少收性品種에 比하여 優性이였다. 그러나 Heujeusseo Trice는 少收性品種으로서 超越優性을 나타내여 品種 및 組合에 따라서 相異한 反應을보였다.

9. 開花所要日數의 遺傳力은 39~34%였으나 狹義 11%로 낮은 것은 우리 나라에서는 個體變異가 甚하여 遺傳力이 多少 낮게 表現되는 것으로 思料된다. 또한 莢重의 遺傳力은 廣義 30%, 狹義 22%로 낮은 傾向이였으나 Diallel Cross F_1에서는 多少 높게 나타났다.

10. 纖維長 및 繰綿比率의 遺傳力은 어느 境遇에서도 높았으므로 選拔效率이 클것으로 期待된다.

11. 株當莢數의 遺傳力 Diallel Cross F_1에서 30%, F_2에서 狹義 36%로 낮은 傾向을 보였으나 廣義 67%로 높았으므로 F_2, F_3에서는 兩親의 特性을 어느 程度 나타낼것으로 期待된다.

12. 繰綿收量의 遺傳力은 Diallel Cross F_1에서는 超越優性이 强하게 作用했기 때문에 낮은 優傳力을 보였으나 F_2, F_3에서는 廣義 38%, 狹義 50%로서 比較的 높았다. 따라서 收量의 遺傳力은 F_1에서는 極히 낮았으나 F_2, F_3 世代에서는 높아가는 傾向이였다.

13. 開花所要日數, 繰綿比率 및 纖維長의 相互間에는 F_1, F_2, F_3에서 모두 表現型相關이 높았으므로 晩熟品種 및 個體가 大體로 長纖維 및 高繰綿의 傾向이였고 이들의 遺傳相關도 높기때문에 遺傳的關係가 컸었다. 開花所要日數와 繰綿收量과의 相關關係가 極히 낮았으므로 이들은 서로 獨立形質로 思料되지만 株當莢數와는 F_3에서 負의 相關이 있으므로 早熟個體가 多莢性인 傾向을 많이 보였다.

14. 繰綿比率과 纖維長과의 表現型 및 遺傳相關은 F_1, F_2, F_3 모두 높았으므로 이 두 形質은 大體로 恰似한 形質이라고 認定할 수 있음에 따라 長纖維品種이 大體로 高繰綿性이였다. 또한 繰綿收量과 繰綿比率과는 Diallel Cross F_1에서 正의 相關, F_2에서는 纖維長과의 正의 相關을 보여 繰綿比率 및 纖維長도 繰綿收量에 多少 關與하는 것으로 나타났다.

15. 繰綿收量은 株當莢數와의 表現型相關이 F_1, F_2, F_3 모두 高度의 正相關을 나타냈고, 遺傳相關도 높음에 따라 遺傳的인 關聯性이 크다고 認定되였다. 따라서 多收性을 選拔하려면 株當莢數가 많은 個體를 後期世代에서 選拔하는 것이 選拔效率이 크다고 思料된다. 또한 良質系統을 選拔하기 爲해서는 長纖維 및 高繰綿個體를 初期世代부터 選拔해도 選拔效率은 클것으로 期待되지만 이러한 個體는 同時에 晩熟性을 內包할 可能性이 있었다.

Ⅷ. Tables Attached

Appendix 1. Average hybrid vigor and mid-parent values in the 7 agronomic characteriatics.

