This is to certify that the

thesis entitled

GENETIC ANALYSIS OF COLOR INHERITANCE

IN PETUNIA

presented by

Clark D. Paris

has been accepted towards fulfillment
of the requirements for

Ph D degree in Horticulture

Walter J. Haney
Major professor

Date November 26, 1956

O-169

ProQuest Number: 10008500

All rights reserved

INFORMATION TO ALL USERS
The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript
and there are missing pages, these will be noted. Also, if material had to be removed,
a note will indicate the deletion.

ProQuest 10008500

Published by ProQuest LLC (2016). Copyright of the Dissertation is held by the Author.

All rights reserved.
This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

GENETIC ANALYSIS OF COLOR INHERITANCE IN PETUNIA

By

CLARK D. PARIS

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1956

Approved Walter J. Haney

CLARK D. PARIS

ABSTRACT

Most previous genetic work has been concerned with wild or near wild petunias. This study was undertaken to analyze the factors concerned with expression of flower color in modern varieties. These colors were first divided into eleven classes; viz., white cream, salmon, scarlet, light rose, deep rose, crimson, silver blue, mid blue, violet blue, and violet purple. Several commercial white varieties were intercrossed to see if more than one type of white were present, but only one was found. Twenty seven varieties were then selected for intercrossing. At least one in each color class was crossed with every other class and the resulting hybrid flowered. Most hybrid colors were magenta or purple. Selected F_2 and backcrosses were analyzed genetically.

From these data nine factors have been named that influence flower color in petunia. These with their actions are:

Iv--- conditions the production of full color; iviv conditions the production of white, cream, or dilute color.

Cl-- with ss grays the colors; clcl conditions the production of clear colors.

R^C-- conditions the production of crimson; R-conditions the production of magenta; rr conditions the production of rose.

S- conditions the production of rose, if rr is also present; ss with rr conditions the production of salmon.

B_1-- conditions the production of rosy colors; b_1b_1 blues them.

B_2-- conditions the production of rosy colors; b_2b_2 blues them.

In_1--- conditions the production of dilute colors; in_1in_1 intensifies them.

In_2--- conditions the production of dilute colors; in_2in_2 intensifies them.

Dil-- conditions the production of intense colors; dildil dilutes them.

A total of 66 crosses with their chi squares and the status of the other genes not segregating in each particular cross is given in tabular form to support the conclusions. The data for the crosses are given in the appendix. Genotypes of the parents are also given.

Interactions of the first six factors are shown in chart form. Three additional charts show the interactions of the R^c, R, and r alleles; the In_2, Cl R, S, B_1, and B_2 genes; and S, In_1, In_2 and Dil genes on specific genotypes.

GENETIC ANALYSIS OF COLOR INHERITANCE IN PETUNIA

By

CLARK D. PARIS

A THESIS

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1956

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Dr. W. J. Haney, under whose supervision this investigation was undertaken. His helpful suggestions and interest in the problem were greatly appreciated.

He is also greatly indebted to Dr. G. B. Wilson for his interest and help in the problems. The other members of the guidance committee, Dr. A. L. Kenworthy, Dean C. R. Megee, and Dr. H. M. Sell, are tendered sincere thanks for their interest and assistance.

Grateful acknowledgments are due to Pan American Seeds, Inc., Paonia, Colorado and especially its president, Mr. Charles Weddle, for financial assistance and donations of seed from some inbred lines, which facilitated the investigation.

Thanks are also due to the Michigan State Florist Association for financial assistance.

The writer also deeply appreciates the assistance given him by the men at the Plant Science Greenhouse of Michigan State University, Mr. Floyd Challender and his predecessor Mr. John Bowling, Mr. Ray Ryerson and Mr. George Warren.

Finally, as this is the culmination of over nine years of college study, may the author take this opportunity to express his heartfelt thanks to all his past professors for their interest in his welfare and the kind considerations given him. This includes the staffs of Michigan State University, Iowa State College, and State University of Iowa.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	3
MATERIALS AND METHODS	16
RESULTS AND DISCUSSION	20
SUMMARY	39
BIBLIOGRAPHY	41
APPENDIX	50

INTRODUCTION

The petunia is one of the best known annual flowers in cultivation. Present day varieties are usually listed as Petunia hybrida Hort., but this is not a valid species. The generally accepted theory is that the cultivated petunias are hybrids of P. axillaris (Lam.) BSP., and P. integrifolia (Hook.) Schinz and Thellung. Both of these are native to the Rio La Plata region of South America. Stout (94) gives a description of each of these species and also reviews the synonymy. P. axillaris, white flowered, was introduced into England in 1823, while the other, a violet flowered species, was introduced in 1831. In 1835 William Herbert grew the first known hybrids of the two. Since that time there have been many hybridizations, both controlled and natural. The color range has been greatly extended from the two original colors.

Since their introduction, petunias have steadily increased in popularity until now they are one of the most important garden flowers. In 1949, the wholesale value of petunia seed produced in the United States was $232, 371. 00 (99). Of this amount, regular varieties accounted for $93, 054. 00, while doubles and fancies were worth $139, 317. 00. Petunias were the most important flower seed produced in this country. The second most important item, zinnias, had a listed value of $177, 211. Petunias constituted 12. 7 percent of the total value of flower seed production. Since 1949 production of F_1 hybrid seed has greatly increased the income of growers. For hybrid production a knowledge of the

genetic make-up of the parent material is essential. Flower color is probably the one factor that contributes most in determining the success of a new flower introduction. The majority of hybridists may know which parent will produce desirable hybrids, but comparatively few know the genetics of the color involved. The public is beginning to realize the advantages of growing hybrids, and is willing to pay the extra cost involved in their production. Seed companies have difficulty supplying the present demand for hybrid seed.

This study was undertaken to determine the genetics of flower color in petunia.

REVIEW OF LITERATURE

The literature of flower color in Petunia is scant and sketchy. In 1911 Westgate (104) published a report of his findings, separating the colors into dark, intermediate, and light shades only. Three years later Malinowski (54) published the first of several papers on the subject. He discovered that violet was a monogenic dominant over red. It was also dominant over mauve. Unfortunately, he did not identify the genes involved. However, later that year (55) in a report on additional crosses, he postulated the presence of genes A and B. In the cross of white with white, having red veins, the F_1 was completely red, while the F_2 gave a 9 red: 3 white, red veins: 4 white ratio. From this observation he thought A was a factor for producing red, B causes even distribution of color and bb limits the color to the veins. In 1916, Malinowski and Sachsowa (58) reported further results. When a lilac colored red flecked and violet throated petunia was crossed with a white, red ringed and red flecked throated one, the F_1 contained both red, violet throated and lilac, red flecked flowered plants. The F_2 produced 202 red, violet throat; 27 lilac, red flecked; 29 red violet; 56 red, ivory throat; 9 white, red ring and flecks; 15 red white; and 23 very small lilac. By combining the first three and second three, they got a 12:3:1 ratio. Lilac, green edge crossed with red, violet throat, gave a red, violet throat hybrid, which segregated in the next generation into 89 red, violet throat; 27 lilac; 29 red, green edge; and 6 lilac, green edge. In another, lilac crossed

with dark rose, yellow throat gave a lilac F_1 and 21 lilac to 7 rose red in the F_2. In the last cross lilac was crossed with the F_1 of white x red, violet throat. This seed produced red, violet throat; lilac; and lilac, red veins and fleck flowered plants. Seed from the lilac individuals were grown for another generation. One produced 23 lilac (16 dark throats and 7 light throats) only. The second produced 70 lilac, violet throat to 25 white, violet throat. The third produced 55 lilac and 18 white. Two more produced 33 and 56 lilac, violet throat; 11 and 22 lilac, lilac throat; 10 and 19 white, violet throat; and 4 and 7 pure white, respectively. They did not identify the genes involved.

In 1918 Rasmuson (73) reported the results of crossing white, blue anthers, pollen and throat with a violet, yellow anthers, pollen and throat. The hybrid colors were shades of violet with both blue and yellow anthers, pollen, and throat while in the next generation the violet shades to the lighter shades fitted a 3:1 ratio. A blue pollen F_1 produced a F_2 of 78 blue to 32 yellow pollen individuals. He concluded that flower color was independent of pollen color. In 1927 Skalinska and Guchtman (91) showed that considerable somatic variability in size, form, and color of flowers in the same genotype could be due to allotypic mitosis.

Ferguson in 1934 (28) contributed to the genetics of pollen color in the petunia by demonstrating two major and two minor genes. B gives blue pollen and bb gives a delicate shade of blue. YY gives yellow, yy gives a light tint of yellow, and Yy is intermediate. BY gives green, bY yellow, By blue and by

gives a delicate shade of green. D is a factor for gray and is incompletely dominant over d, which gives white. D tones down the other colors, while d dilutes them. The last gene G, which gives green, is hypostatic to B and Y. Gg is slightly weaker while gg produces a very pale green. In the absence of D, G gives a greenish cast to the yellows and deepens the blues and greens. In 1941 Dale (22) concluded that both pale veined and pale corrolla are due to recessive monogenic characters.

In 1937 Störmer and v. Witsch (93) demonstrated that a gene for color production was present in petunia, but it remained for Mather and Edwardes to name it in 1943 (60). They identified two loci, W w (color-white) and M m (purple-magenta) and concluded that Petunia axillaris was wwMM and P. integrifolia was WWmm. Backcross data showed that P. axillaris was heterozygous for a dilution factor D. They blamed some of their aberrant ratios in the F_2 and F_3 populations on selective fertilization of pollen tubes. Another observation they made was that most pale colored or near white petunias are genetically white, but with a dilution factor.

In 1944 Walker (102) reported his observations on a Flaming Velvet (crimson) x Hollywood Star (violet purple, white star) cross. The crimson appeared to be a monogenic dominant.

Most of the foregoing literature dealt with the expression of the self colors. The genetics of variegation is much more complex. In 1914 Malinkowski (55) reported that the crossing of self-colored flowers with variegated gave

self-colored hybrids. In the next generation only 4.5 per cent of the plants had variegated flowers. Later (57) he reported on an unstable race in Petunia which differed in size of flowers, distribution and amount of pigment, size of petals, per cent of abortive pollen grains, and germination. He found that pigment spot size was correlated with flower size, and that the extreme types are not cytologically different. This did not bear out his earlier (56) assumption that variegation was due to loss of chromosome fragments. He also postulated that an agency outside the chromosomes determines size of the chromosome and thus characteristics of the flower. Four years later Malinowski and Smolska (59) attempted to associate large corolla size with self color. They also observed that variegation was not constant even on the same plant.

In 1921 Skalinska (78) described two polymorphic races of Petunia integrifolia which differed from the species in form and color. One had specks of lilac on the rim of the corolla, while the other was white with red flecks. Both races bred true. She also described a variegation which she believed was a periclinal chimera. This last race was the subject of a later paper (1924) (89). Assuming it was a chimera, she did not work on the genetics of color.

In 1934 Schröder (83) reported results of a series of physiological experiments with a blue and white variegated petunia. The color was varied from pure blue through increasing white variegation to pure white by changing the environment. Nutrition and humidity had no visible effects. Raising

temperature and lowering light intensity increased the blue areas, while lowering temperature and increasing light extended the white areas. The critical period for pattern formation was ten to fifteen days before anthesis. This reaction was found to be specific for each cell. The number of cells maturing under the same environmental conditions determines the pattern. He also observed that flowers of different branches on the same plant may have very dissimilar variegation. Clones grown under similar environment had analogous patterns. The same year Harder (39) published his work which had been conducted independently. In both this paper, and in a later one with a co-worker (1935) (40), Schröder's conclusions were substantiated. Still later (1940) (41), Harder and v. Witsch tried, inconclusively, to correlate variegation with heteroauxins.

In 1935 Moore and Haskins (68) published their findings on x-ray induced variegation in petunia. They also found that the pattern of variegation was not constant, but appeared to be correlated with age of the flower bud at time of radiation. In 1943 Creighton (21) worked with the effect of nutrition on color patterns in petunia flowers. The variegation was not affected by low iron, zinc, manganese, or boron; or a deficiency of nitrogen, phosphorus, potassium, sulphur, magnesium or calcium. However, high nitrogen or potassium seemed to reduce the amount of variegation. She also demonstrated that the photoperiod had no effect on color pattern.

In 1936 v. Witsch (107) published a paper on the genetics of variegation. He noted that different types of patterns showed different modes of inheritance, and postulated the presence of multiple alleles and a precursor gene. He also suggested that variegation might be caused by a labile gene. Later (1939) v. Witsch (108) pointed out that reciprocal crosses did not always give the same ratios.

In 1939 Levan also studied the genetic aspects of variegation (53). He classified colored petunias into three categories: constant self-colored, indifferent and pattern forms. In a series of self-colored x patterned crosses only 11 variegated were observed out of 5567 F_2 plants. When the hybrids were backcrossed to the patterned parent, the ratio became 273 out of 1971. He demonstrated that x-ray induced variegation could be inherited. Levan concluded that flecking was not due to unstable genes and that variegation was due to at least four or five polymorphic genes.

In 1941 Dale (22) reported on some experiments he had conducted. In his work with flecking he thought it was a simple recessive, but due to self incompatability he was unable to check it. In another paper (1942) (23) he described a broken variegation which appeared to be a recessive monogenic character in purple-flowered strains, but not in pink-flowered strains. Green-edged flowers occasionally segregated from broken variegated lines. Green edge x broken variegated gave 19 per cent broken variegated hybrids. His plants may have had tobacco mosaic virus.

Much of the above genetic work was done with wild or near wild material. Little has been published on the genetics of flower color in improved varieties. The reason may be due to the fact that considerable work has been done on self incompatibility in petunia. Stout (94) gives an excellent review of these studies. It is probable that these investigations made subsequent workers hesitate before tackling problems with petunias. By continued reselection petunia breeders have considerably reduced the uncertainty due to this aspect. In this study very little self sterility was encountered.

In 1922 Vavilov (100) propounded his law of homologous variation stating that similar mutations frequently occur in different species. At first, his law was limited to related plants, but later observations (101) permitted him to extend it to cover unrelated species by modifying it to include parallel variation. Therefore, a survey of the literature on flower color genetics was begun to study gene interactions that might have analogues in petunia. To assist this study one or more line charts as developed by Haney (37) were drawn for each species. A total of 62 charts on 52 species were prepared, showing 310 different color factors. Most pattern factors were omitted.

It soon became apparent that genes of similar action were present. In the final analysis about two-thirds of the factors identified could be placed in one of the eight classes listed below. In some cases the dominance

was reversed. The designations given the various genes are almost as varied as the number of factors. Confusion could be avoided if there were standard rules governing the naming of genes. The practice of naming a gene for its recessive phenotype seems to have the widest acceptance. By using this procedure the gene designations and their actions for the eight categories would be:

C - gives white; cc permits color.

W - permits color; ww gives white.

Iv - gives non ivory; iviv gives ivory.

Y - gives non yellow; yy gives yellow.

B - gives purple or magenta; bb gives blue.

R - gives purple or magenta; rr gives rose, red, or pink.

Dil - intensifies color; dildil dilutes it.

Int - dilutes color; intint intensifies it.

A summary of known flower color genetics in which three or more genes have been identified is given in Table I. Since the chart accounts for all phenotypes, completeness of each paper is ascertained when the information is charted. With seven genes and complete dominance there are 128 possible phenotypes. Without epistasis each additional gene doubles the size of the chart. Sometimes more factors had been identified than were practical to chart. In these cases, these genes are given by the second number in column 3. Completeness of the information for the charted factors only,

is given in the recombination columns. Analogous genes of each species are listed under appropriate categories. The few genes with dominance reversed are designated by an asterisk.

TABLE I

Summary of Known Flower Color Genetics

Family and Species	Citation	Number of Genes	Recombinations		Analogous Genes Identified								Other Genes	Remarks
			Given	Not Given	C	W	Iv	Y	B	R	Dil	Int		
IRIDACEAE														
Freesia hybrida	69	5-6	72	0							A, A_1	Y	M, Y_1, L, I, S, S_1, P, P_1	Y and Y_1 are incompletely dominant
ORCHIDACEAE														
Spathoglottis spp.	92	3-0	8	0			P				T		B	
PORTULACACEAE														
Portulaca grandiflora	43	4-0	13	3		C		B					G, R	
CARYOPHYLLACEAE														
Dianthus caryophyllus	63	6-0	64	0			Y	I		R	S		A, M	
RANUNCULACEAE														
Aquilegia vulgaris	80	3-0	12	0			A			B	L			A has 3 alleles
Aquilegia hybrida	9, 90	3-0	10	2			R	F					Y	R has 3 alleles
Delphinium orientale	6	5-0	25	7			E		D	B	A		C	
Nigella damascena	97	4-0	12	4		X	H	I*					K	
PAPAVERACEAE														
Eschscholtzia californica	25	3-0	8	0		R					V		I	Anthocyanins
		5-0	30	2		B					K, M		J, O	Carotinoids
Papaver alpina	27	4-0	14	2		A					D	F	O	
Papaver nudicaule	26	5-0	32	0	C						D		W, O, R	
Papaver Rhoeas	71	7-1	91	37						P*	B, C, F	T	I, E, W	
Papaver somniferum	52	4-0	16	0						P*	L		M, R	
Papaver somniferum	64	5-0	32	0	H	S	B			R*			I	

TABLE I Continued

Family and Species	Citation	Number of Genes	Recombinations Given	Recombinations Not Given	Analogous Genes Identified C	W	Iv	Y	B	R	Dil	Int	Other Genes	Remarks
CRUCIFERAE														
Cheiranthus Cheiri	30	4-0	16	0				C, R		P			Y	
Matthiola incana	98	5-0	32	0		A_1, A_2, A_3				B	C			
Matthiola incana	8	5-0	30	2		C, R				B	V	P		
Matthiola incana	20	5-0	48	0		C, R	W			B	V			W has 3 alleles
Matthiola incana	81, 82	8-0	256	0		A, A', C, R				B	V	P	Mo	
LEGUMINOSAE														
Cajanus indicus	15	5-0	32	0				P					A,C,V,E	
Lathyrus odoratus	5, 84	8-4	211	45		C, R			D	E			M,Co, K, Sm, Br,Dw,P, H	
Lathyrus odoratus	10	3-0	6	2						E			K, Co	
Lupinus angustifolius	36	4-0	14	2		R			B*	V	F			
Pisum sativum	31	5-0	31	1		A	A_m			A_p			A_r, B	
Pisum sativum	103	3-0	8	0		Aw					Ce		Cr	
TROPAEOLACEAE														
Tropaeolum majus	67, 95	7-2	256	32				A			T, R, P, Q		M, C, X, Y	T and M are incompletely dominant
LINACEAE														
Linum usitatissimum	87,96	7-0	125	3		B, C					E	N	F, D, K	
BALSAMINACEAE														
Impatiens Balsamina	74	4-0	15	1		A			R	B			F	
Impatiens Balsamina	7	3-0	8	0		P				M	R			
Impatiens Balsamina	46	5-0	28	4		W				R	D, S		P	
MALVACEAE														
Gossypium spp.	42, 88	4-0	76	6				Y*				Ydp	R_2, R_3	

