GENETIC STUDIES OF CHRYSANTHEMUMS

by

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INTRODUCTION

Although chrysanthemums have occupied a prominent position among greenhouse and garden flowers for a long time, the genetical study of this flower represents an almost untouched field. Two Japanese workers have made some contributions to the study of the various species of chrysanthemum, but not the species studied in this investigation.

There are many species of chrysanthemums, but the greenhouse and garden varieties belong to Chrysanthemum hortorum W. Mill. Unless otherwise noted, the word chrysanthemum as used in this work will mean that particular species. This species has a high chromosome number. Most varieties are heterozygous, and therefore do not breed true to seed. As a result the plant is seldom propagated by seed except to secure new varieties, but since the young succulent shoots arising from stolons root easily, any desirable variety can be carried on from year to year by cuttings.

Chrysanthemums rank third in importance among greenhouse crops although the blossoming season is of short duration in the fall. They are also a favorite garden flower in regions where blooming may occur before freezing weather prevails.

While chrysanthemum breeding has been carried on in Europe and the Orient as well as in this country for over

one hundred years, little scientific work has been published on the genetics of chrysanthemum. In this investigation it was decided to study genetically some of the varieties of chrysanthemums and their offspring when crossed, and to secure if possible new varieties suitable for commercial greenhouse use. Greenhouse varieties were used in the experiment but a plan for testing some of the seedlings for garden use is now under way.

REVIEW OF LITERATURE

Introduction and History

That the chrysanthemum derived its name from the Greek words, "chrysos", gold and "anthos", a flower was suggested by Morton (1891). It is an extensive genus of composite plants and includes species which are found native in Asia, North Africa, Asiatic Turkey, Hungary, Austria, Spain, France, Great Britain, United States, Russia, Switzerland, Italy, Sicily, Mexico, India, China, and Japan. The species that are native to India, China, and Japan are the progenitors of our common varieties for greenhouses and gardens and are the ones most usually denoted by the comprehensive word chrysanthemum.

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one hundred years, little scientific work has been published on the genetics of chrysanthemum. In this investigation it was decided to study genetically some of the varieties of chrysanthemums and their offspring when crossed, and to secure if possible new varieties suitable for commercial greenhouse use. Greenhouse varieties were used in the experiment but a plan for testing some of the seedlings for garden use is now under way.

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Bahr (1937) stated that while the season of the chrysanthemum is over in about ten weeks, yet everything else in

of chrysanthemums. In these works the history was taken up from 550 B. C. to the present time giving the date of introduction of the new types, the date of introduction of chrysanthemums into England, France, and the United States and the originators of new seedlings in each country.

The hairy variety, Mrs. Alphicus Hardy, was sold for $1,500.00 in 1888 and started the chrysanthemum craze in America. Charles Totty of Madison, New Jersey has originated and distributed many greenhouse and garden varieties. The firm of Dreer of Philadelphia under the guidance of Eugene H. Mitchel has taken the lead in popularizing the garden varieties of chrysanthemums. Elmer D. Smith of Adrian, Michigan is the outstanding figure of American breeders. Mr. Smith's first variety was introduced in 1890. He consistently kept accurate records of his crosses. In all, Elmer Smith originated, named, and disseminated over 425 varieties, many of which have stood the test of years and are still looked upon with favor. American breeders of out-door chrysanthemums who have contributed many new varieties lately are E. M. Byrnes, J. W. Byrnes and F. L. Mulford of the United States Department of Agriculture, V. R. DePetris, of Detroit, Michigan, Alex Cumming, Jr., of Bristol, Connecticut, and Bauer and Steinkemp of Indianapolis, Indiana.

Taylor (1936) stated that since the hybridizer began his work in the United States about 3,000 varieties have been grown and listed. The majority of these are not hardy and

must be grown under glass. Each year new varieties are disseminated, while others are discarded and not over 75 or 80 varieties are extensively cultivated in any one period of years.

Sports

Chrysanthemums sport or mutate quite frequently and many new varieties are formed by this method.

Morton (1891) stated that the "sports" are due to the kindly assistance of nature. It appears that any color is capable of sporting into any color peculiar to the chrysanthemum. All four varieties of Cedo Nulli have sprung from one. The Queen of England has sported into six different colors.