Variety	Days to flowering	Wt. of boll	Lint %	Fiber length	100 seeds weight	No. of boll per plant	Lint yield
Suwon #1	80.0	3.05	31.25	20.75	9.05	9.00	8.24
MP	83.1	3.90	33.48	23.81	9.52	8.82	8.66
F_1	83.0	4.12	34.69	25.88	9.45	11.12	12.09
F_1-MP	−0.1	0.22	1.21	2.07	−0.07	2.30	3.43
Mokpo #4	84.0	3.90	36.35	23.25	8.35	11.10	10.36
MP	84.8	4.28	35.78	24.94	9.20	9.77	9.62
F_1	83.9	4.45	35.83	25.95	9.78	11.62	12.72
F_1-MP	−0.9	0.17	0.05	1.01	0.58	1.85	3.10
Mokpo #6	84.5	5.05	38.30	27.00	9.65	8.60	12.75
MP	85.0	4.80	36.66	26.62	9.66	8.64	10.69
F_1	83.7	4.89	37.05	27.22	9.83	11.21	13.35
F_1-MP	−1.3	0.09	0.39	0.60	0.17	2.57	2.66
Copt 6390	84.5	4.75	34.65	25.90	9.45	9.10	9.70
MP	85.0	4.67	35.01	26.13	9.70	8.87	9.32
F_1	83.4	4.80	35.60	26.83	9.96	11.39	12.74
F_1-MP	−1.6	0.13	0.59	0.70	0.16	2.52	3.42
Heujueusseo Trice	82.5	4.65	33.20	25.55	11.20	7.00	6.45
MP	84.1	4.62	34.36	25.97	10.49	7.92	7.86
F_1	83.2	4.70	34.96	26.65	10.42	9.66	10.59
F_1-MP	−0.9	0.08	0.60	0.68	−0.07	1.74	2.73
Lockett 140	87.0	4.60	35.75	26.85	10.55	9.40	9.15
MP	86.1	4.60	35.51	26.56	10.20	9.00	9.07
F_1	85.9	4.70	36.23	27.10	10.21	11.49	13.14
F_1-MP	−0.2	0.10	0.72	0.54	0.01	2.49	4.07
D.P.L.	87.0	4.30	33.95	25.85	9.65	8.40	8.03
MP	86.1	4.46	34.70	26.11	9.79	8.55	10.37
F_1	85.2	4.61	35.22	26.82	9.95	11.90	12.71
F_1-MP	−0.9	0.15	0.52	0.71	0.16	3.35	2.34
Paymaster	87.0	6.05	39.45	27.25	9.90	8.35	8.53
MP	86.1	5.25	37.17	26.74	9.91	8.53	8.79
F_1	85.7	5.49	37.84	27.18	9.88	11.37	12.65
F_1-MP	−0.4	0.24	0.67	0.44	−0.03	2.84	3.86
Acala 1517w	87.0	5.00	30.30	26.85	11.55	8.05	6.90
MP	86.1	4.78	33.06	26.56	10.65	8.40	8.09
F_1	85.0	4.93	35.03	26.98	10.42	11.17	11.98
F_1-MP	−1.1	0.15	1.97	0.42	−0.23	2.77	3.89
Delfos 9169	87.0	4.30	36.60	29.25	9.45	9.55	10.93
MP	86.1	4.46	35.89	27.64	9.70	9.07	9.87
F_1	85.2	4.60	36.14	28.55	9.87	11.84	12.97
F_1-MP	−0.9	0.14	0.25	0.91	0.17	2.77	3.10
Arijona	89.0	4.90	38.60	30 95	10.50	10.25	8.05
MP	87.0	4.73	36.79	28.40	10.18	7.88	8.58
F_1	85.5	4.88	37.20	29.19	10.09	9.32	11.09
F_1-MP	−1.5	0.15	0.41	0.79	−0.09	1.44	2.51

Appendix 2. SCA effects of 7 agronomic characteristics in the 11-parent diallel cross F_1.