Family and Species	Citation	Number of Genes	Recombinations Given	Recombinations Not Given	Analogous Genes Identified C	W	Iv	Y	B	R	Dil	Int	Other Genes	Remarks
VIOLACEAE														
Viola hybrida	17, 18, 19	11-2	4096	0				L*		R		M_1, M_2, M_3, M_4, M_5	D, W, V, A_1, A_2, A_3	
OENOTHERACEAE														
Clarkia elegans	74	4-0	11	5		A							B, C, D	
PRIMULACEAE														
Cyclamen persica	85, 86	7-0	128	0	F, S	W	E					I, C	M	
Primula acaulis	14, 84	4-0	11	5	G		B	Y*	S					
Primula sinensis	105	6-0	64	0					R	K, B	V		G, D	Diploid
Primula spp.	29	3-0	8	0				R_1	R				P	
CONVOLVULACEAE														
Ipomoea purpurea	1	5-0	30	2		C, R					I		B, X	
Ipomoea purpurea	44	4-0	48	0		R					S, U	D		R and U incompletely dominant
Pharbitis Nil	33, 34, 35, 45	11-14	4096	0	H^1, H^2	C_a, C, R			P*	M_g	Lt^1, Lt^2, Tg, Fd	I, D	D_k, D_y, Sp, Sp-r, Ry, Sa, Fl, Fd^s, Bz_1, Bz_2, F^a, F^b	
POLEMONIACEAE														
Phlox Drummondii	47	7-1	110	18	W	A, E				B	D		P, R, M	
HYDROPHYLLACEAE														
Nemophila atromaria	16	4-2	16	0									A, B, C, M, S, U	
Nemophila liniflora	16	3-0	8	0		C							S, P	
VERBENACEAE														
Verbena hybrida	3, 4	4-2	28	8		A		Ye					P, M, U, D	M and P each have 3 alleles
LABIATAE														
Galeopsis bifida	70	4-3	32	0			R	G*			D, E		C, I, K	R has 4 alleles

TABLE 1 Continued

Family and Species	Citation	Number of Genes	Recombinations Given	Recombinations Not Given	Analogous Genes Identified C	W	Iv	Y	B	R	Dil	Int	Other Genes	Remarks
LABIATAE														
Galeopsis tetrahit	70	3-2	12	6								H	A, R, I, F	H and R each have 3 alleles
SOLANACEAE														
Nicotiana spp.	79	6-2	56	8		F				C*	I_1, I_2		P, R, N, T	
SCROPHULARIACEAE														
Antirrhinum majus	2	7-0	128	0		B	F	C			S, Pal_3		D, A	
Antirrhinum majus	61	6-0	60	4		Y	L	I		P	D		T	
Antirrhinum majus	37, 38	5-0	32	0		W	Iv	Y		Dil_p	Dil_1			
Digitalis purpurea	8, 32	4-0	15	17			F	C		Pal_2	Pal_1			Pal_1 has 4 alleles
Mimulus cardinalis	12, 13	3-0	18	0			R						P, C	C and R are incompletely dominant
Nemesia strumosa	75, 76, 77	7-0	232	24				Y		O			C, Gl, Bi, Bu, P	O has 4 alleles
Verbascum phoenicum	48	4-0	16	0			R			V	C		E	
GESNERIACEAE														
Streptocarpus spp.	51	4-0	16	0			A		O*				D, R	
CAMPANULACEAE														
Campanula medium	49	4-0	16	0		A, R				B	V			
COMPOSITAE														
Callistephus chinensis	106	7-0	160	128		W			I	R	Pa, w^d S, X		M	R and W each have 3 alleles
Centaurea cyanus	62	3-0	8	0						A			B, C	
Cosmos bipinnatus	65, 66	6-0	64	0		C					S, I		E, P, Q	
Dahlia variabilis	50	5-0	200	0			I*				B		A, H, Y	Tetraploid
Helichrysum bracteatum	24	3-0	8	0	W						A		S	
Zinnia elegans	72	5-4	80	0			C				Pr, Sr, I		A, S, Y, Yp, Sp	S has 5 alleles

See text for explanations

MATERIALS AND METHODS

The wide range of colors found in present day petunia varieties is a great departure from the two colors, white and violet, present in the two original parental species. The purpose of this investigation is to determine how these various colors are inherited.

Most of the petunias used in this study were grown in the Plant Science greenhouse of Michigan State University. To facilitate pollination and other work involved in production of petunia seed, dwarf small-flowered diploid races were used wherever possible. Normally, these have better pollen, more seeds per capsule, and are dwarfer and less easily broken. The parent plants were grown in 4-inch clay pots, and fertilized at regular intervals. All pollinations were made in a screened greenhouse to reduce the possibilities of insect contamination. At time of emasculation most of the corolla was removed to further reduce the hazard due to stray insects. All flowers used for crossing were tagged with small white price tags. All populations were flowered in 3-inch clay pots.

In any study such as this, the problem of color nomenclature is of utmost importance. Since the publication of the Horticultural Colour Chart (11) this job has been less difficult. However, even this has its limitations; the names used in the chart do not correspond to those in use in this country. For example, 'salmon' is a popular shade in many flowers, yet this is called rose in the chart and what is popularly called deep rose becomes purple; so the

color names used by the seed trade are given with the H. C. C. number to which each corresponds in parenthesis after the name. All color determinations were made in the dark room under photoflood lights to ensure uniform illumination.

Petunia colors can be grouped into several classes. These classes, as well as the parents used in each class, seed source, and H. C. C. number are given in Table II.

One of the first projects was to intercross all whites to see if more than one type of white is present in petunia. The next proposal undertaken was to cross at least one in each color class to every other color. "Selfed" seed was harvested from the F_1 plants for F_2 generations, and the hybrid was backcrossed to both parents. For backcrosses, approximately 64 plants were grown, while F_2 populations contained about 200 plants. When space permitted, 30 plants were grown of the F_1 generation to check the color uniformity adequately.

In segregating populations the plants were first separated into all distinguishable colors. Each of these was designated by a letter. The color, amount of corolla veining, type of corolla edges, throat color, color and amount of throat veining, and pollen color were recorded for each plant. To facilitate note-taking, a number code was used. A newly opened bloom from each color was matched with the Horticultural Color Chart. All determinations were made on greenhouse grown plants. Most colored flowers faded

TABLE II

Petunia Parents Used in This Study

Color Class	Parent	Source	Horticultural Color Chart Number
White	Popcorn	George J. Ball Seeds, Inc.	
White	Snowball	Vaughans Seed Store	
White	White Perfection	George J. Ball Seeds, Inc.	
White	Snowstorm	Vaughans Seed Store	
Cream	Cream Star	Pan American Seeds, Inc.	
Cream	Moonbeam	W. Atlee Burpee Co.	601/3
Salmon	Salmonet	George J. Ball Seeds, Inc.	022
Salmon	Bright Mid Salmon seedling (W131-1-7)	Selection from Winsome x Mid Salmon seedling F_2	024/1
Salmon	Salmon and White variegated seedling	W. J. Haney	0625
Scarlet	Bright Light Scarlet seedling (T214-2-112)	Selection from Twinkles x Light Scarlet seedling F_2	721/1
Scarlet	Deep Bright Scarlet seedling (1062)	Pan American Seeds, Inc.	820/3
Light Rose	Winsome	Pan American Seeds, Inc.	26/1
Light Rose	Celestial Rose	George J. Ball Seeds, Inc.	26/1
Deep Rose	Robin	George J. Ball Seeds, Inc.	25
Deep Rose	Coronet	George J. Ball Seeds, Inc.	25 (Dull)
Deep Rose	Glow	George J. Ball Seeds, Inc.	025
Deep Rose	Lipstick	Vaughans Seed Store	727
Silver Blue	Silver Blue seedling (43s-6-7)	Pan American Seeds, Inc.	637/2
Mid Blue	Heavenly Blue	George J. Ball, Seeds, Inc.	636
Mid Blue	Blue Seedling (6D-21a)	Pan American Seeds, Inc.	637
Violet Blue	Burpee Blue	W. Atlee Burpee Co.	934/1
Violet Purple	Dark Purple (Harris Purple)	Joseph Harris Co., Inc.	937
Crimson	King Henry	George J. Ball Seeds, Inc.	931 (near)

about one H. C. C. unit before withering. Thus, if a deep rose was number 25 at anthesis, it would usually be 25/1 before it fell. Occasionally it faded two units. Only rarely did the older flowers change to a different color category. Some bluing occurred in some shades of rose. In variegated flowers, the color of the pigmented portion was used and the plant was placed in that color class.

Selected plants from each lettered color were arranged from light to deep within their appropriate classes. For the F_2's, the populations were not large enough to permit fitting them to a genetic ratio of more than four factors; consequently, some of these related colors had to be combined in order to fit them to such a proportion. After several populations had been analyzed genetically the gene actions became apparent so that the genes could be recognized. Later, the genotypes of the phenotypes were critically compared. Finally, a six factor line chart was drawn to show the interaction of the six major genes.

RESULTS AND DISCUSSION

The intercrossing of various white commercial varieties gave all white hybrids and nothing but whites in the next generation. Colors of the F_1 hybrids are given in Table III. A study of this table will reveal a weakness of the Horticultural Color Chart. Matching a rose or salmon with the correct shade is comparatively easy, but in blues, purples, and violets there are gaps in the charts that make classification difficult. In the backcross (King Henry x Harris Purple) x King Henry (Cross 66) all of the five colors that were distinguished had to be called Dahlia Purple (931). The prefix "near" is used to designate those colors that could not be accurately matched with the Chart. These are distinguished by appropriate color adjectives in the appendix.

One accepted practice is to name a gene for a distinctive recessive phenotype. A more recent concept is to name it for the chemical action it controls, but in the petunia no work has been published on the genetico-chemical action of flower color genes; so the first practice was followed. It is probable that when the biochemistry of these factors has been worked out they should be renamed. Wherever possible the designations for the eight categories in Table I were used. The genes identified in this study are given in Table IV.

The Iv factor is analogous to the common color precursor gene in a wide variety of plants. It appears to be the W gene of Mather and Edwardes (60)

TABLE III

Color of the Petunia F_1 Hybrids

Color	Cream	Salmon	Scarlet	Light Rose	Deep Rose	Crimson	Silver Blue	Blue	Violet Blue	Violet Purple
White	Cream (601/3)	Magenta (632/1)	Light Rose (632/2)	Light Lilac Rose (630)	Dilute Rose (29/2)	Dull Crimson Purple (31)	Light Magenta (632)	Magenta (633)	Magenta (633)	Deep Purple (near 732)
	Cream	Light Rose (627)	Light Rose (629)	Light Rose (629)	Seed	Magenta Purple (near 732)	Lilac Veined Deeper (533)	Seed	Blue Magenta (35)	Deep Magenta (near 732)
		Salmon	Salmon Red (021)	Light Rose (629)	Deep Rose (025)	Crimson (near 827)	Magenta Purple (near 732)	Orchid (32)	Purple Magenta (834/1)	Red Purple (near 934/1)
			Scarlet	Mid Rose (26/1)	Deep Rose (025/1)	Crimson (near 827)	Magenta Purple (near 732)	Rose Orchid (729)	Magenta (near 733)	Purple Magenta (733)
				Light Rose	Deep Rose (25)	Rose Purple (830)	Red Purple Magenta (31)	Light Magenta (632)	Magenta (near 733)	Red Purple (31)
					Deep Rose	Crimson Purple (near 931)		Magenta Purple (near 732)	Seed	Magenta Purple (near 732)
						Crimson	Seed	Magenta Purple (near 732)	Deep Magenta Purple (near 931)	Red Violet Purple (near 937)
							Silver Blue	Magenta Blue (35)	Violet Blue (934/1)	Deep Violet Blue (near 934)
								Blue		Deep Magenta (834)
									Violet Blue	Deep Violet Blue (near 934)
										Violet Purple

TABLE IV

Description of the Identified Petunia Flower Color Genes

Gene	Analogous Genes	Distinctive Phenotypes: Recessive	Distinctive Phenotypes: Dominant	Identified from the Crosses Given in the Appendix
Iv(ory)	Table I-Iv	White or Cream Bluish Veined with Cl—R-in_2in_2	Colored	19, 23, 25, 34, 42, 46, 47, 49, 58, 61, 62
Cl(ear Color)	See Text	Clear colors with ss	Grayed colors with ss	3, 4, 12, 13, 14, 15, 18, 21, 22, 23, 24, 27, 31, 33, 35, 36, 40, 42, 43, 46, 48, 54, 55, 56, 57, 63, 64
R(ose)	Table I-R	Rose with S- Salmon with ss	Magenta See Text	1, 3, 4, 5, 7, 10, 12, 13, 14, 15, 16, 18, 21, 23, 26, 27, 31, 33, 35, 36, 44, 46, 47, 54, 56, 57, 60, 61, 64, 65, 66, 68
S(almon)	See Text	Salmon with rrclcl Violet Purple with B_1--b_2b_2R-	Rose with rr	1, 3, 4, 5, 6, 7, 8, 19, 20, 21, 28, 30, 34, 40, 44, 45, 49, 50, 51, 52, 54, 55, 60, 63, 64, 65
B(lue)$_1$	Table I-B	Violet Blue with b_2b_2R-ss	Violet Purple with b_2b_2R-ss	1, 3, 4, 5, 8, 9, 10, 12, 16, 17, 19, 21, 22, 26, 27, 28, 31, 33, 34, 39, 46, 47, 48, 51, 61, 62, 65
B(lue)$_2$	Table I-B	Blue with b_1b_1R-S- Violet Purple with B_1--R-ss	Scarlet with B_1--rrssclcl	3, 4, 7, 11, 14, 16, 17, 25, 26, 31, 32, 35, 37, 40, 41, 54, 56, 58, 59, 61, 62, 65
Dil(ute)	Table I-Dil	Dilutes color	Intense color	2, 6, 25, 34, 38, 40, 42, 48, 51, 53, 63
Int(ense)$_1$	Table I-Int	Intense color	Dilute color	5, 6, 7, 8, 10, 11, 14, 16, 18, 19, 20, 22, 24, 26, 30, 32, 39, 43, 44, 45, 47, 48, 49, 50, 52, 55, 59, 63
Int(ense)$_2$	Table I-Int	Intense color Bluish Veined with Cl--R-iviv	Dilute color	1, 5, 6, 8, 9, 12, 13, 14, 15, 17, 20, 24, 27, 28, 29, 35, 36, 39, 40, 41, 49, 50, 51, 55, 56

and probably Malinkowski's A (55). The W designation was not retained because its action is more like those listed under the Iv category in Table I. The W genes permit color only if a dominant allele is present, while the Iv gene in petunia cuts out all the reds but at times it only dilutes the blues. The terms 'ivory' and 'cream' are used for the same color. The name used depends on the flower. It so happens that cream is commonly used in petunia. Perhaps the symbol Cr should have been used; but a gene of similar action has previously been named Iv in the snapdragon (37) and I in the dahlia (50). To avoid possible confusion the designation Iv was given this factor.

Under certain conditions iviv is epistatic. In two crosses, Harris Purple x White Perfection (cross 34) and Snowball x Bright Light Scarlet (cross 49) the non creams to the cream gave very low chi squares, but in Moonbeam x Bright Light Scarlet (cross 19) there were only 11 creams against an expected 22.2 which is a significant difference. Moonbeam has given several aberrant ratios in this study. There may be more than one explanation for this deviation. This is one of the few large flowered varieties used in this study. It was also one of the few self incompatable strains. Repeated self pollinations on several individuals produced no seed. This case may be similar to that of Mather and Edwardes (60) who suggested that some of their observed inconsistencies were due to selective fertilization of pollen tubes. In the backcross (Moonbeam x White Perfection) x Moonbeam both cream and large-flowered classes were deficient. Only three creams, two of which

were large flowered, were observed in 65 plants. Only one other large flowered plant was present. Large flowered petunia seed germinates more slowly than the small flowered. It may be that there is a linkage between cream and large flowers and that when the plants were pricked out, the more vigorous small flowered seedlings were chosen. More work will have to be done before a conclusion can be reached.

The iviv genotypes will act as a blue dilutor if R-Cl--in_2in_2 are also present. Under these conditions the color is lavender, lilac, or rose pink with prominent veins on the corolla blade. If S- is also present, the veins are purple or violet, while if the plant is ss, they are red. The Silver Blue seedling proved to be iv iv. As a proof of this, cream appeared in the F_2's of both Winsome x Silver Blue (Cross 61) and Silver Blue x Bright Light Scarlet (Cross 54).

The Cl factor has no analogous genes that have been identified. However, D_k in Pharbitis Nil (35), M in the Chinese Primrose (105), and R in the China Aster (106) have similar action, but with the dominance reversed. This graying is very pronounced in certain petunia populations. This phenomenon is known in other flowers where it has been variously called 'slaty', 'smoky', or 'grayed'. This color seems to be very closely linked with an imperfectly opened corolla. Only one normal flower was observed in 116 grayed lilac (0027/2) and grayed salmon (027/2) flowered plants. This abnormality is less pronounced in grayed rose shades (030 to 033).

The S factor is analogous to M in Carnation (63), V in California Poppy (25), Sm in Sweet Pea (5), and R in Streptocarpus (51).

In the F_2 of Snowball x King Henry (Cross 44) crimson appeared to be dominant over magenta. At the time the possibility that this gene might be an allele of R was advanced. Subsequent investigation showed that King Henry was ss. This being so, if the variety was RR, then when it was crossed with a salmon or scarlet which is rrss, magenta purple, violet blue, or violet purple should segregate from the F_2. Violet purple, as will be shown later, differs from the crimson at the R locus only. Conversely, if King Henry was rr, when it was crossed with a plant containing RR, the F_2 should contain salmon or scarlet, since recombinations that produce these colors would be possible. No magenta purple, violet blue, or violet purple was observed in the following crosses; King Henry x Salmonet and both backcrosses (Crosses 10, 11 and 12); King Henry x Bright Light Scarlet backcrossed to Bright Light Scarlet (Cross 13); and King Henry x Deep Bright Scarlet and both backcrosses (Crosses 14, 15, and 68). A total of 699 plants were examined. Likewise, no salmon or scarlet was observed in the 863 plants from the crosses Snowball x King Henry and both backcrosses (Crosses 44, 45, and 46); Harris Purple x King Henry backcrossed to both parents (Crosses 66 and 67); and King Henry x Heavenly Blue and the backcross to Heavenly Blue (Crosses 8 and 9). From these data the most plausible conclusion would be that the gene causing the crimson color is on the R locus. This factor has been designated R^C. Not

all the manifestations of this gene have been worked out.

After analyzing the F_2 crosses and backcrosses, the genotypes of the parents were worked out. The parents of the crosses from the Pan American Seeds, Inc. are included, although in some cases these parents were never grown at Michigan State University. All proved to be homozygous; so only the haploid genotype is given in the following list:

Snowball - $ivb_1B_2RSc1In_1In_2dil$ (a few are r)

White Perfection - $ivb_1b_2RSC1In_1In_2dil$

Moonbeam - $ivB_1b_2rSclIn_1In_2dil$

Mid Salmon seedling (PA131) - $Ivrsclin_1Dil$

Bright Mid Salmon seedling (W131-1-7) - $Ivrsclin_1$

Salmonet - $Ivb_1B_2rsclIn_1in_2Dil$

Salmon and White Variegated seedling - $Ivb_1B_2rsclIn_1In_2Dil$

Light Scarlet seedling (PA214) - $Ivrsclin_1in_2$

Bright Light Scarlet seedling (T214-2-112) - $Ivb_1B_2rsclin_1in_2Dil$

Deep Bright Scarlet seedling (PA1062) - $IvB_1B_2rsclin_1in_2Dil$

Twinkles - $IvrSClIn_1In_2$

Winsome - $IvB_1B_2rSClIn_1in_2dil$

Celestial Rose - $Ivb_1B_2rSclIn_1in_2dil$

Robin - $IvB_1B_2rSclIn_1In_2dil$

Coronet - $Ivb_1rSIn_1in_2$

Glow - $IvrSin_1in_2dil$

Lipstick - $IvB_1B_2rSclin_1In_2dil$

Silver Blue seedling (PA43s-6-7) - $ivb_1b_2RSClIn_1in_2dil$

Blue seedling (PA6D-21a) - $Ivb_1b_2RsClin_1In_2Dil$

Heavenly Blue - $Ivb_1b_2RSClIn_1in_2Dil$

Burpee Blue - $IvB_1b_2RSClin_1In_2dil$

Violet Purple seedling (PASSRP) - Ivb_2Rin_1Dil

Harris Purple - $IvB_1b_2RsClin_1In_2Dil$

King Henry - $IvB_1b_2R^CsClin_1In_2Dil$

It is probable that many of the missing genes could be filled in; but this has been done in only a few cases where the status is obvious; e.g., rs in salmons and scarlets. In all other cases there has been at least one verification for each assumption. It was deemed impractical to include all the data to support the conclusions in the body of the thesis. These will be given in the appendix. A resume of all the crosses is given in Table V. This gives the number of color classes distinguished, chi square, and probability for each cross. It also tells the status of each gene.

TABLE V

Summary of the Petunia Crosses

Appendix No.	Cross	Classes	x^2	P more Than	Status of the Genes								
					Iv	B_1	B_2	R	S	Cl	In_1	In_2	Dil
1	Burpee Blue x Salmonet	15	8.574	.80	D	s	u	s	s	u	u	s	u
2	(Burpee Blue x Salmonet) x Burpee Blue	4	3.566	.30	D	D	s	D	D	D	s	D	s
3	(Burpee Blue x Salmonet) x Salmonet	11	3.378	.95	D	s	D	s	s	s	D	u	D
4	Burpee Blue x Bright Light Scarlet	25	30.302	.10	D	s	s	s	s	s	r	u	u
5	Coronet x Harris Purple	15	4.640	.99	D	s		s	u		s	s	
6	Glow x Bright Light Scarlet	11	1.978	.99	D			r	s		s	s	s
7	Heavenly Blue x Bright Light Scarlet	15	16.866	.20	D	r	s	s	s	u	s	r	u
8	King Henry x Heavenly Blue	14	16.203	.20	D	s	r	u	s	D	s	s	D
9	(King Henry x Heavenly Blue) x Heavenly Blue	3	1.985	.30	D	s	r	u	D	D	D	s	D
10	King Henry x Salmonet	8	3.287	.80	D	s	u	s	r	u	s	u	D
11	(King Henry x Salmonet) x King Henry	2	.197	.50	D	D	s	D	r	D	s	D	D
12	(King Henry x Salmonet) x Salmonet	7	3.174	.70	D	s	D	s	r	s	D	s	D
13	(King Henry x Bright Light Scarlet) x Bright Light Scarlet	6	4.848	.30	D	u	D	s	r	s	r	s	D

TABLE V Continued

Appendix No.	Cross	Classes	x^2	P more Than	Status of the Genes								
					Iv	B_1	B_2	R	S	Cl	In_1	In_2	Dil
14	King Henry x Deep Bright Scarlet	11	11.061	.30	D	D	s	s	r	s	r	s	D
15	(King Henry x Deep Bright Scarlet) x Deep Bright Scarlet	6	3.750	.50	D	D	D	s	r	s	r	s	D
16	Lipstick x Heavenly Blue	10	4.398	.80	D	s	s	s	D	u	s	u	u
17	(Lipstick x Heavenly Blue) x Heavenly Blue	7	2.201	.90	D	s	s	D	D	D	D	s	D
18	(Lipstick x Heavenly Blue) x Lipstick	6	1.778	.80	D	D	D	s	D	s	s	D	u
19	Moonbeam x Bright Light Scarlet	9	11.730	.10	s	s	u	r	s	r	s	u	u
20	(Moonbeam x Bright Light Scarlet) x Bright Light Scarlet	6	5.937	.30	D	u	D	r	s	r	s	s	u
21	Moonbeam x Blue Seedling	14	7.143	.80	u	s	r	s	s	s	u	D	u
22	(Moonbeam x Blue Seedling) x Blue Seedling	6	.849	.95	D	s	r	D	u	s	s	D	D
23	(Moonbeam x Blue Seedling) x Moonbeam	4	1.258	.70	s	D	r	s	D	s	D	D	u
24	(Moonbeam x Deep Bright Scarlet) x Deep Bright Scarlet	8	7.164	.30	D	D	D	r	s	s	s	s	D
25	(Moonbeam x Deep Bright Scarlet) x Moonbeam	4	.891	.80	s	D	s	r	D	D	D	D	s
26	Harris Purple x Celestial Rose	12	9.840	.50	D	s	s	s	u	u	s	u	u
27	(Harris Purple x Celestial Rose) x Celestial Rose	8	.666	.99	D	s	D	s	D	s	D	s	u
28	Harris Purple x Heavenly Blue	7	10.008	.10	D	s	r	D	s	D	u	s	D

TABLE V Continued

Appendix No.	Cross	Classes	x^2	P more Than	Status of the Genes								
					Iv	B_1	B_2	R	S	Cl	In_1	In_2	Dil
29	(Harris Purple x Heavenly Blue) x Heavenly Blue	4	6.124	.10	D	u	r	D	D	D	D	s	D
30	(Harris Purple x Heavenly Blue) x Harris Purple	4	2.430	.30	D	D	r	D	s	D	s	D	D
31	Harris Purple x Salmon and White	14	11.402	.50	D	s	s	s	r	s	u	D	D
32	(Harris Purple x Salmon and White) x Harris Purple	3	1.714	.30	D	D	s	D	r	D	s	D	D
33	(Harris Purple x Salmon and White) x Salmon and White	6	4.097	.50	D	s	D	s	r	s	D	D	D
34	Harris Purple x White Perfection	9	5.370	.70	s	s	r	D	s	D	u	D	s
35	Harris Purple x Deep Bright Scarlet	14	24.632	.02	D	D	s	s	r	s	r	s	D
36	(Harris Purple x Deep Bright Scarlet) x Deep Bright Scarlet	8	3.564	.80	D	D	D	s	r	s	r	s	D
37	(Harris Purple x Deep Bright Scarlet) x Harris Purple	3	.155	.90	D	D	s	D	r	D	r	D	D
38	(Robin x Bright Light Scarlet) x Robin	2	.164	.50	D	D	D	r	D	r	D	D	s
39	(Robin x Bright Light Scarlet) x Bright Light Scarlet	8	6.330	.30	D	s	D	r	s	r	s	s	D
40	Snowball x Heavenly Blue	8	3.910	.70	u	r	s	D	D	s	D	s	s
41	(Snowball x Heavenly Blue) x Heavenly Blue	4	1.405	.70	D	r	s	D	D	D	D	s	D
42	(Snowball x Heavenly Blue) x Snowball	4	.917	.80	s	r	D	D	D	s	D	D	s

TABLE V Continued

Appendix No.	Cross	Classes	x^2	P more Than	Status of the Genes								
					Iv	B_1	B_2	R	S	Cl	In_1	In_2	Dil
43	(Snowball x Heavenly Blue) x Blue Seedling	4	.541	.90	D	r	D	D	u	s	s	D	D
44	Snowball x King Henry	13	8.928	.70	u	u	u	s	s	u	s	D	s
45	(Snowball x King Henry) x King Henry	4	3.977	.20	D	D	s	D	s	D	s	D	D
46	(Snowball x King Henry) x Snowball	7	10.140	.10	s	s	D	s	D	s	D	D	u
47	Snowball x Lipstick	9	7.981	.30	s	s	D	s	D	r	s	D	r
48	Snowball x Harris Purple	9	9.068	.30	u	s	u	D	u	s	s	D	s
49	Snowball x Bright Light Scarlet	7	7.631	.30	s	r	D	u	s	r	s	s	u
50	(Snowball x Bright Light Scarlet) x Bright Light Scarlet	8	4.552	.70	D	r	D	u	s	r	s	s	D
51	Snowball x Deep Bright Scarlet	11	7.352	.50	u	u	D	u	s	r	s	s	s
52	(Celestial Rose x Bright Light Scarlet) x Bright Light Scarlet	4	1.734	.50	D	r	D	r	s	r	s	r	D
53	(Celestial Rose x Bright Light Scarlet) x Celestial Rose	2	1.554	.20	D	r	D	r	D	r	D	r	s
54	Silver Blue x Bright Light Scarlet	16	17.752	.20	u	r	s	s	s	s	u	r	u
55	Twinkles x Light Scarlet	15	17.729	.20	D			r	s	s	s	s	

TABLE V Continued

Appendix No.	Cross	Classes	x^2	P more Than	Status of the Genes								
					Iv	B_1	B_2	R	S	Cl	In_1	In_2	Dil
56	White Perfection x Celestial Rose	11	7.435	.50	u	r	s	s	D	s	D	s	r
57	(White Perfection x Celestial Rose) x Celestial Rose	3	.093	.95	D	r	D	s	D	s	D	u	r
58	(White Perfection x Celestial Rose) x White Perfection	4	2.644	.30	s	r	s	D	D	D	D	D	r
59	Winsome x Violet Purple seedling	15	15.431	.30	D		s	s			s		s
60	White Perfection x Salmon and White	13	13.454	.30	u	r	u	s	s	u	D	D	s
61	Winsome x Silver Blue	12	9.578	.50	s	s	s	s	D	D	D	r	r
62	(Winsome x Silver Blue) x Silver Blue	7	2.083	.90	s	s	s	D	D	D	D	r	r
63	Winsome x Mid Salmon	9	11.453	.10	D			r	s	s	s		s
64	(Bright Mid Salmon x Silver Blue) x Bright Mid Salmon	8	3.500	.80	u			s	s	s			
65	Blue Seedling x Deep Bright Scarlet	13	5.721	.90	D	s	s	s	s	r	r	u	D
66	(Harris Purple x King Henry) x King Henry	2	.266	.50	D	D	r	s	r	D	D	D	D

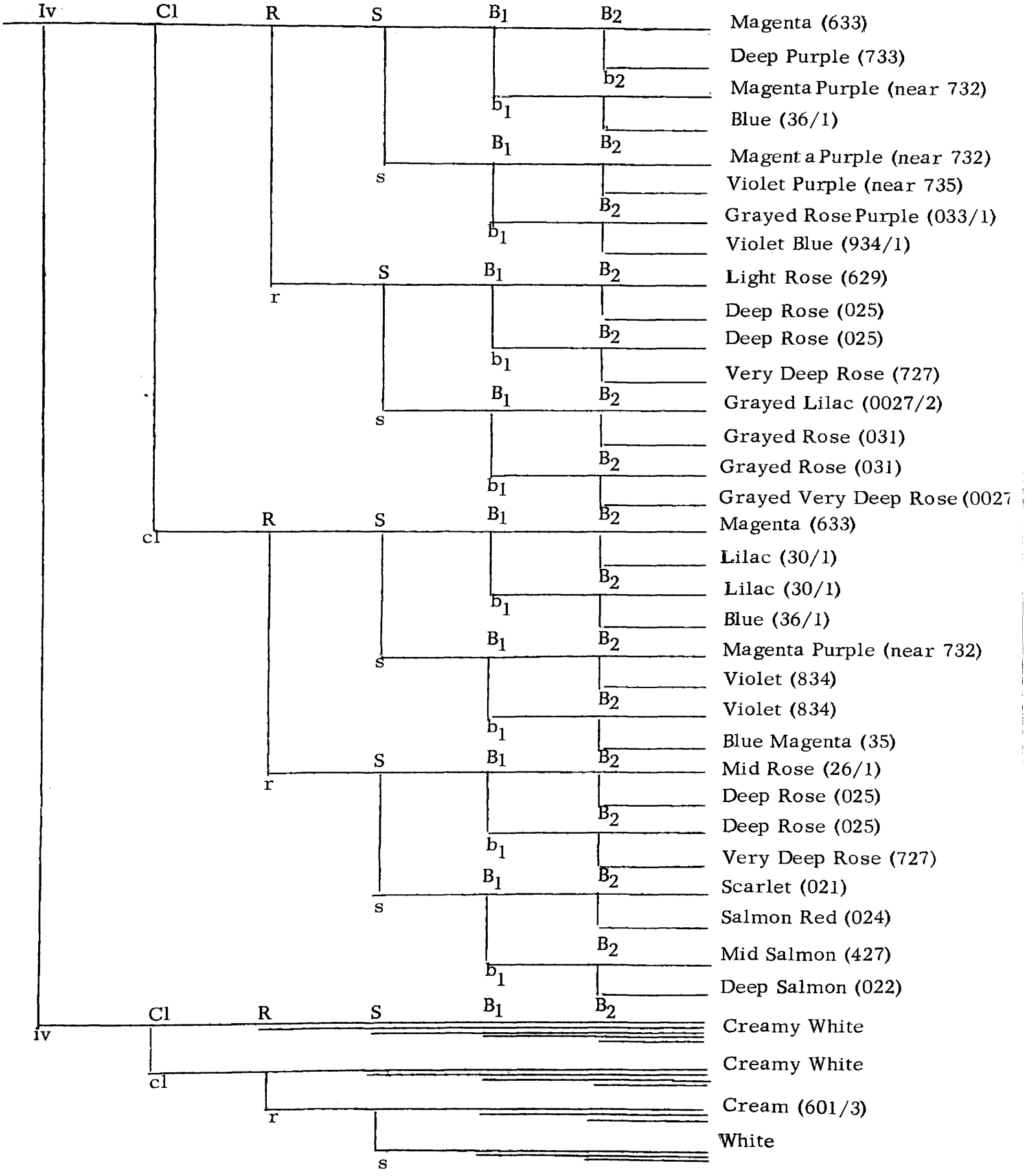
r - gene recessive in both parents
s - identified as a segregating gene
u - unidentified, but should be segregating
D - gene dominant in both parents

In any study involving two or more factors affecting the same characteristic, the gene interactions are very important. It is always possible that each genotype will have a different phenotype. When dominance is complete, the total number of phenotypes possible for any number (n) of genes is 2^n plus 2^{n-1} for each additional allele above two, if multiple allelism is present. Since in this study nine genes, one of which has three alleles, have been identified, there will be 768 possible phenotypes. To list all these would be a tremendous undertaking; so a chart has been drawn for six genes, for which all interactions have been defined.

A word of explanation may be necessary before the value of such a chart can be easily understood. The genes are listed in a horizontal line at the top of the page with the multiple dominant phenotype at the right. Any epistatic genes are placed on the left, while hypostatic genes are placed on the right. To determine the genotype of any color start at the name and read left. Any gene or genes that are on that line are dominant until the end of the line is reached, which means that that particular gene is recessive. Follow the vertical line up to the next horizontal line and read left. Continue this procedure until all the genes are accounted for. Epistasis is expressed by drawing a parallel line from the hypostatic gene to the right a short distance below the line from the epistatic gene. To illustrate from the chart in Chart I, White is ivivclclrrss with both B_1 and B_2 hypostatic and Violet Purple is Iv--Cl--R-ssB_1--b_2b_2.

CHART I

Chart of Six Genes in the Petunia



Another advantage of this chart is that the expected number for any genotype in a F_2 can be easily calculated. All dominant genes are assigned the value of 3; recessives 1; and hypostatic genes 4. The gene values are then multiplied. Thus, one could expect 16 Whites and 81 Violet Purples from a six factor segregation, such as postulated in Chart I.

As mentioned previously more than six or seven genes give an ineffective chart because it is too long; therefore, a chart for six color genes in petunia has been drawn, which is given in Chart I.

Since the three other genes are all intensity modifiers, their concerted action may alter the expression of the colors given in Chart I. Thus, in in_1-in_1-in_2-in_2 Dil--plants the magenta may become magenta purple and a deep rose can be deepened into a very deep carmine. Conversely, In_1-In_2- dil can lighten the colors. This work does not exclude the possibility of other modifiers. It was shown in Table I that in Pharbitis Nil twenty-five flower color genes have been identified. The precise phenotype for each recombination has not been determined. The influence of the In_2 factors on the iviv genotype is given in Chart II. Chart III shows the effect of the R^c, R, and r alleles on the IvB_1s in_1Dil genotype with Cl, B_2, and In_2 also segregating. Finally, Chart IV gives the effect of the S, In_1, In^2, Dil genes on a specific genotype.