Combination	Days to flowering	wt. of boll	Lint %	Fiber length	100 Seeds Weight	No. of boll per plant	Lint yield
1 × 2	−1.487	−0.024	0.307	−1.096	0.469	0.671	−0.838
〃 3	−0.448	0.364	0.969	0.999	−0.423	1.517	0.758
〃 4	0.820	0.029	0.246	0.918	0.565	0.201	1.560
〃 5	1.743	−0.082	−0.792	0.207	0.042	−0.048	0.845
〃 6	4.012	−0.024	0.442	0.564	−0.650	−0.067	0.149
〃 7	−2.448	0.091	−0.600	1.080	0.542	0.421	1.152
〃 8	−0.871	−0.255	0.634	0.491	−0.446	0.586	−0.108
〃 9	0.666	−0.008	0.253	0.703	0.134	−0.513	0.428
〃 10	−0.448	0.102	0.034	1.076	0.130	1.540	0.943
〃 11	−0.025	0.294	1.257	0.272	−0.696	−0.667	0.926
2 × 3	−1.179	0.133	−0.046	0.810	0.230	−0.740	0.017
〃 4	0.089	0.248	−0.119	−0.019	0.019	0.394	0.950
〃 5	1.512	0.037	0.392	−0.481	−0.153	−0.155	1.160
〃 6	−0.217	−0.055	−0.823	0.576	0.403	0.325	−1.200
〃 7	2.320	−0.139	−0.415	−0.008	−0.403	0.636	1.366
〃 8	−3.102	−0.035	0.369	0.603	0.007	−1.271	0.190
〃 9	0.435	0.160	0.888	0.463	0.638	1.328	2.063
〃 10	2.329	−0.078	−0.530	0.637	−0.115	2.432	0.883
〃 11	−2.256	0.064	−0.807	0.483	0.557	−0.075	0.226
3 × 4	1.128	−0.012	0.642	−0.223	−0.023	1.540	0.777
〃 5	−0.448	−0.124	−0.246	0.064	0.253	−0.309	−1.097
〃 6	5.320	−0.116	0.338	−0.027	0.161	−0.328	1.096
〃 7	−1.641	−0.201	−0.253	−0.012	0.003	1.209	2.008
〃 8	−3.046	−0.047	−0.919	−0.450	0.115	2.175	0.328
〃 9	0.525	0.098	0.250	−0.289	0.295	0.025	1.080
〃 10	0.358	0.010	−0.169	−0.366	−0.407	−0.271	−0.235
〃 11	−2.217	−0.047	0.296	0.180	0.215	−0.328	−1.301
4 × 5	−1.179	−0.058	−0.219	0.533	0.192	−0.925	−0.535
〃 6	−2.910	−0.051	0.065	−0.008	−0.050	2.155	1.268
〃 7	−0.371	0.014	0.173	−0.642	−0.057	1.294	1.536
〃 8	−1.794	−0.082	0.207	0.118	0.803	0.809	1.080
〃 9	1.743	0.114	0.276	−0.019	−0.815	−0.590	−0.696
〃 10	0.628	0.075	−0.392	0.103	0.280	−0.336	0.172
〃 11	−1.948	−0.082	−0.019	0.249	−0.246	−0.194	−0.334
5 × 6	−1.987	−0.012	0.026	0.030	−0.023	0.355	−0.731
〃 7	−0.948	0.102	0.284	−0.554	0.019	0.094	0.666
〃 8	2.128	0.056	0.569	0.007	−0.319	1.559	2.600
〃 9	−0.833	0.102	0.138	−0.231	−0.338	0.959	1.328
〃 10	0.051	0.014	0.069	0.591	0.057	−0.186	−0.727
〃 11	−1.525	0.006	0.492	0.787	−0.069	0.605	0.180
6 × 7	−1.179	−0.039	0.219	−0.346	−0.511	2.025	1.605
〃 8	1.897	0.364	0.253	−0.285	−0.080	−0.109	1.719
〃 9	−1.564	−0.089	1.073	−0.273	0.415	0.540	1.946
〃 10	−1.679	0.021	−0.046	0.349	0.380	−0.505	1.706
〃 11	−1.256	0.114	−0.473	−0.054	−0.169	−0.163	0.224
7 × 8	−0.564	0.479	0.361	0.130	0.161	0.728	−0.043
〃 9	1.974	−0.124	−0.169	0.091	−0.242	0.428	−0.135
〃 10	−1.141	−0.062	0.111	0.614	0.380	0.762	−0.040
〃 11	2.282	0.129	0.934	0.710	0.123	0.525	−0.102
8 × 9	−0.448	0.179	−0.715	−0.196	0.169	0.894	−0.066
〃 10	0.935	0.041	−0.153	0.126	0.042	−0.351	−0.276
〃 11	4.858	−0.166	−0.930	−0.327	−0.050	0.290	1.706
9 × 10	1.089	−0.012	1.215	−0.262	−0.876	1.498	1.105
〃 11	−2.525	−0.170	0.488	0.183	0.126	0.540	0.203
10 × 11	−1.102	0.091	−0.330	−1.192	0.169	0.494	1.268

note : 1: Suwon #1 2:Mokpo#4 3:Mokpo#6 4:Copt 6390 5:Heujueusseo Trice 6:Lockett 140 7:D.P.L. 8: Paymaster 9: Acala 1517W 10: Delfos 9169 11: Arijona