CHART II

Effect of the In_2, Cl, R, B_1, and B_2 Genes on the iv, In, and dil Genotypes

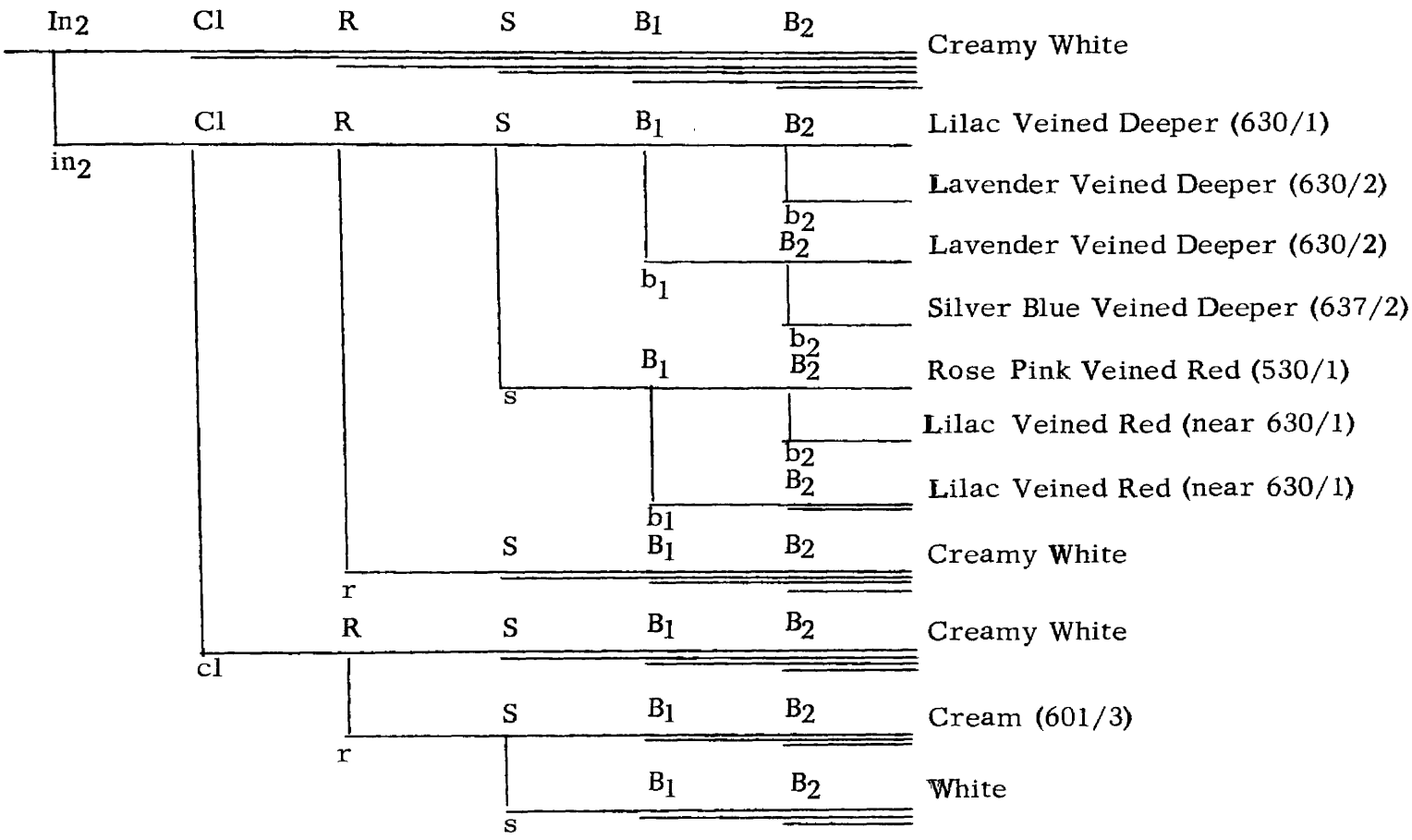


CHART III

Effect of the R^c, R, and r Alleles and the Cl, B_2 and In_2 Segregation on the $IvB_1 sin_1 Dil$ Genotype

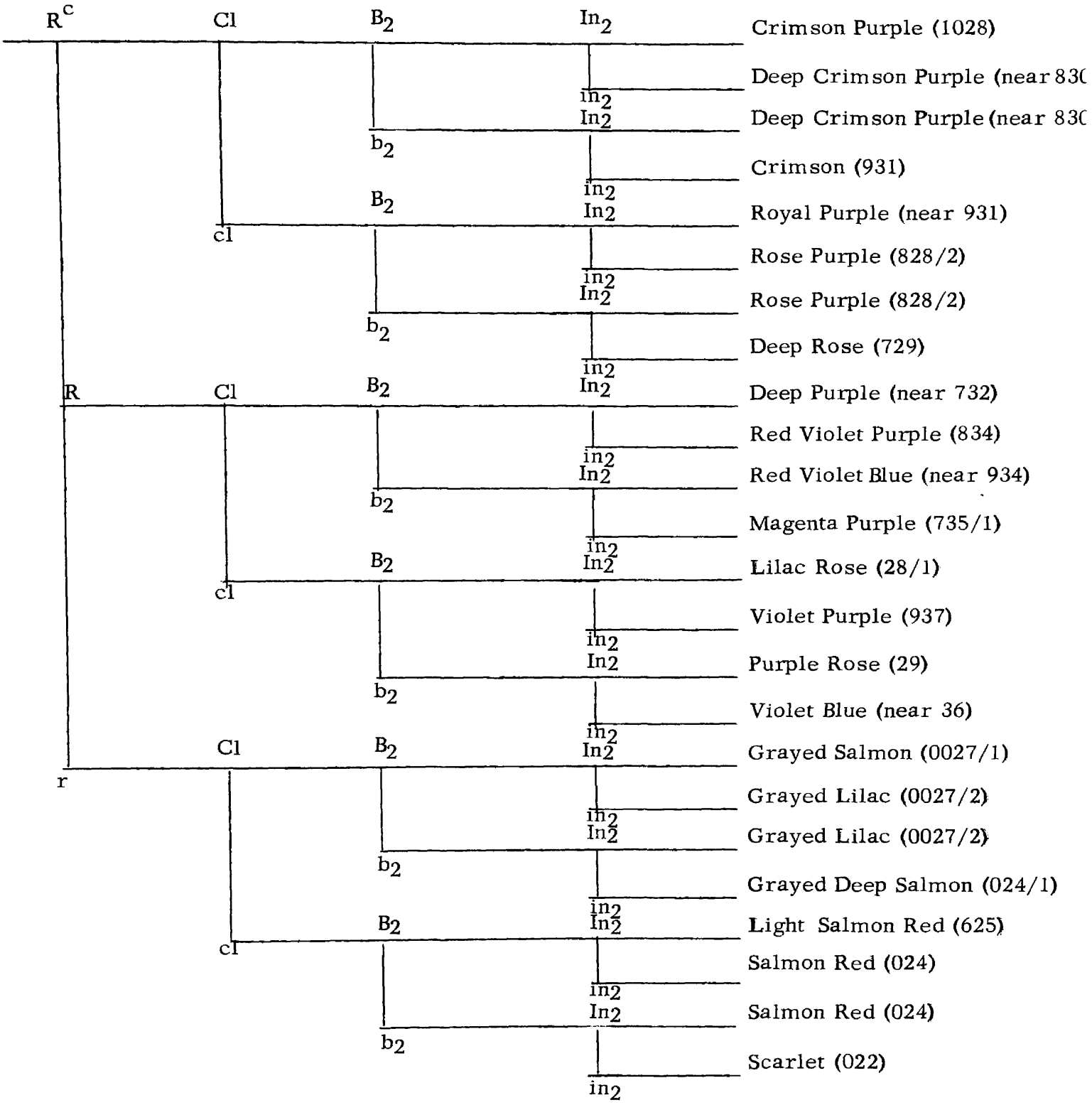
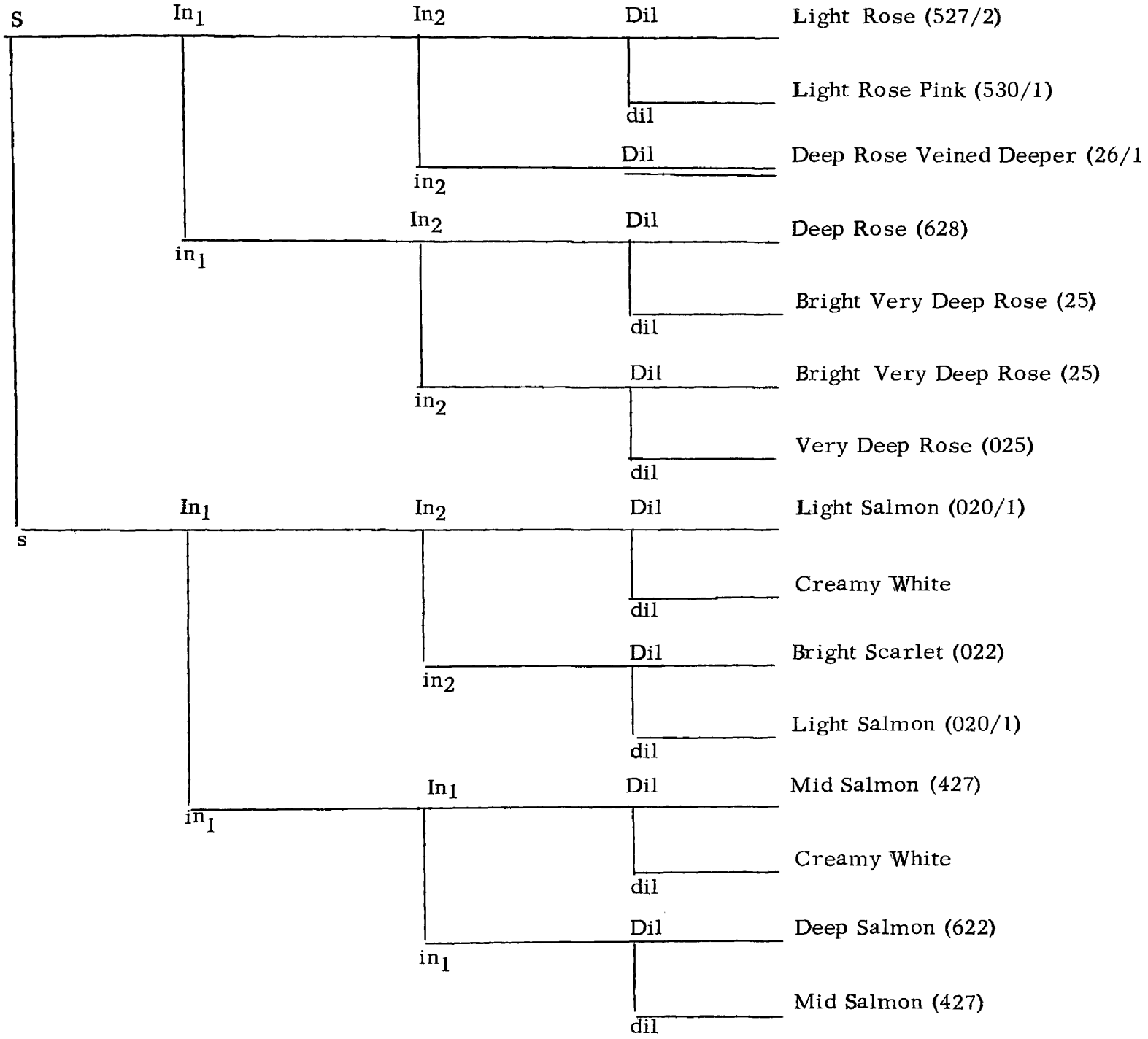


CHART IV

Effect of the S, In_1, In_2, and Dil Segregation on the Iv, b_1, B_2, r, and cl Genotypes



SUMMARY

This study was undertaken to determine the genetics of flower color in petunia. As the variegated and pattern forms are due to both genetic and physiological factors, only the inheritance of self colored flowers was studied.

The parents were divided into eleven color classes. This material is given in Table II. Each color class was crossed with all other classes, and the hybrids grown. Colors of the F_1 hybrids are listed in Table III.

Selected F_2 and backcrosses were grown and analyzed genetically. From these data nine genes were identified. These were named for their most distinctive phenotype when in a homozygous recessive condition. The genes with their actions follow:

Iv - gives full color; iviv gives cream, white, or dilute blues.

Cl - with ss grays the colors; clcl gives clear colors.

R^c - gives crimson; R - gives magenta; rr gives rose.

S - with rr gives rose; ss with rr gives salmon.

B_1 - gives rosy colors; b_1b_1 gives blues.

B_2 - gives rosy colors; b_2b_2 gives blues.

In_1 - gives dilute colors; in_1in_1 intensifies them.

In_2 - gives dilute colors; in_2in_2 intensifies them.

Dil - gives intense colors; dildil dilutes them.

The size of the population, with one exception, permitted the analysis of a maximum of four factors. A chi square was determined for each of

66 crosses. Table V gives a resume of these. The genotypes of the parents was deduced from the data from these crosses.

The first six factors are important flower color genes in petunias. With few exceptions, the actions of the various genes appear to be independent.

Finally, a chart is drawn to show the six genes with all interactions. Only one gene, Iv, was found to be epistatic.

BIBLIOGRAPHY

1. Barker, Elmer E. Hereditary studies in the morning glory (Ipomoea purpurea (L.) Roth.) Cornell Univ. Agr. Expt. Sta. Bul. 292. 38 pp. 1917.

2. Baur, Erwin. Untersuchungen über das Wesen, die Enstehung und die Vererbung von Rassenunterschieden bei Antirrhinum majus. Bibliotheca Genetica 4: 1-170. 1924.

3. Beale, G. H. The genetics of Verbena. I. Jour. Gen. 40: 337-358. 1940.

4. _____, J. R. Price, and R. Scott-Moncrieff. The genetics of Verbena II. Chemistry of the flower colour variations. Jour. Gen. 41: 65-74. 1941.

5. _____, G. M. Robinson, Robert Robinson, and R. Scott-Moncrieff. Genetics and chemistry of flower colour variation in Lathyrus odoratus. Jour. Gen. 37: 375-388. 1939.

6. Beckman, Iwar. Kreuzungsuntersuchungen an Delphinium orientale. Hereditas 11: 107-128. 1928.

7. Bedell, B. S. The inheritance of certain characters in Impatiens Balsamina Linn. Gard. Chron. (3) 82: 349-351. 1927.

8. Benl, Gerhard. Die genetischen Grundlagen der Blütenfarben. Zeitschr. f. ind. Abst. u. Vererbungsl. 74: 242-329. 1938.

9. Brieger, F. Faktoranalyse bei Sippenbastarden von Aquilegia vulgaris. Biol. Zbl. 52: 430-436. 1932.

10. Brieger, F. G. As anthocyaninas e sua transmissao hereditaria. Jour. Agron. 1: 107-132. 1938.

11. British Colour Council. Horticultural colour chart. 2 vol. Banbury, 1938 and 1941.

12. Brozek, A. Further investigations on the genetics of flower colours in Mimulus cardinalis Hort. Preslia, Praha. 10: 42-46. 1931.

13. Brozek, A. Mendelian analysis of the 'red-orange-yellow' group of flower-colours in Mimulus cardinalis Hort. Preslia, Praha. 11: 16-25. 1932.

14. Buxton, B. H. Genetics of the primrose, Primula acaulis. Jour. Gen. 25: 195-205. 1932.

15. Cave, B. B. Inheritance of characters in Cajanus indicus. Indian Jour. Agr. Sci. 4: 674-691. 1934.

16. Chittenden, R. J. Notes on species crosses in Primula, Godetia, Nemophila, and Phacelia. Jour. Gen. 19: 285-314. 1928.

17. Clausen, J. Genetical and cytological investigation on Viola tricolor L. and V. arvensis Murr. Hereditas. 8: 1-156. 1926.

18. _____. Inheritance of variegation and of black flower colour in Viola tricolor L. Hereditas. 13: 342-356. 1930.

19. _____. Cyto-genetic and taxonomic investigations on Melanium violets. Hereditas. 15: 219-308. 1931.

20. Crane, M. B., and W. J. C. Lawrence. The genetics of garden plants. London. pp. 45-46. 1934.

21. Creighton, Harriet B. Color pattern and doubleness in Petunia flowers. Genetics 28: 72. 1943.

22. Dale, Ernest E. Inheritance of two factors affecting anthocyanin distribution in flowers of Petunia. Papers Mich. Acad. Sci. Arts and Letters. 27: 3-6. 1941.

23. _____. Further studies of inheritance of variegation in Petunia: broken variegation. Papers Mich. Acad. Sci. Arts and Letters. 28: 9-14. 1942.

24. Dambekalns, Zelma. On the inheritance of involucre colour in Helichrysum bracteatum (Vent.) Willd. Acta Horti Botanici Universitatis Latviensis (Riga) 9/10: 227-233. (Latvian summary p. 233) (From Resumptio Genetica 11:50).

25. Douwes, H. Een genetisch-chemisch enderzeek van Eschscholtzia californica Cham. Genetica. 23: 353-464. 1943. (German summary pp. 438-451. English summary pp. 452-464).

26. Faberge, A. C. Genetics of the Scapiflora section of Papaver. I. The garden Iceland poppy. Jour. Gen. 44: 169-193. 1944.

27. _____. Genetics of the Scapiflora section of Papaver. II. The alpine poppy. Jour. Gen. 45: 139-170. 1945.

28. Ferguson, M. C. A cytological and a genetical study of Petunia. V. The inheritance of color in pollen. Genetics 19: 394-411. 1934.

29. Frimmel, F. Die genetischen Grundlagen für die Farbenzüchtung der Gartenprimmel. Zeitschr. Pfl.-Züchtg. 17: 173-185. 1932. (From Benl).

30. Gairdner, A. E. The inheritance of factors in Cheiranthus Cheiri. Jour. Gen. 32: 479-486. 1936.

31. Haan, H. de. Contributions to the genetics of Pisum. Genetica 12: 321-440. 1930.

32. Haase-Bessell, Gertrud. Digitalisstudien. III. Zeitschr. f. ind. Abst.- u. Vererbungsl. 42: 1-46. 1926.

33. Hagiwara, Tokio. Genetico-physiological studies on the formation of pigments in several organs of Japanese morning glories. Bot. Mag. Tokyo. 42: 292-301. 1928.

34. _____. Genetical studies on the dominant white flowers in Pharbitis Nil. Bot. Mag. Tokyo. 43: 133-145. 1929.

35. _____. The genetics of flower color of Pharbitis Nil. Jour. Col. Agr. Imp. Univ. Tokyo. 11: 241-262. 1931.

36. Hallqvist, Carl. The inheritance of the flower colour and the seed colour in Lupinus angustifolius. Hereditas. 2: 299-363. 1931.

37. Haney, W. J. Color genotypes of the greenhouse snapdragons. Jour. Hered. 15: 146-148. 1954.

38. _____. Unpublished data.

39. Harder, R. Über die Musterbildung an Petunienblüten. Ges. Wiss. Gottingen. Math.-physik. Nachr. a. d. Biol. Bd. 1. Nr. 2. 5-9. 1934.

40. Harder, R., und J. Mahreineke. Weitere Untersuchungen über die Musterbildung an Petunienblüten. Ges. Wiss. Gottingen Math.-physik. Nachr. a. d. Biol. 2: 97-105. 1935.

41. _____ und H. v. Witsch. Blutenscheckung und Korrelationsstorüngen. Ges. Wiss. Gottingen Math.-physik. Nachr. a. d. Biol. 3: 225-237. 1940.

42. Hutchinson, J. B. The genetics of cotton. VIII. The inheritance of anthocyanin pigmentation in Asiatic cotton. Jour. Gen. 26: 317-339. 1932.

43. Ikeno, S. Studies in the genetics of flower-colours in Portulaca grandiflora. Jour. Col. Agr. Imp. Univ. Tokyo. 8: 93-133. 1921.

44. Imai, Yoshitaka. The genetics of Pharbitis purpurea. Jour. Col. Agr. Imp. Univ. Tokyo. 9: 199-222. 1927.

45. _____. Analysis of flower colour in Pharbitis Nil. Jour. Gen. 24: 203-224. 1931.

46. Kanna, Benso. Genetic studies in Impatiens Balsamina L. Jour. Col. Agr. Imp. Univ. Tokyo. 12: 421-477. 1934.

47. Kelly, James P. A genetical study of flower form and flower color in Phlox Drummondii. Genetics 5: 189-248. 1920.

48. Krievins-Hofmanis, Lucija. On the inheritance of flower colour in Verbascum phoenicum L. (preliminary report). Lavijas Biologijas Biedribas Raksti. (Riga). 5: 61-66. 1936. (Latvian summary p. 66) (From Resumptio Genetica 11: 50).

49. Lathouwers, M. V. Recherches experimentales sur l'heredite chez Campanula medium L. Mem. Acad. Roy. Belg. Brux. Classe des Sciences. 4 (8): 1-33. 1922.

50. Lawrence, W. J. C., and R. Scott-Moncrieff. The genetics and chemistry of flower colour in Dahlia; A new theory of specific pigmentation. Jour. Gen. 30: 155-226. 1935.

51. _____, _____, and V. C. Sturgess. Studies in Streptocarpus. I. Genetics and chemistry of flower colour in garden strains. Jour. Gen. 38: 299-306. 1939.

52. Leake, H. Martin, and B. Ram Pershad. A preliminary note on the flower colour and associated characters of the opium poppy. Jour. Gen. 10: 1-20. 1920.

53. Levan, A. Studien über die Vererbung der Blutenscheckung bei Petunia. Hereditas 25: 145-184. 1939.

54. Malinowski, E. Les hybrides du Petunia. Spraw. Towarz. Nauk. Warszawsk. (Compt. Rend. Soc. Sci. Varsovie) 7: 43-54. 1914. (In Polish, French resume pp. 53-54).

55. _____. On the inheritance of some characters in Petunia. Spraw. Towarz. Nauk. Warszawsk. (Compt. Rend. Soc. Sci. Varsovie) 7: 533-545. 1914. (In Polish with an English summary).

56. _____. Variegation and chromosomes in Petunia. Jour. Hered. 19: 521-526. 1928.

57. _____. Studies of unstable characters in Petunia. I. The extreme flower types of the unstable race with mosaic flower patterns. Genetics 20: 342-356. 1935.

58. _____, und M. S. Sachsowa. Die Vererbung einiger Blumengestalten bei Petunia. Spraw. Towarz. Nauk. Warszawsk. (Compt. Rend. Soc. Sci. Varsovie) 9: 865-894. 1916. (In Polish, German summary pp. 882-894).

59. _____, and A. Smolska. Studies on a mosaic strain of Petunia violacea. Bul. Internat. Acad. Polonaise Sci. et. Lettr. Cl. Sci. Math. et Nat. Ser. B. Sci. Nat. (I) (Bot.) 1931: 187-229. 1932.

60. Mather, K., and P. M. J. Edwardes. Specific differences in Petunia. II. Flower colour and genetic isolation. Jour. Gen. 45: 243-260. 1943.

61. Matsuura, Hajime. A bibliographic monograph on plant genetics. (1900-1925). Tokyo. 1929. p. 6. (After Onslow).

62. Mekel, J. G. Genetische Untersuchungen über Centaurea cyanus L. Genetica 17: 377-384. 1935.

63. Mehlquist, Gustav A. L., and T. A. Geissman. Inheritance in the carnation (Dianthus caryophyllus). III. The inheritance of flower color. Ann. Mo. Bot. Gard. 34: 39-72. 1947.

64. Miyake, Kiichi, and Yoshitaka Imai. Genetic studies on Papaver somniferum. Jour. Col. Agr. Imp. Univ. Tokyo. 9: 275-332. 1927.

65. Miyake, Kiichi, Yoshitaka Imai, and Kiyoo Tabuchi. On the inheritance of Cosmos. Bot. Mag. Tokyo. 40: 592-598. 1926. (In Japanese. English summary p. 598).

66. _____, _____, and _____. Genetic experiments with Cosmos. Jour. Col. Agr. Imp. Univ. Tokyo. 9: 139-146. 1927.

67. Moffett, A. A. The genetics of Tropaeolum majus. Jour. Gen. 33: 151-161. 1936.

68. Moore, C. N., and C. P. Haskins. X-ray induced modification of flower color in Petunia. Jour. Hered. 26: 349-355. 1935.

69. Morgan, W. P. Color inheritance in hybrid freesias. Proc. Ind. Acad. Sci. 52: 45-51. 1942.

70. Müntzing, Arne. Outlines to a genetic monograph of the genus Galeopsis. Hereditas. 13: 185-341. 1930.

71. Philp, James. The genetics of Papaver Rhoeas and related forms. Jour. Gen. 28: 175-203. 1933.

72. Pollard, Leonard H. The inheritance of some flower and plant characters in Zinnia. Unpublished Ph. D. thesis from the University of California. 1939.

73. Rasmuson, Hans. Ueber die Petunia-Kreuzung. Bot. Notiser. 1918: 287-294.

74. _____. Die Hauptergebnisse von einigen genetischen Versuchen mit verschieden Formem von Tropaeolum, Clarkia und Impatiens. Hereditas. 1: 270-276. 1920.

75. Riley, Herbert Parkes. Inheritance of orange and yellow flower color in Nemesia strumosa. Bul. Torrey Bot. Club 72: 435-453. 1945.

76. _____. Inheritance of the main anthocyanin pigmentation and some of its patterns in flowers of Nemesia strumosa. Bot. Gaz. 107: 32-52. 1945.

77. _____. Relationship of blue and orange flower color types in Nemesia strumosa. Bot. Gaz. 111: 43-52. 1949.

78. Sachs-Skalinska, M. Le polymorphisme dans les lignes pures du Petunia. Mem. Inst. Genet. de l'Ecole Sup. d'Agri. Varsovie. 1: 15-33. (From Bot. Abst. 13, No. 5867. 1924).

79. _____. Bandania nad mieszancami Tytuniu. Pam. Zakladu Genet. Szkoly Glownej Gospod. Wiejskiego. 1: 47-122. 1921. (In Polish, with a French resume) (From Matsuura).

80. Schafer, Brenhilda. The genetics of Aquilegia vulgaris. Jour. Gen 41: 339-347. 1941.

81. Schnack, Benno, y Ada M. Castronovo. Genetica des los pigmentos florales del aleli. Rev. Arg. Agron. 12: 103-114. 1945.

82. _____, y Onofre Fernandez. Nuevo resultados en la genetica des los pigmentos florales del aleli. Rev. Invest. Agric. 1: 103-111. 1947.

83. Schröder, H. Untersuchung über die Beinflussing des Blutenfarbmusters von Petunia hybrida grandiflora. Hort. Jahr. Wiss. Bot. (Leipsig). 79: 714-752. 1934.

84. Scott-Moncrieff, Rose. A biochemical survey of some mendelian factors for flower colour. Jour. Gen. 32: 117-170. 1936.

85. Seyffert, W. Die Vererbung die Blütenfarben bei hemiploiden Cyclamen. Der Züchter. 25: 275-287. 1955.

86. _____. Über die Wirkung von Blütenfarbgenen bei Cyclamen. Zeitschr. f. ind. Abst. - u. Vererbungsl. 87: 311-334. 1955.

87. Shaw, F. J. F., Khan Sahib Abdur Rahman Khan and Mahbub Alam. Studies in Indian oil-seeds. V. The inheritance of characters in Indian linseed. Indian Jour. Agr. Sci. 1: 1-57. 1931.

88. Silow, R. A. The comparative genetics of Gossypium anomalum and the cul-vated Asiatic cottons. Jour. Gen. 42: 259-358. 1941.

89. Skalinska, M. S. Recherches sur la selection des bourgeons chez une race polymorphe du petunia et la probleme de la production de nouvelles varietes. Pam. Zakl. Genetycz Szkoly Glownej Gosp. Wiejsk. (Mem. Inst. Genetique Ecole Super. Agr. Varsovie) 2: 69-121. 1924. (In Polish. French resume pp. 107-120).

90. Skalinska, M. S. Sur les causes d'une disjonction nontypique des hybrides du genre Aquilegia. Acta Soc. Bot. Polon. 2: 141-173. 1928. (From Benl).

91. _____, und S. Cuchtman. Karologische Analyse einer polymorphen Rasse von Petunia violacea. Bibl. Univ. Liberae Polonae. 19: 1-27. 1927.

92. Storey, W. B. Genetics of flower color in a Spathoglottis cross. Bul. Pacific Orchid Soc. Hawaii. 8: 326-331. 1950. (From Biol. Abst. 25: No. 3630).

93. Störmer, Inge, und H. v. Witsch. Chemische und entwicklungsphysiologische Untersuchungen über das Blütenfarbmuster der Gartenpetunia. Planta. 27: 1-29. 1937.

94. Stout, A. B. Reproduction in Petunia. Mem. Torrey Bot. Club 20: No. 3. 202 pp. 1952.

95. Sutton, Eileen. The genetics of Tropaeolum majus. II. Jour. Gen. 38: 161-176. 1939.

96. Tammes, Tine. The genetics of the genus Linum. Bibliog. Genetica. 4: 1-36. 1928.

97. Toxopeus, H. J. Erblichkeitsuntersuchungen an Nigella damascena L. Genetica. 9: 341-442. 1927.

98. Tschermak, Erich von. Bastardierungsversuche an Levkojen, Erbsen und Bohnen mit Rücksicht auf die Faktorlehre. Zeitschr. f. ind. Abst. - u. Vererbungsl. 7: 81-234. 1912.

99. United States Census of Agriculture, Special Reports. Vol. 5. Pt. 1. Horticultural Specialties. Bur. of Census, U. S. Dept. Commerce. 1952.

100. Vavilov, N. I. The law of homologous series in variation. Jour. Gen. 12: 47-90. 1922.

101. _____. The Linnean species as a system. Proc. 5th Int. Bot. Cong. Cambridge. 213-216. 1930.

102. Walker, John. Association of characters in Petunia. Sci. Agr. (Ottawa). 24: 251-258. 1944.

103. Wellensiek, S. J. Pisum crosses. IX. The new flower color "cerise". Genetica. 25: 525-529. 1951.

104. Westgate, V. V. Color inheritance in Petunia. Amer. Breeders Assoc. Rpt. 6: 459-462. 1911.

105. Winton, D. de, and J. B. S. Haldane. The genetics of Primula sinensis. II. Segregation and interaction of factors in the diploid. Jour. Gen. 27: 1-44. 1933.

106. Wit, F. Contributions to the genetics of the China aster. Genetica. 19: 1-104. 1937.

107. Witsch, H. v. Zur genetischen Grundlage der Blütenscheckung bei Petunia hybr. grandiflora. Ges. Wiss. Gottingen Math.-physik. Nachr. a. d. Biol. 2: 201-213. 1936.

108. _____. Weitere Untersuchungen zur genetischen Grundlage der Blütenscheckung bei Petunia hybr. grandiflora. Ges. Wiss. Gottingen Math.-physik. Nachr. a. d. Biol. 3: 203-208. 1939.

APPENDIX

The data to support the conclusions in the body of this thesis are given here. The order is the same as in Table V. The status of non-segregating genes is given. In some cases several colors were combined to make the class listed. In these instances only the numbers of the lightest and the deepest are given. To save space only the haploid genotype is given.

Cross I

Burpee Blue x Salmonet

Non-segregating gene - Iv

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1RSIn_2	81	Magenta (533/1 to 834)	34	33.4	.2	.012
b_1RSIn_2	27	Violet Blue (near 834/2)	13	11.3	1.7	.256
B_1rSIn_2	27	Deep Lilac Rose (630 to 29/1)	10	11.3	1.3	.150
B_1RsIn_2	27	Light Purple (732 to 934)	12	11.3	.7	.043
B_1RSin_2	27	Magenta Purple (732/1)	10	11.3	1.3	.150
B_1Rsin_2) b_1RSin_2)	18	Grayed Violet Blue (033)	7	7.4	.4	.002
b_1rSIn_2	9	Light Rose (025/1)	2	3.8	1.8	.853
B_1rsIn_2	9	Grayed Rose (027 to 030)	5	3.8	1.2	.379
B_1rSin_2	9	Deep Purple (near 732/2)	4	3.8	.2	.010
b_1RsIn_2	9	Grayed Rose Purple (near 030)	2	3.8	1.8	.853
b_1rsIn_2	3	Grayed Lilac (033/2)	3	1.2	1.8	2.700

Cross 1 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_1rSin_2	3	Deep Rose (27 to 628/1)	2	1.2	.8	.533
b_1Rsin_2	3	Grayed Very Deep Rose (near 033)	2	1.2	.8	.533
B_1rsin_2	3	Grayed Salmon	0	1.2	1.2	1.200
b_1rsin_2	1	Mid Salmon (022)	1	.4	.6	.900
	256		107	107.0		8.574

$P > .80$

Cross 2

(Burpee Blue x Salmonet) x Burpee Blue

Non-segregating Genes - $IvB_1RSClIn_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2dil---	2	Purple Violet (near 732/1)	14	16.2	2.2	.299
b_2dilIn_1) b_2Dil---)	3	Reddish Violet Blue (735 to 934/1)	24	24.3	.3	.004
b_2dilin_1	1	Violet Blue (near 834/2)	13	8.1	4.9	2.964
B_2Dil---	2	Violet (732)	14	16.2	2.2	.299
	8		65	64.8		3.566

$P > .30$

Cross 3

(Burpee Blue x Salmonet) x Salmonet

Non-segregating Genes - IvB_2In_1Dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
--rsCl) B_1RsCl)	3	Very Grayed Salmon Pink (0027/2)	16	12.2	3.8	1.184
--RSCl	2	Deep Red Purple (732/1)	7	8.1	1.1	.149
--RScl	2	Crimson Purple (732)	8	8.1	.1	.001
B_1rscl	1	Salmon Pink (024 to 025/1)	5	4.0	1.0	.250
b_1RsCl	1	Grayed Light Rose (0027)	4	4.0	0.0	.000
$b_1$rscl	1	Deep Salmon (021/1 to 622)	3	4.0	1.0	.250
B_1RScl	1	Rose Purple (730/1 to 31)	5	4.0	1.0	.250
b_1rS--	2	Lilac Rose (29/1 to 729/2)	6	8.1	2.1	.544
B_1rScl	1	Deep Rose (828/2)	3	4.0	1.0	.250
B_1rSCl	1	Grayed Deep Rose (near 027)	5	4.0	1.0	.250
b_1RsCl	1	Deep Purple Violet (near 733)	3	4.0	1.0	.250
	16		65	64.5		3.378

$P > .95$

Cross 4

Burpee Blue x Bright Light Scarlet

Non-segregating Genes - $Ivin_1$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1B_2RSCl	243	Magenta (632/2 to 732/1)	132	134.6	2.6	.050
B_1b_2RSCl) b_1B_2RSCl)	162	Violet Blue (934/2 to 834)	84	89.6	5.6	.350
B_1B_2RsCl	81	Violet Magenta (732/2 to near 733)	47	44.8	2.2	.108
B_1B_2rSCl	81	Grayed Rose (27/1 to 027)	45	44.8	.2	.001
B_1B_2RScl	81	Lilac (433/1 to 29/1)	45	44.8	.2	.001
b_1b_2RSCl	27	Magenta Violet Blue (834/1)	11	15.0	4.0	1.067
b_1--rSCl	36	Grayed Violet (031)	23	19.9	3.1	.483
b_1--RsCl	36	Grayed Lilac (0027/2)	22	19.9	2.1	.222
B_1B_2RScl	27	Magenta Purple (near 1030)	20	15.0	5.0	1.667
B_1b_2rSCl	27	Deep Magenta Purple (733/1)	17	15.0	2.0	.267
B_1b_2RsCl	27	Mid Rose, slightly Grayed (627)	9	15.0	6.0	2.400
b_1B_2RScl	27	Purple Magenta (733)	15	15.0	0.0	.000
B_1B_2rsCl	27	Grayed Salmon Red (027)	13	15.0	2.0	.267
B_1B_2rScl	27	Mid Rose (627/1)	11	15.0	4.0	1.067
B_1B_2Rscl	27	Rose Lilac (632)	13	15.0	2.0	.267
B_1b_2rsCl) b_1--rsCl)	21	Grayed Mid Salmon (0027)	12	11.6	.4	.014
b_1b_2RScl) b_1B_2Rscl)	18	Purple (830/1)	11	10.0	1.0	.100

Cross 4 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$--b_2Rscl$	12	Light Purple (30)	6	6.6	.6	.054
B_1b_2rScl	9	Light Rose (629)	4	5.0	1.0	.200
b_1B_2rScl	9	Lilac Rose (630/1)	4	5.0	1.0	.200
B_1B_2rscl	9	Salmon Pink (427)	11	5.0	6.0	7.200
b_1b_2rScl	3	Rose Pink (629/2)	1	1.6	.6	.225
B_1b_2rscl	3	Light Salmon (625/1)	5	1.6	3.4	7.225
b_1B_2rscl	1	Bright Light Scarlet (022)	2	.6	1.4	3.267
b_1b_2rscl	3	Salmon (23/1)	4	1.6	2.4	3.600
	1024		567	567.0		30.302

$P > .10$

Cross 5

Coronet x Harris Purple

Non-segregating Gene - Iv

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1RIn_1In_2$	81	Reddish Violet Blue (near 934)	76	69.6	6.4	.587
$B_1RIn_1in_2$	27	Violet Purple (near 735 to near 934)	24	23.2	.8	.028
$B_1Rin_1In_2$	27	Rose Purple (near 733)	23	23.2	.2	.002
$B_1rIn_1In_2$	27	Magenta Rose (732/1 to 732/3)	21	23.2	2.2	.209
$b_1RIn_1In_2$	27	Purple (near 732 to near 931/1)	23	23.2	.2	.002
$b_1RIn_1in_2)$ $b_1Rin_1In_2)$	18	Dull Violet (near 934)	13	15.5	2.5	.403

Cross 5 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1Rin_1in_2$	9	Deep Purple Violet (near 733)	6	7.7	1.7	.375
$B_1rin_1In_2$	9	Dull Purple (near 733)	9	7.7	1.3	.219
$B_1rIn_1in_2$	9	Bright Purple (931)	7	7.7	.7	.064
$b_1rIn_1In_2$	9	Magenta Blue (735/1)	8	7.7	.3	.012
$B_1rin_1in_2$	3	Deep Magenta Rose (29)	1	2.6	1.4	.985
$b_1Rin_1in_2$	3	Violet (834)	4	2.6	1.4	.754
$b_1rIn_1in_2$	3	Lilac Rose (30)	3	2.6	.4	.062
$b_1rin_1In_2$	3	Lilac (630/1)	2	2.6	.6	.138
$b_1rin_1in_2$	1	Deep Rose	0	.8	.8	.800
	256		220	219.9		4.640

$P > .99$

Cross 6

Glow x Bright Light Scarlet

Non-segregating Genes - Ivr

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1---Dil) SIn_1in_2dil)	117	Deep Rose (025/1)	90	87.4	2.6	.077
Sin_1---Dil	36	Bright Deep Rose (near 025)	29	26.8	2.2	.181
SIn_1In_2dil	27	Mid Rose (025 to 25/1)	19	20.1	1.1	.060
sIn_1In_2Dil	27	Salmon Scarlet (020)	20	20.1	.1	.001
sin_1---Dil	12	Salmon Red (024)	10	8.9	1.1	.136

Cross 6 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1in_2dil	9	Grayed Deep Rose (26)	5	6.7	1.7	.431
sIn_1in_2Dil	9	Salmon Red, slightly Grayed (20/1)	6	6.7	.7	.073
sIn_1In_2dil	9	Scarlet Salmon (820/2 to 021)	5	6.7	1.7	.431
Sin_1in_2dil	3	Bright Deep Rose Veined (25)	3	2.2	.8	.291
sIn_1in_2dil	3	Deep Scarlet Salmon (021)	2	2.2	.2	.018
sin_1---dil	4	Deep Salmon (022/1)	2	2.9	.9	.279
	256		191	190.7		1.978

P > .99

Cross 7

Heavenly Blue x Bright Light Scarlet

Non-segregating Genes - Ivb_1in_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RSIn_1	81	Magenta (31 to 633)	33	38.0	5.0	.658
b_2RSIn_1	27	Deep Purple (near 733 to 733/1)	13	12.6	.4	.013
B_2rSIn_1	27	Rose Purple (near 027 to 729)	16	12.6	3.4	.917
B_2RsIn_1	27	Grayed Rose (027/1 to 033/1)	10	12.6	2.6	.536
B_2RSin_1	27	Lilac (527 to 533)	10	12.6	2.6	.536
B_2Rsin_1) b_2RsIn_1)	18	Very Deep Carmine (29)	8	8.4	.4	.019

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2rsIn_1	9	Salmon, slightly Grayed (22/1)	7	4.2	2.8	1.867
B_2rSin_1	9	Mid Rose (27)	4	4.2	.2	.010
b_2rSIn_1	9	Light Rose (530)	4	4.2	.2	.010
b_2RSin_1	9	Blue (36/1 to 35)	6	4.2	1.8	.771
B_2rsin_1	3	Deep Salmon (022)	1	1.4	.4	.114
b_2Rsin_1	3	Deep Violet (near 733/1 to near 934)	2	1.4	.6	.257
b_2rSin_1	3	Deep Rose	0	1.4	1.4	1.400
b_2rsIn_1	3	Grayed Salmon (0027/1 to 027)	5	1.4	3.6	9.257
b_2rsin_1	1	Salmon Red (near 022)	1	.5	.5	.500
	256		120	119.7		16.866

$P > .20$

Cross 8

King Henry x Heavenly Blue

Non-segregating Genes - Ivb_2ClDil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1SIn_1In_2$	81	Deep Purple (near 732 to near 934/1)	113	117.4	4.4	.165
$b_1SIn_1In_2$	27	Purple (near 733)	38	39.1	1.1	.031
$B_1sIn_1In_2$	27	Magenta (633/1 to 31)	39	39.1	.1	.000
$B_1Sin_1In_2$	27	Rose Purple (near 830)	37	39.1	2.1	.113
$B_1S---in_2$	36	Bright Purple (near 830)	54	52.2	1.8	.062

Cross 8 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$b_1sIn_1In_2$	9	Violet Blue (near 735 to 934/1)	16	13.0	3.0	.692
$B_1sin_1In_2$	9	Crimson (near 827 to 729/1)	3	13.0	10.0	7.692
$B_1sIn_1in_2$	9	Deep Bright Purple (934)	14	13.0	1.0	.077
$b_1Sin_1In_2$	9	Magenta Blue (735/1)	20	13.0	7.0	3.769
$b_1SIn_1in_2$	9	Deep Blue (735)	11	13.0	2.0	.308
$b_1Sin_1in_2$) $b_1sIn_1in_2$)	6	Violet (36)	13	8.6	4.4	2.251
$B_1sin_1in_2$	3	Light Violet (37/1)	6	4.3	1.7	.672
$b_1sin_1In_2$	3	Deep Blue Magenta (near 732)	5	4.3	.7	.114
$b_1sin_1in_2$	1	Mid Blue (36/1)	2	1.4	.6	.257
	256		271	270.5		16.203

$P > .20$

Cross 9

(King Henry x Heavenly Blue) x Heavenly Blue

Non-segregating Genes - Ivb_2SClIn_1Dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1---	2	Magenta Purple (near 732)	67	65.0	2.0	.062
b_1In_2	1	Light Blue (35)	26	32.5	6.5	1.300
b_1in_2	1	Mid Blue (636 to 735/1)	37	32.5	4.5	.623
	4		130	130.0		1.985

$P > .30$

Cross 10

King Henry x Salmonet

Non-segregating Genes - IvsDil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1R^cIn_1$	27	Magenta Crimson (827 to 1030)	19	20.7	1.7	.140
$B_1R^cin_1$	9	Deep Crimson Purple (near 931)	5	6.8	1.8	.476
B_1rIn_1	9	Grayed Lilac (0027/2)	10	6.8	3.2	1.506
$b_1R^cIn_1$	9	Purple Crimson (near 1028)	5	6.8	1.8	.476
B_1rin_1	3	Purple Magenta (928)	3	2.3	.7	.213
$b_1R^cin_1$	3	Crimson Purple (near 931/1)	3	2.3	.7	.213
b_1rIn_1	3	Mid Salmon (022)	3	2.3	.7	.213
b_1rin_1	1	Old Rose (0022)	1	.8	.2	.050
	64		49	48.5		3.287

$P > .80$

Cross 11

(King Henry x Salmonet) x King Henry

Non-segregating Genes - $IvB_1RsClIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2---) b_2In_1)	3	Purple Crimson (near 1028)	79	81	2.0	.049
b_2in_1	1	Crimson (near 827)	29	27	2.0	.148
	4		108	108		.197

$P > .50$

Cross 12

(King Henry x Salmonet) x Salmonet

Non-segregating Genes - IvB_2sIn_1Dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1rCl---) b_1rClIn_2)	3	Grayed Lilac (0027/2)	11	10.2	.8	.063
b_1R^cCl---) $B_1R^cclIn_2$)	3	Crimson Purple (830)	8	10.2	2.2	.474
B_1rcl---) b_1rclIn_2)	3	Salmon Red (024 to 0027)	11	10.2	.8	.063
b_1R^ccl---	2	Purple Rose (near 730)	7	6.8	.2	.006
b_1rClin_2) B_1R^cCl---)	3	Dull Crimson Purple (730)	8	10.2	2.2	.474
$B_1R^cclin_2$	1	Dull Deep Rose (729)	4	3.4	.6	.106
b_1rclin_2	1	Deep Salmon (022/1 to 025/2)	6	3.4	2.6	1.988
	16		55	54.4		3.174

$P > .70$

Cross 13

(King Henry x Bright Light Scarlet) x Bright Light Scarlet

Non-segregating Genes - IvB_2sin_1Dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
r--in_2) R^cClin_2)	3	Deep Purple (830)	45	47.2	2.2	.102
R^cclin_2	1	Purple (729/2 to 730)	14	15.8	1.8	.205
R^cclIn_2	1	Rose (727/1 to near 729/1)	11	15.8	4.8	1.458
$rclIn_2$	1	Scarlet (820/3 to 024)	21	15.8	6.2	2.433

Cross 13 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$rClIn_2$	1	Grayed Salmon Red (024)	19	15.8	3.2	.648
R^cClin_2	1	Grayed Rose (0023 to 0027)	16	15.8	.2	.002
	8		126	126.2		4.848

P > .30

Cross 14

King Henry x Deep Bright Scarlet

Non-segregating Genes - $IvB_1 sin_1 Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_2R^cClIn_2$	81	Crimson Purple (830 to 1028)	54	52.8	1.2	.027
$B_2R^cClin_2$) $b_2R^cClIn_2$)	54	Deep Crimson Purple (near 830)	32	35.2	3.2	.291
$B_2r\ ClIn_2$	27	Grayed Lilac (0027/2)	27	17.6	9.4	5.020
$B_2R^cclIn_2$	27	Royal Purple (near 931)	17	17.6	.6	.020
b_2r Cl---) $B_2r\ Clin_2$)	21	Grayed Deep Salmon (0027/1)	12	13.7	1.7	.211
$B_2R^cclin_2$) $b_2R^cclIn_2$)	18	Rose Purple (828/2 to 830)	9	11.7	2.7	.623
$b_2R^cClin_2$	9	Crimson (931)	8	5.9	2.1	.747
$B_2r\ clIn_2$	9	Fading Salmon Red (022)	3	5.9	2.9	1.425
$b_2R^cclin_2$	3	Deep Rose (near 26)	3	2.0	1.0	.500
$B_2r\ clin_2$	3	Deep Bright Scarlet	0	2.0	2.0	2.000
b_2r cl---	4	Salmon Red (021/1)	2	2.6	.6	.138
	256		167	166.9		11.061

P > .30

Cross 15

(King Henry x Deep Bright Scarlet) x Deep Bri ght Scarlet

Non-segregating Genes - $IvB_1B_2sin_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
R^c--In_2	2	Deep Crimson Purple (near 830)	18	16.0	2.0	.250
rCl---	2	Grayed Salmon (025/1)	20	16.0	4.0	1.000
R^cClin_2	1	Crimson Carmine (near 827/1)	5	8.0	3.0	1.125
R^cclin_2	1	Deep Carmine Rose (25 to 828/1)	9	8.0	1.0	.125
$rclIn_2$	1	Scarlet (820/3)	5	8.0	3.0	1.125
$rclin_2$	1	Deep Scarlet (822/1)	7	8.0	1.0	.125
	8		64	64.0		3.750

$P > .50$

Cross 16

Lipstick x Heavenly Blue

Non-segregating Genes - IvS

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1B_2RIn_1$	81	Magenta (632 to 31)	61	56.3	4.7	.392
$B_1b_2RIn_1$) $b_1B_2RIn_1$)	54	Very Deep Carmine (729)	37	37.5	.5	.007
$B_1B_2Rin_1$	27	Magenta Purple (732/1)	20	18.8	1.2	.076
$B_1B_2rIn_2$	27	Rose (630 to 25)	14	18.8	4.8	1.226
$B_1b_2rIn_2$) $b_1B_2rIn_2$) $b_1b_2rin_2$)	19	Light Rose Pink (31/2)	14	13.2	.8	.048

Cross 16 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1b_2Rin_2$) $b_1B_2Rin_2$)	18	Lilac Magenta (630 to 32/1)	11	12.5	1.5	.180
$B_1B_2rin_2$) $b_1b_2rIn_2$)	12	Very Deep Rose (727)	6	8.3	2.3	.637
$b_1b_2RIn_2$	9	Mid Blue (637)	7	6.2	.8	.103
$B_1b_2rin_2$) $b_1B_2rin_2$)	6	Cream Tinted (533/1)	4	4.2	.2	.010
$b_1b_2Rin_2$	2	Bright Purple (732)	4	2.1	1.9	1.719
	256		176	177.8		4.398

P $>$ .80

Cross 17

(Lipstick x Heavenly Blue) x Heavenly Blue

Non-segregating Genes - $IvRSClIn_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1B_2---	2	Magenta (632)	32	30.0	2.0	.133
$B_1b_2in_2$	1	Deep Magenta Blue (735/2)	14	15.0	1.0	.067
$B_1b_2In_2$	1	Deep Purple (732)	13	15.0	2.0	.267
$b_1B_2in_2$	1	Mid Blue (637)	12	15.0	3.0	.600
$b_1B_2In_2$	1	Light Magenta (near 632)	17	15.0	2.0	.267
$b_1b_2in_2$	1	Deep Blue Violet (735/1)	18	15.0	3.0	.600
$b_1b_2In_2$	1	Light Blue (636/2)	13	15.0	2.0	.267
	8		119	120.0		2.201

P $>$ .90

Cross 18

(Lipstick x Heavenly Blue) x Lipstick

Non-segregating Genes - $IvB_1B_2SIn_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
Rcl---	2	Deep Magenta (732/2)	19	16.2	2.8	.484
rCl---	2	Light Rose (632/1)	16	16.2	.2	.002
$rclIn_1$	1	Deep Rose Veined (727)	8	8.1	.1	.001
$rclin_1$	1	Deep Rose (727)	8	8.1	.1	.001
$RClIn_1$	1	Deep Carmine (828/2)	9	8.1	.9	.100
$RClin_1$	1	Very Deep Carmine	5	8.1	3.1	1.186
	8		65	64.8		1.778

$P > .80$

Cross 19

Moonbeam x Bright Light Scarlet

Non-segregating Gene - r

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB_1SIn_1	81	Light Rose (629 to 27)	27	28.1	1.1	.043
iv------	64	Cream	11	22.2	11.2	5.650
Ivb_1SIn_1	27	Rose Pink (31/3 to 022/3)	12	9.4	2.6	.719
IvB_1sIn_1	27	Deep Salmon Pink (024 to 23/1)	12	9.4	2.6	.719
IvB_1Sin_1	27	Deep Rose (027/1 to 27)	12	9.4	2.6	.719

Cross 19 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
Ivb_1sIn_1	9	Salmon (020/1 to 022)	5	3.1	1.9	1.164
Ivb_1Sin_1	9	Carmine Rose (29)	3	3.1	.1	.009
IvB_1sin_1	9	Scarlet (819/2)	6	3.1	2.9	2.713
Ivb_1sin_1	3	Scarlet Red (23)	1	1.0	0.0	.000
	256		89	88.1		11.730

$P > .10$

Cross 20

(Moonbeam x Bright Light Scarlet) x Bright Light Scarlet

Non-segregating Genes - IvB_2R

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
sin_1---	2	Salmon Scarlet (721/3 to 819/2)	9	16.0	7.0	3.062
sIn_1---	2	Salmon Pink (25/2 to 23/1)	16	16.0	0.0	.000
SIn_1In_2	1	Light Rose (28)	10	8.0	2.0	.500
SIn_1in_2	1	Deep Rose (26)	11	8.0	3.0	1.125
Sin_1In_2	1	Deep Rose Pink (27)	11	8.0	3.0	1.125
Sin_1in_2	1	Bright Deep Rose (727)	7	8.0	1.0	.125
	8		64	64.0		5.937

$P > .30$

Cross 21

Moonbeam x Blue Seedling

Non-segregating Genes - b_2In_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1RSCl	81	Magenta (633 to 733)	40	37.3	2.7	.195
b_1RSCl	27	Mid Blue (37/1)	15	12.4	2.6	.545
B_1rSCl	27	Lilac Rose (near 27/1)	10	12.4	2.4	.464
B_1RsCl	27	Very Deep Carmine (31)	14	12.4	1.6	.206
B_1RScl	27	Lilac (530/1 to 433)	10	12.4	2.4	.464
b_1RsCl) B_1Rscl)	18	Magenta Purple (834/1)	5	8.2	3.2	1.249
b_1rSCl	9	Very Deep Rose (near 729)	2	4.1	2.1	1.076
b_1RScl	9	Deep Purple (near 830/1)	4	4.1	.1	.002
B_1rsCl	9	Grayed Rose (27/1)	5	4.1	.9	.198
B_1rScl	9	Carmine (730/1)	4	4.1	.1	.002
b_1Rscl) b_1rScl)	6	Purple Violet (near 732)	5	2.8	2.2	1.728
B_1rscl	3	Salmon Red (022/1)	2	1.4	.6	.257
b_1rsCl	3	Grayed Mid Salmon (027/2)	2	1.4	.6	.257
b_1rscl	1	Deep Salmon	0	.5	.5	.500
	256		118	117.6		7.143

$P > .80$

Cross 22

(Moonbeam x Blue Seedling) x Blue Seedling

Non-segregating Genes - Ivb_2RClIn_2Dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_1-in_1	2	Mid Blue (35)	14	16.2	2.2	.299
b_1-In_1	2	Light Blue (636/1)	18	16.2	1.8	.200
B_1sin_1	1	Mid Lilac (31)	9	8.1	.9	.100
B_1Sin_1	1	Magenta (732/1)	7	8.1	1.1	.149
B_1sIn_1	1	Light Lilac (633)	8	8.1	.1	.001
B_1SIn_1	1	Lilac Magenta (632)	9	8.1	.9	.100
	8		65	64.8		.849

$P > .95$

Cross 23

(Moonbeam x Blue Seedling) x Moonbeam

Non-segregating Genes - $B_1b_2SIn_1In_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
iv-----	4	Light Magenta (733/2)	31	32.5	1.5	.069
IvRcl) IvrCl)	2	Mid Magenta (732/1)	16	16.2	.2	.002
IvRCl	1	Deep Magenta (733/1)	7	8.1	1.1	.149
Ivrcl	1	Dilute Magenta (633/1)	11	8.1	2.9	1.038
	8		65	64.9		1.258

$P > .70$

Cross 24

(Moonbeam x Deep Bright Scarlet) x Deep Bright Scarlet

Non-segregating Genes - $IvB_1B_2rclDil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$SInin_2$	1	Deep Lilac Rose (28)	4	7.1	3.1	1.353
$SinIn_2$	1	Light Lilac Rose (729/3)	9	7.1	1.9	.508
Sin_1in_2	1	Deep Bright Rose (near 25)	4	7.1	3.1	1.353
Sin_1In_2	1	Deep Rose (727)	6	7.1	1.1	.170
sin_1In_2	1	Deep Salmon Pink (23/1)	12	7.1	4.9	3.382
sIn_1In_2	1	Salmon Pink (027/1)	8	7.1	.9	.114
sIn_1in_2	1	Deep Scarlet (820/1)	8	7.1	.9	.114
sin_1in_2	1	Deep Bright Scarlet (721/1)	6	7.1	1.1	.170
	8		57	56.8		7.164

$P > .30$

Cross 25

(Moonbeam x Deep Bright Scarlet) x Moonbeam

Non-segregating Genes - $B_1b_2SIn_1In_2dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
iv----	4	Cream	29	30.5	1.5	.074
Iv-Dil	2	Lilac Magenta (31 to 633)	14	14.6	.6	.025
IvRdil	1	Light Magenta (632/1)	9	7.3	1.7	.396
Ivrdil	1	Light Lavender Magenta (near 633)	9	7.3	1.7	.396
	8		61	59.7		.891

$P > .80$

Cross 26

Harris Purple x Celestial Rose

Non-segregating Gene - Iv

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1B_2RIn_1$	81	Magenta (632/1 to 31)	53	50.3	2.7	.145
$B_1B_2rIn_1$	27	Rose Magenta (730/2)	14	16.8	2.8	.467
$b_1B_2RIn_1$	27	Light Magenta (632 to 732/1)	21	16.8	4.2	1.050
$B_1b_2RIn_1$	27	Deep Lilac (30)	15	16.8	1.8	.193
$B_1B_2Rin_1$	27	Magenta Purple (732 to near 732)	15	16.8	1.8	.193
$B_1b_2Rin_1$) $b_1B_2Rin_1$)	18	Violet (33)	12	11.2	.8	.057
b_1b_2R---	12	Violet Blue (934)	4	7.6	3.6	1.705
$B_1B_2rin_1$	9	Lilac Rose (630)	7	5.6	1.4	.350
$b_1B_2rIn_1$	9	Mid Rose (29/1)	3	5.6	2.6	1.207
$B_1b_2rIn_1$	9	Light Blue (633/1 to 634/1)	4	5.6	1.6	.457
$B_1b_2rin_1$) b_1b_2r---)	7	Mid Blue (733)	7	4.3	2.7	1.695
$b_1B_2rin_1$	3	Deep Rose (29)	4	1.9	2.1	2.321
	256		159	159.3		9.840

$P > .50$

Cross 27

(Harris Purple x Celestial Rose) x Celestial Rose

Non-segregating Genes - IvB_2SIn_1

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1R--in_2) B_1RclIn_2)	3	Magenta Purple (near 732/1)	11	12.0	1.0	.083
b_1r--in_2) B_1rclIn_2)	3	Deep Rose (27)	11	12.0	1.0	.083
b_1R--In_2) b_1RClin_2)	3	Mid Lilac (30/1)	12	12.0	0.0	.000
B_1Rclin_2	1	Crimson Purple (730)	5	4.0	1.0	.250
b_1r--In_2	2	Deep Lilac (630)	8	8.0	0.0	.000
B_1r--in_2	2	Dull Magenta Purple (near 31)	8	8.0	0.0	.000
b_1RClIn_2	1	Dull Crimson Purple (729/1)	5	4.0	1.0	.250
B_1rClIn_2	1	Carmine Rose (28)	4	4.0	0.0	.000
	16		64	64.0		.666

$P > .99$

Cross 28

Harris Purple x Heavenly Blue

Non-segregating Genes - $Ivb_2RClDil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1SIn_2	27	Reddish Violet Blue (near 834)	15	22.8	7.8	2.668
B_1s---	12	Violet Purple (near 735 to near 937)	11	10.1	.9	.080
b_1SIn_2	9	Violet Blue (735)	14	7.6	6.4	5.389

Cross 28 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1Sin_2	9	Deep Magenta (near 735)	8	7.6	.4	.021
B_1sin_2	3	Crimson Violet Purple (near 937)	4	2.5	1.5	.900
b_1Sin_2	3	Deep Blue (35/1)	1	2.5	1.5	.900
b_1sin_2	1	Violet Crimson (931)	1	.8	.2	.050
	64		54	53.9		10.008

$P > .10$

Cross 29

(Harris Purple x Heavenly Blue) x Heavenly Blue

Non-segregating Genes - $Ivb_2RSClIn_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1In_2	1	Deep Blue (near 37 to near 834)	21	16.0	5.0	1.562
B_1in_2	1	Deep Magenta Purple (733)	16	16.0	0.0	.000
b_1In_2	1	Light Blue (near 937/3 to near 35)	8	16.0	4.0	4.000
b_1in_2	1	Mid Blue (37 to near 937/2)	19	16.0	3.0	.562
	4		64	64.0		6.124

$P > .10$

Cross 30

(Harris Purple x Heavenly Blue) x Harris Purple

Non-segregating Genes - $IvB_1b_2RClIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1	1	Violet Blue (near 937/2)	17	16.2	.8	.040

Cross 30 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
Sin_1	1	Deep Blue (near 36 to near 735)	20	16.2	3.2	.632
sIn_1	1	Purple Violet (near 834)	17	16.2	1.2	.089
sin_1	1	Violet Purple (near 834/1 to near 937)	11	16.2	5.2	1.669
	4		65	64.8		2.430

$P > .30$

Cross 31

Harris Purple x Salmon and White

Non-segregating Genes - $IvsIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1B_2RCl	81	Deep Purple (732/2 to 834)	91	82.9	8.1	.791
B_1--Rcl	36	White	31	36.8	5.8	.914
B_1b_2RCl	27	Violet Blue (934 to 934/1)	25	27.6	2.6	.245
b_1B_2RCl	27	Purple (near 732 to near 931)	26	27.6	1.6	.093
B_1B_2rCl	27	Deep Rose (632 to 730)	23	27.6	4.6	.767
b_1B_2Rcl	9	Royal Purple (834 to near 934/1)	13	9.2	3.8	1.570
b_1b_2RCl	9	Grayed Rose Purple (033)	9	9.2	.2	.004
b_1B_2rCl	9	Light Rose (628/1)	7	9.2	2.2	.526
B_1b_2rCl	9	Grayed Deep Rose (031)	15	9.2	5.8	3.656
B_1B_2rcl	9	Salmon Red (025/1)	6	9.2	3.2	1.113

Cross 31 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
--$b_2$rcl	4	Deep Salmon (025/2)	3	4.1	1.1	.295
b_1b_2Rcl	3	Blue Purple (near 937)	5	3.1	1.9	1.164
$b_1B_2$rcl	3	Mid Salmon (0625)	3	3.1	.1	.003
b_1b_2rCl	3	Grayed Light Rose (527)	4	3.1	.9	.261
	256		261	261.9		11.402

P > .50

Cross 32

(Harris Purple x Salmon and White) x Harris Purple

Non-segregating Genes - $IvB_1RsClIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2---	2	Deep Purple Violet (near 732)	37	32.5	4.5	.623
b_2In_1	1	Violet Blue (near 937/3)	16	16.2	.2	.002
b_2in_1	1	Violet Purple (937)	12	16.2	4.2	1.089
	4		65	64.9		1.714

P > .30

Cross 33

(Harris Purple x Salmon and White) x Salmon and White

Non-segregating Genes - $IvB_2sIn_1In_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
--RCl	2	Grayed Purple (near 0027/3)	19	15.8	3.2	.648
---rcl	2	Salmon Scarlet (23/1 to 022)	14	15.8	1.8	.205

Cross 33 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1rCl	1	Light Scarlet, Slightly Grayed (0023)	11	7.9	3.1	1.216
B_1Rcl	1	Deep Purple (733 to near 834/2)	8	7.9	.1	.001
b_1Rcl	1	Grayed Deep Rose (727 to near 727/1)	7	7.9	.9	.102
b_1rCl	1	Grayed Lilac (0027/2)	4	7.9	3.9	1.925
	8		63	63.2		4.097

$P > .50$

Cross 34

Harris Purple x White Perfection

Non-segregating Genes - b_2RClIn_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB_1SDil	81	Deep Magenta (730 to 732/1)	64	75.0	11.0	1.613
iv------	64	Cream (433/3)	62	59.2	2.8	.132
Ivb_1SDil	27	Dark Blue (735 to 934/1)	25	25.0	0.0	.000
IvB_1sDil	27	Violet Purple (834 to 934)	25	25.0	0.0	.000
IvB_1Sdil	27	Magenta (732/2 to 733)	26	25.0	1.0	.040
IvB_1sdil	9	Rose Magenta (830/1)	12	8.3	3.7	1.649
Ivb_1sDil	9	Lilac Magenta (31)	12	8.3	3.7	1.649
Ivb_1Sdil	9	Light Purple Magenta (near 732)	9	8.3	.7	.059
Ivb_1sdil	3	Lilac Pink (29)	2	2.8	.8	.228
	256		237	236.9		5.370

$P > .70$

Cross 35

Harris Purple x Deep Bright Scarlet

Non-segregating Genes - IvB_1 sclDil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RClIn_2	81	Deep Purple (near 732 to 934)	56	61.1	5.1	.426
B_2RClin_2	27	Reddish Violet Purple (834 to near 934)	22	20.4	1.6	.126
B_2rClIn_2	27	Grayed Deep Rose (031 to 931/2)	26	20.4	5.6	1.537
B_2RclIn_2	27	Lilac Rose (28/1 to 29)	15	20.4	5.4	1.429
b_2RClIn_2	27	Reddish Violet Blue (near 934)	22	20.4	1.6	.126
b_2rClIn_2) B_2rClin_2)	18	Grayed Lilac (027/2)	11	13.6	2.6	.497
B_2Rclin_2	9	Violet Purple (937)	1	6.8	5.8	4.947
b_2RClin_2	9	Magenta Purple (29/1 to 735/1)	5	6.8	1.8	.476
B_2rclIn_2	9	Light Salmon Red (625)	6	6.8	.8	.094
b_2RclIn_2	9	Purple Rose (729/1 to 29)	11	6.8	4.2	2.594
B_2rclin_2) b_2rclIn_2)	6	Salmon Red (024)	6	4.6	1.4	.426
b_2Rclin_2	3	Violet Blue (near 36)	6	2.3	3.7	5.952
b_2rClin_2	3	Grayed Salmon Red (near 827)	6	2.3	3.7	5.952
b_2rclin_2	1	Scarlet (022)	1	.8	.2	.050
	256		193	193.5		24.632

$P > .02$

Cross 36

(Harris Purple x Deep Bright Scarlet) x Deep Bright Scarlet

Non-segregating Genes - $IvB_1B_2sIn_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$rClIn_2$	1	Grayed Light Salmon (027/2)	6	8.1	2.1	.544
$RClin_2$	1	Deep Violet (near 732)	9	8.1	.9	.100
$RClIn_2$	1	Carmine (28 to 826)	7	8.1	1.1	.149
$RclIn_2$	1	Rose (23/1 to 729/3)	7	8.1	1.1	.149
$Rclin_2$	1	Deep Crimson Purple (730 to 732/2)	9	8.1	.9	.100
$rClin_2$	1	Grayed Deep Rose (027 to 0027)	12	8.1	3.9	1.878
$rclIn_2$	1	Light Scarlet (022/1)	6	8.1	2.1	.544
$rclin_2$	1	Deep Scarlet (820/1 to 23)	9	8.1	.9	.100
	8		65	64.8		3.564

P > .80

Cross 37

(Harris Purple x Deep Bright Scarlet) x Harris Purple

Non-segregating Genes - $IvB_1RsclIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$--In_1$	2	Deep Purple (near 934/1 to 834)	32	33.5	1.5	.067
B_2in_1	1	Violet Purple (934 to 937/1)	18	16.8	1.2	.086
b_2in_1	1	Violet Blue (735 to 937/3)	17	16.8	.2	.002
	4		67	67.1		.155

P > .90

Cross 38

(Robin x Bright Light Scarlet) x Robin

Non-segregating Genes - $IvB_1B_2rSclIn_1In_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
dil	1	Deep Rose (26)	29	27.5	1.5	.082
Dil	$\frac{1}{2}$	Deep Bright Rose (25)	26	27.5	1.5	.082
			55	55.0		.164

$P > .50$

Cross 39

(Robin x Bright Light Scarlet) x Bright Light Scarlet

Non-segregating Genes - $IvB_2rclDil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$B_1S---In_2$) $B_1Sin_1in_1$)	3	Deep Bright Rose (near 727/1)	14	10.8	3.2	.948
$b_1S---In_2$) $b_1Sin_1in_1$)	3	Bright Mid Rose (26)	12	10.8	1.2	.133
$--SIn_1in_2$	2	Deep Rose (near 26)	11	7.2	3.8	2.005
B_1sin_1---	2	Scarlet (near 021)	6	7.2	1.2	.200
b_1sIn_1---	2	Red Scarlet (820/2)	4	7.2	3.2	1.422
b_1sin_1---	2	Bright Light Scarlet (020)	4	7.2	3.2	1.422
$B_1sIn_1in_1$	1	Bright Scarlet (820/3)	3	3.6	.6	.100
$B_1sIn_1In_2$	$\frac{1}{16}$	Scarlet Salmon (021)	3	3.6	.6	.100
			57	57.6		6.330

$P > .30$

Cross 40

Snowball x Heavenly Blue

Non-segregating Genes - b_1RSIn_1

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
--$ClIn_2Dil$	108	Mid Lilac (633)	132	123.6	.6	.003
--$Clin_2Dil$	36	Deep Lilac (632)	39	41.2	2.2	.117
B_2ClIn_2dil) B_2clin_2dil)	30	Light Lilac (634/1)	38	34.3	3.7	.399
B_2clIn_2Dil	27	Lilac Pink (530)	26	30.9	4.9	.777
B_2clin_2Dil) B_2Clin_2dil)	18	Fading Lilac (635)	25	20.6	4.4	.940
B_2clIn_2dil) b_2ClIn_2dil)	18	Very Dilute Lilac (533/1)	20	20.6	.6	.017
b_2cl---Dil	12	Blue (537 to 636/1)	11	13.7	2.7	.532
b_2cl---dil) b_2Clin_2dil)	7	White	11	8.0	3.0	1.125
	256		293	292.9		3.910

$P > .70$

Cross 41

(Snowball x Heavenly Blue) x Heavenly Blue

Non-segregating Genes - $Ivb_1RSClIn_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2In_2	1	Light Magenta (35/1 to 633)	18	16.2	1.8	.200
B_2in_2	1	Magenta (732/1 to 732)	13	16.2	3.2	.632
b_2In_2	1	Light Blue (637 to 36)	15	16.2	1.2	.089
b_2in_2	1	Deep Blue (35 to 37)	19	16.2	2.8	.484
	4		65	64.8		1.405

$P > .70$

Cross 42

(Snowball x Heavenly Blue) x Snowball

Non-segregating Genes - $b_1B_2RSIn_1In_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
ivcl---) ivCldil)	3	Pure White	23	24.0	1.0	.042
Ivcl---) IvCldil)	3	Light Magenta (633/1 to 732/2)	27	24.0	3.0	.375
IvClDil	1	Magenta (533 to 31)	6	8.0	2.0	.500
ivClDil	1	Very Dilute Magenta (630/3)	8	8.0	0.0	.000
	8		64	64.0		.917

P > .80

Cross 43

(Snowball x Heavenly Blue) x Blue Seedling

Non-segregating Genes - $Ivb_1B_2RIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1	1	Deep Lilac (733/2)	16	16.2	.2	.002
Sin_1	1	Magenta (633 to 735)	14	16.2	2.2	.299
sIn_1	1	Light Blue (636/2 to 636)	18	16.2	1.8	.200
sin_1	1	Mid Blue (36)	17	16.2	.8	.040
	4		65	64.8		.541

P > .90

Cross 44

Snowball x King Henry

Non-segregating Gene - In_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
R^CSIn_1Dil	81	Dull Crimson Purple (near 31)	98	86.7	11.3	1.471
$R\ SIn_1Dil$	27	Lilac Magenta (633)	26	28.9	2.9	.291
R^CsIn_1Dil	27	Crimson Purple (near 732)	26	28.9	2.9	.291
R^CSin_1Dil	27	White Variegated Crimson Purple (733)	19	28.9	9.9	3.390
R^CSIn_1dil	27	White >	25	28.9	3.9	.526
R^CsIn_1dil) $R\ sin_1Dil$)	12	Light Crimson (828)	17	12.8	4.2	1.378
R^Csin---	12	Crimson (830/1)	12	12.8	.8	.050
R^CSin_1dil	9	White Streaked Magenta (732)	10	9.6	.4	.017
$RsIn_1Dil$	9	Rose Crimson (32)	13	9.6	3.4	1.204
$RSin_1Dil$	9	Deep Lilac (633/1 to 633)	11	9.6	1.4	.204
$RSIn_1dil$	9	Light Lilac Rose (630/1)	9	9.6	.6	.038
$RsIn_1dil$) $RSin_1dil$)	6	Lilac Rose (632)	7	6.4	.6	.056
$Rsin_1dil$	1/256	Light Rose (632/2)	1/274	1.1/273.8	.1	.009/8.928

P > .70

Cross 45

(Snowball x King Henry) x King Henry

Non-segregating Genes - $IvB_1R^CClIn_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2-In_1) b_2SIn_1)	3	Purple Crimson (931/2)	27	24.3	2.7	.300
B_2-in_1) b_2sIn_1)	3	Deep Purple Crimson (near 828)	25	24.3	.7	.020
B_2sIn_1	1	Crimson Purple (732/1)	10	8.1	1.9	.446
b_2sin_1	1	Crimson (1030)	3	8.1	5.1	3.211
	8		65	64.8		3.977

P > .20

Cross 46

(Snowball x King Henry) x Snowball

Non-segregating Genes - $B_2SIn_1In_1$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
iv------	8	White	22	31.5	9.5	2.865
Iv--RCl	2	Deep Magenta (31)	10	7.8	2.2	.620
Iv--Rcl	2	Light Magenta (31/1 to 632/2)	11	7.8	3.2	1.313
IvB_1R^CCl	1	Very Deep Rose (25)	3	3.9	.9	.207
Ivb_1R^CCl	1	Deep Rose (826/3)	3	3.9	.9	.207
IvB_1R^Ccl	1	Mid Rose (28/1)	7	3.9	3.1	2.464
Ivb_1R^Ccl	1	Deep Rose Pink (23)	7	3.9	3.1	2.464
	16		63	62.7		10.140

P > .10

Cross 47

Snowball x Lipstick

Non-segregating Genes - B_2ClIn_2dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB_1R---	108	Lilac Rose (629/1 to 630)	89	101.2	12.2	1.471
IvB_1r---	36	Mid Rose (627 to 26)	35	33.8	1.2	.043
Ivb_1RIn_1	27	Lilac (630/1)	24	25.3	1.3	.067
ivB_1RIn_1	27	Cream Tinted Rose (530)	26	25.3	.7	.019
iv--Rin_1) iv--rin_1) ivB_1rin_1)	27	White Tinted (530/2)	27	25.3	1.7	.114
Ivb_1r---	12	Deep Rose (26)	19	11.2	7.8	5.432
ivb_1RIn_1	9	Pale Magenta (near 630)	11	8.4	2.6	.805
Ivb_1Rin_1	9	Light Mauve (30/1)	8	8.4	.4	.019
ivb_1rin_1	1	Creamy White	1	.9	.1	.011
	256		240	239.9		7.981

$P > .30$

Cross 48

Snowball x Harris Purple

Non-segregating Genes - RIn_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1--In_1Dil) B_1clin_1Dil)	117	Magenta (33 to near 33)	112	109.2	2.8	.072
B_1ClIn_1dil	27	Light Magenta Rose (632/2)	16	25.2	9.2	3.359
B_1Clin_1Dil	27	Violet Purple (732 to 834)	28	25.2	2.8	.311

Cross 48 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_1ClIn_1Dil	27	Purple (733 to 934/1)	29	25.2	3.8	.573
b_1--In_1dil) B_1clIn_1dil)	21	White	21	19.6	1.4	.100
b_1--in_1Dil	12	Violet Blue (733)	14	11.2	2.8	.700
b_1clIn_1Dil	9	Blue (533/3 to 34/1)	6	8.4	2.4	.686
B_1Clin_1dil	9	Flushed Lilac (533/2)	4	8.4	4.4	2.305
--$clin_1$dil) $b_1Clin_1$dil)	7	Magenta Rose (632)	9	6.5	2.5	.962
	256		239	238.9		9.068

P > .30

Cross 49

Snowball x Bright Light Scarlet

Non-segregating Genes - b_1B_2cl

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$IvSIn_1In_2$	81	White	56	60.8	4.8	.379
iv-------	64	Cream	51	48.0	3.0	.188
$IvSin_1In_2$) $IvSIn_1in_2$)	54	Light Magenta (533/1 to 633)	38	40.4	2.4	.143
$Ivsin_1In_2$) $IvsIn_1in_2$)	18	Mid Salmon (021)	22	13.5	8.5	5.352
$IvsIn_1In_2$	27	Light Salmon (024/1)	15	20.2	5.2	1.339
$IvSin_1in_2$	9	Mid Rose (628/1)	8	6.8	1.2	.212
$Ivsin_1in_2$	3	Deep Salmon (022/1)	2	2.2	.2	.018
	256		192	191.9		7.631

P > .30

Cross 50

(Snowball x Bright Light Scarlet) x Bright Light Scarlet

Non-segregating Genes - Ivb_1B_2clDil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1In_2	1	Light Rose (26/1)	10	7.8	2.2	.620
SIn_1in_2	1	Deep Bright Rose (28)	7	7.8	.8	.082
Sin_1In_2	1	Carmine (28/1)	6	7.8	1.8	.415
Sin_1in_2	1	Rose Red (25)	6	7.8	1.8	.415
sIn_1In_2	1	Salmon Pink (024/1)	11	7.8	3.2	1.313
sIn_1in_2	1	Light Scarlet Salmon (623)	7	7.8	.8	.082
sin_1In_2	1	Deep Salmon Pink (24/2)	10	7.8	2.2	.620
sin_1in_2	1	Deep Scarlet (820/2)	5	7.8	2.8	1.005
	8		62	62.4		4.552

$P > .70$

Cross 51

Snowball x Deep Bright Scarlet

Non-segregating Genes - B_2cl

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1In_2Dil	81	Light Rose (527/1 to 629/1)	82	79.4	2.6	.085
sIn_1In_2Dil) sIn_1in_2dil)	30	Light Salmon (020/1 to 024/1)	28	29.4	1.4	.067
Sin_1in_2---	36	Deep Rose Veined Deeper (26/1 to 727/1)	28	35.3	7.3	1.510
Sin_1In_2Dil	27	Deep Rose (628 to 629/1)	29	26.5	2.5	.236

Cross 51 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1In_2dil	27	Light Rose Pink (530/2 to 527/2)	24	26.5	2.5	.236
Sin_1In_2dil) Sin_1in_2Dil)	18	Bright Very Deep Rose (25)	14	17.6	3.6	.731
s---In_2dil	12	Creamy White	12	11.8	.2	.003
Sin_1in_2dil	3	Very Deep Rose (025)	4	2.9	1.1	.417
sin_1In_2Dil) sin_1in_2dil)	10	Mid Salmon (427)	15	9.8	5.2	2.759
sIn_1in_2Dil	9	Bright Scarlet (022)	6	8.8	2.8	.891
sin_1in_2Dil	3	Deep Salmon (622 to 0027/1)	4	2.9	1.1	.417
	256		251	250.9		7.352

P > .50

Cross 52

(Celestial Rose x Bright Light Scarlet) x Bright Light Scarlet

Non-segregating Genes - $Ivb_1B_2rclin_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
SIn_1	1	Mid Rose (27)	12	15.0	3.0	.600
Sin_1	1	Deep Rose (727 to 824/3)	19	15.0	4.0	1.067
sIn_1	1	Light Scarlet (721/3)	14	15.0	1.0	.067
sin_1	1	Bright Light Scarlet (020 to 0625)	15	15.0	0.0	.000
	4		60	60.0		1.734

P > .50

Cross 53

(Celestial Rose x Bright Light Scarlet) x Celestial Rose

Non-segregating Genes - $Ivb_1B_2rSclIn_1in_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
Dil	1	Carmine Rose (727/1 to 26)	38	32.5	5.5	.931
dil	1	Light Rose (27)	27	32.5	4.5	.623
	2		65	65.0		1.554

$P > .20$

Cross 54

Silver Blue x Bright Light Scarlet

Non-segregating Genes - b_1in_2

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RSCl	81	Magenta (633/1 to near 934)	72	68.0	4.0	.235
b_2RSCl	27	Lilac Veined (632/2 to 635/2)	22	22.7	.7	.022
B_2rSCl	27	Lilac (537/2 to 632/2)	19	22.7	3.7	.603
B_2RsCl	27	Grayed Rose (0027 to 033)	26	22.7	3.3	.480
B_2RScl	27	Creamy White	20	22.7	2.7	.321
B_2rsCl	9	Grayed Deep Rose (027)	12	7.6	4.4	2.547
B_2rScl	9	Very Light Lilac (537/3)	6	7.6	1.6	.337
B_2Rscl	9	Light Lavender (440)	9	7.6	1.4	.258
b_2rSCl	9	Blue (637 to 37)	11	7.6	3.4	1.521
b_2RsCl	9	Violet Blue (934/1)	5	7.6	2.6	.889

Cross 54 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_2RScl	9	White	5	7.6	2.6	.889
B_2rscl	3	Salmon Pink (527/1)	3	2.5	.5	.100
b_2Rscl	3	Flushed Pink (527/2)	2	2.5	.5	.100
b_2rScl	3	Light Rose (27/1 to 027/1)	5	2.5	2.5	2.500
b_2rsCl	3	Grayed Light Salmon (0027/1)	1	2.5	1.5	.900
b_2rscl	1	Deep Salmon (022/1)	3	.8	2.2	6.050
	256		215	215.2		17.752

$P > .50$

Cross 55

Twinkles x Light Scarlet

Non-segregating Genes - Ivr

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$SClIn_1In_2$	81	Satiny Rose (527 to 027)	84	76.9	7.1	.656
$sClIn_1In_2$	27	Satiny Deep Salmon (024/1 to 024)	26	25.6	.4	.006
$SclIn_1In_2$	27	Very Deep Rose (25 to 824/2)	28	25.6	2.4	.225
$SClin_1In_2$	27	Very Grayed Rose (030 to 033)	24	25.6	1.6	.100
$SClIn_1in_2$	27	Grayed Deep Rose (0027 to 031)	22	25.6	3.6	.506
$sclIn_1In_2$	9	Salmon Scarlet (021/1 to 021)	13	8.5	4.5	2.382
$sClin_1In_2$	9	Grayed Salmon Red (025/1)	5	8.5	3.5	1.441
$sClIn_1in_2$	9	Grayed Deep Salmon (0023 to 724/1)	5	8.5	3.5	1.441

Cross 55 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$Sclin_1In_2$	9	Deep Rose (near 26)	5	8.5	3.5	1.441
$SclIn_1in_2$	9	Bright Mid Rose (727/1)	9	8.5	.5	.029
$SClin_1in_2$	9	Grayed Very Deep Rose (033/1)	6	8.5	2.5	.735
$Sclin_1in_2$	3	Deep Rose Red (824)	3	2.8	.2	.014
$sClin_1in_2$	3	Light Grayed Salmon Red (26/2)	1	2.8	1.8	1.157
$sclIn_1in_2$	3	Mid Salmon (024)	3	2.8	.2	.014
$sclin_1$---	4	Light Scarlet (721/1 to 721/3)	9	3.7	5.3	7.592
	256		243	242.4		17.729

$P > .20$

Cross 56

White Perfection x Celestial Rose

Non-segregating Genes - b_1SIn_1dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RClIn_2	81	Rose Lilac (629)	39	37.6	1.4	.052
b_2RCl---	36	Lilac Rose (630)	22	16.7	5.3	1.682
B_2r--In_2	36	Light Rose (26/1)	18	16.7	1.3	.101
B_2RclIn_2	27	Pale Lilac (433)	12	12.6	.6	.029
B_2RClin_2	27	Lilac (630/1)	12	12.6	.6	.029
B_2rClin_2) b_2rClIn_2)	18	Mid Rose (628)	3	8.4	5.4	3.471
B_2Rclin_2	9	Light Lilac (530)	4	4.2	.2	.010

Cross 56 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_2RclIn_2	9	Very Pale Magenta (533/3)	2	4.2	2.2	1.152
B_2rclin_2) b_2rClin_2) b_2rclIn_2)	9	Deep Rose (26)	5	4.2	.8	.152
b_2Rclin_2	3	Lavender Lilac (30/1)	2	1.4	.6	.257
b_2rclin_2	1	Carmine	0	.5	.5	.500
	256		119	119.0		7.435

$P > .50$

Cross 57

(White Perfection x Celestial Rose) x Celestial Rose

Non-segregating Genes - $Ivb_1B_2SIn_1dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
R--	2	Lilac (632 to 629)	31	32.0	1.0	.031
rCl	1	Very Deep Rose (25)	16	16.0	0.0	.000
rcl	1	Deep Rose (26/1)	17	16.0	1.0	.062
	4		64	64.0		.093

$P > .95$

Cross 58

(White Perfection x Celestial Rose) x White Perfection

Non-segregating Genes - $b_1RSClIn_1In_2dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB_2	1	Magenta (31)	11	15.5	4.5	1.306
Ivb_2	1	Light Magenta (632/1)	16	15.5	.5	.016

Cross 58 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
ivB_2	1	Dilute Magenta (633/1)	20	15.5	4.5	1.306
ivb_2	1/4	White	15	15.5	.5	.016
			62	62.0		2.644

$P > .30$

Cross 59

Winsome x Violet Purple Seedling

Non-segregating Gene - Iv

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RIn_1Dil	81	Red Purple (near 830/1 to 830)	85	71.2	13.8	2.675
B_2rIn_1Dil	27	Purple Magenta (28 to 828)	21	23.7	2.7	.308
b_2RIn_1Dil	27	Red Violet Purple (near 730 to 733)	18	23.7	5.7	1.371
B_2RIn_1dil	27	Purple (31 to 730)	21	23.7	2.7	.308
B_2Rin_1Dil	27	Deep Red Violet Purple (834)	23	23.7	.7	.021
$--rIn_1dil$	12	Light Rose (28/1 to 628)	15	10.5	4.5	1.929
b_2rIn_1Dil	9	Lavender Rose (630)	4	7.9	3.9	1.925
b_2RIn_1dil	9	Light Magenta (28/1)	9	7.9	1.1	.153
b_2Rin_1Dil	9	Bright Deep Reddish Violet Purple (732)	7	7.9	.9	.102
B_2rin_1Dil	9	Rose Purple (732/1)	6	7.9	1.9	.457
B_2Rin_1dil	9	Deep Lilac Rose (near 29)	7	7.9	.9	.102

Cross 59 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2rin_1dil	3	Bright Mid Rose (26)	3	2.6	.4	.062
b_2rin_1Dil	3	Lilac Rose (629)	1	2.6	1.6	.985
b_2Rin_1dil	3	Lavender Magenta (632)	2	2.6	.6	.138
b_2rin_1dil	1	Mid Rose (26/1)	3	.9	2.1	4.900
	256		225	224.7		15.431

$P > .30$

Cross 60

White Perfection x Salmon and White

Non-segregating Genes - $b_1In_1In_2$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_2RSDil	81	Magenta (630 to 632/1)	69	70.2	1.2	.020
b_2RSDil	27	Pale Magenta (632/2)	25	23.4	1.6	.109
B_2rSDil	27	Lilac Rose (629/1 to 630/1)	27	23.4	3.6	.554
B_2RsDil	27	Magenta Purple (629 to 733/1)	27	23.4	3.6	.554
B_2RSdil	27	White	23	23.4	.4	.007
B_2rsDil) b_2RSdil)	18	Light Lilac Veined Red (601/3)	8	17.6	9.6	5.236
B_2rSdil	9	Lavender Veined Purple (533 to 29/2)	8	7.8	.2	.005
b_2RsDil	9	Bright Magenta (632)	11	7.8	3.2	1.313
b_2rSDil	9	Dull Salmon Lilac (530)	8	7.8	.2	.005
B_2Rsdil	9	Rose Pink Veined Red (530/1)	4	7.8	3.8	1.851

Cross 60 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
b_2Rsdil) b_2rSdil)	6	Cream Flushed (533/2 to 632/1)	9	5.2	3.8	2.777
$b_2$rsDil) B_2rsdil)	6	Deep Salmon (0625)	6	5.2	.8	.123
$b_2$rsdil	1/256	Salmon	0	.9	.9	.900
			222	221.9		13.454

P > .30

Cross 61

Winsome x Silver Blue

Non-segregating Genes - SClIn$_1$in$_2$dil

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB$_1$B$_2$R	81	Magenta (31 to near 732)	80	67.4	12.6	2.355
ivB$_1$B$_2$R	27	Lavender Veined Deeper (630/2 to 635/1)	23	22.5	.5	.011
Ivb$_1$B$_2$R	27	Red Violet Purple (730/1 to 033)	19	22.5	3.5	.544
IvB$_1$b$_2$R	27	Violet (near 732/1)	17	22.5	5.5	1.344
IvB$_1$B$_2$r	27	Rose (near 630 to 26)	17	22.5	5.5	1.344
iv----r	16	Cream	16	13.3	2.7	.548
iv--b$_2$R	12	Cream Veined Red (601/3 to 630/2)	10	10.0	0.0	.000
Ivb$_1$b$_2$R	9	Light Magenta Blue (33)	7	7.5	.5	.033
Ivb$_1$B$_2$r	9	Light Magenta (632)	10	7.5	2.5	.833

Cross 61 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
IvB_1b_2r	9	Lavender (630 to 630/1)	7	7.5	.5	.033
ivB_1b_2r	9	Cream Veined Purple (533)	7	7.5	.5	.033
Ivb_1b_2r	3	Pale Blue	0	2.5	2.5	2.500
	256		213	213.1		9.578

$P > .50$

Cross 62

(Winsome x Silver Blue) x Silver Blue

Non-segregating Genes - $RSClIn_1in_2dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$iv--B_2$	2	Lavender Heavily Veined (637/2)	18	16.2	1.8	.200
ivb_1b_2	1	Lavender Veined Deeper (533/1)	9	8.1	.9	.100
ivB_1b_2	1	Orchid Veined Deeper (32)	8	8.1	.1	.001
IvB_1B_2	1	Purple Magenta (31)	8	8.1	.1	.001
Ivb_1B_2	1	Deep Purple (730)	5	8.1	3.1	1.186
IvB_1b_2	1	Magenta Blue (34 to 35)	10	8.1	1.9	.446
Ivb_1b_2	1	Violet Blue (735)	7	8.1	1.1	.149
	256		65	64.8		2.083

$P > .90$

Cross 63

Winsome x Mid Salmon

Non-segregating Genes - Ivr

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1SIn_1Dil	81	Deep Rose (26 to 27/1)	79	73.4	5.6	.427
--Sin_1Dil) B_1Sin_1dil)	45	Bright Mid Rose (628)	36	40.8	4.8	.564
--SIn_1dil) b_1SIn_1Dil)	63	Light Rose (24/2)	50	57.1	7.1	.883
B_1sIn_1Dil	27	Deep Salmon (022)	25	24.5	.5	.010
B_1sIn_1dil) b_1sIn_1Dil) b_1sin_1dil)	19	Light Salmon (523)	19	17.2	1.8	.188
B_1sin_1dil) b_1sin_1Dil)	6	Mid Salmon (021)	10	5.4	4.6	3.918
B_1sin_1Dil	9	Bright Mid Salmon (622)	5	8.2	3.2	1.249
b_1Sin_1dil	3	Light Rose Pink (530/2)	2	2.7	.7	.181
b_1sIn_1dil	3	Very Light Salmon (623/1)	6	2.7	3.3	4.033
	256		232	232.0		11.453

$P > .10$

Cross 64

(Bright Mid Salmon x Silver Blue) x Bright Mid Salmon

Non-segregating Genes - Not Known

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$RSin_2$	1	Dull Magenta Purple (near 732/2)	10	8.0	2.0	.500
$RSIn_2$	1	Purple (near 1030/3)	5	8.0	3.0	1.125

Cross 64 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$RsIn_2$	1	Lilac Rose (28 to 632)	9	8.0	1.0	.125
$Rsin_2$	1	Grayed Deep Rose (030)	6	8.0	2.0	.500
$rSIn_2$	1	Dull Deep Rose (26)	10	8.0	2.0	.500
$rSin_2$	1	Very Grayed Rose (030/1 to 031/1)	6	8.0	2.0	.500
$rsIn_2$	1	Grayed Lilac (0027/2)	9	8.0	1.0	.125
$rsin_2$	1	Deep Salmon (022/1)	9	8.0	1.0	.125
	8		64	64.0		3.500

$P > .80$

Cross 65

Blue Seedling x Deep Bright Scarlet

Non-segregating Genes - $Ivclin_1Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
$--B_2RS$	108	Magenta (031/1 to 632)	72	80.6	8.6	.918
B_1b_2RS	27	Magenta Purple (near 732 to 733)	18	20.1	2.1	.219
B_1B_2rS	27	Satiny Rose (027 to 0027)	25	20.1	4.9	1.194
B_1B_2Rs	27	Rose (28 to 729/1)	23	20.1	2.9	.418
b_1b_2RS	9	Magenta Blue (35/1 to 35/2)	5	6.7	1.7	.413
b_1B_2Rs) B_1b_2Rs)	18	Very Deep Carmine (729/1)	14	13.4	.6	.027
b_1B_2rS	9	Lilac Pink (530 to 031/2)	8	6.7	1.3	.252
B_1b_2rS	9	Mid Lilac Blue (34)	6	6.7	.7	.073

Cross 65 Continued

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
B_1B_2rs	9	Mid Salmon Pink (near 24/2)	6	6.7	.7	.073
B_1b_2rs	3	Deep Salmon (0023/1 to 024/1)	4	2.2	1.8	1.473
b_1--rs	4	Scarlet Red (near 721/2 to 022)	4	3.0	1.0	.333
b_1b_2Rs	3	Deep Blue (near 36)	3	2.2	.8	.291
b_1b_2rS	3	Mid Blue (36)	2	2.2	.2	.018
	256		190	190.7		5.721

$P > .90$

Cross 66

(Harris Purple x King Henry) x King Henry

Non-segregating Genes - $IvB_1b_2sClIn_1In_2Dil$

Genotype	Ratio	Color	Obs.	Exp.	Diff.	D^2/e
R^CR^C	1	Purple Crimson (near 931)	28	30.0	2.0	.133
R^CR	1	Crimson Purple (near 931)	32	30.0	2.0	.133
	2		60	60.0		.266

$P > .50$

Cross 67

(Harris Purple x King Henry) x Harris Purple

Non-segregating Genes - $IvB_1b_2sClIn_1In_2Dil$

Discarded, by mistake, before exact data was taken. Contained Crimson Purple (near 931) and Violet Purple (937) only.

Cross 68

(King Henry x Deep Bright Scarlet) x King Henry

Non-segregating Genes - $IvB_1R^CsClIn_1In_2Dil$

All Crimson (827)