Shamel (1918) listed 400 varieties originating from bud sports. Bud variation in chrysanthemums occasionally show so complete a change of form as to put the new plant in another class. For example the reflexed carmine, King of Crimsons, produced vegetatively the carmine anemone variety, Mrs. R. A. Murdie; the incurved white John Bradner came from the reflexed White Christine Caine. Flowers from one color become striped as in the case of the striped Queen of England sport which came from the red Queen of England. The variation of vegetative parts is not as common as blossom variations. Some varieties are not known to have ever produced bud

variations as Nonpareil which has been grown for 60 years.

Writing of sports, Herrington (1917) said:

> It is curious that a variety will often remain true to itself for several years, then suddenly, and sometimes, simultaneously in widely remote places, will develop sporting proclivities with exactly similar results: a sport identically alike in all respects having been known to appear in three or four separate places the same year.

Emsweller et al. (1937) found that the production of bud sports or mutations has also played a rather important role in the development of the chrysanthemum. The mutation rate is undoubtedly higher in some varieties than in others.

Species of Chrysanthemums

There are many related species of Chrysanthemum according to Cumming (1939), but with few exceptions they are of little garden value. A few species are given here which are of value for breeding or garden use.

Chrysanthemum hortorum. Any cultivated chrysanthemum supposedly derived from inter-breeding the species C. indicum and C. morifolium.

Chrysanthemum arcticum (Arctic Daisy). A remarkably hardy and somewhat deciduous species in nature. It is of dwarf stature and has single flowers one and one-half to two inches in diameter, white in color and shading to pink when mature. Arcticum breeds readily with garden varieties, but after six generations of its hybrids using intercrossing,

inbreeding and outbreeding, all attempts were of no avail in adding hardiness to commercial varieties.

Chrysanthemum coreanum (Korean Daisy). It has the appearance of C. articum only it is taller. Single flowers open pure white changing to pink. It crosses with C. hortorum to form Korean hybrids.

Chrysanthemum coccineum (Colored Daisy). This is the Pyrethrum hybridum of commerce. Interbred with the garden chrysanthemum it has proved of value as a pollen parent; although hybrids so far have been dominantly chrysanthemum. C. coccineum is not susceptible to the insects which malform or destroy most early hybrid chrysanthemums.

Chrysanthemum maximum (Shasta Daisy). There exists little affinity between this and the garden chrysanthemum but as a pollen parent this species has possibilities, although so far the hybrids have lacked hardiness.

Chrysanthemum morifolium. A native species found in China and Japan. It was originally a single flower but a double form appeared in 910 A. D. The single flowers varied from white to pink or yellow with a prominent yellow disc. It has not proved desirable for breeding purposes.

Chrysanthemum nipponicum (Nippon Oxeye Daisy). This species is found native only in Japan. It is shrub-like with woody deciduous stems and oblong leathery leaves. Flowers are single, three inches or more across and pure white. It crosses readily with garden varieties.

Chrysanthemum uliginosum (Giant Daisy). A species that comes from Hungary. It is an erect growing plant that may be six feet tall. Flowers are single and measure from two and one-half to three inches across. The color is pure white. Species crosses with this so far have been unsuccessful.

Chrysanthemum indicum. A native species found in Japan and China. This species has miniature pure yellow, single blossoms that are seldom more than one-half inch across and are carried on dainty sprays. This species is not very hardy but blossoms early thus escaping frost.

Most of the cytological studies on chrysanthemums have been made in Japan. Below is a partial list of species showing the chromosome number for somatic tissue as reported by Gaiser (1930) from the work of Tahara and Shimotomai.

Species	Somatic chromosome number
Chrysanthemum alpinum L.	36
" articum L.	90
" carinatum	18
" cinerariifolium	18
" coronarium L.	18
" Decaisneanum	72
" hakusanense	54
" indicum L.	36
" japonicum	18
" Lecanthemum	36
" marginatum	90
" morifolium	54
" nipponicum	18
" segetum	18
" hybridum	54

Shimotomai (1934b) added others to the list.

Chrysanthemum	roundifolium	18
"	japonese	54
"	sibiricum	54
"	ornatum	72
"	maximum	72
"	pacificum	90

Shimotomai (1934a) reported that in Japan the high polyploid types are found naturally near the coast and the low polyploid numbers are found in the higher areas. Crosses between wild and different chromosome multiples as a rule gave true breeding hybrids. C. japonese (54 chromosomes) x C. pacificum (90 chromosomes) gave a constant hybrid with 72 chromosomes. C. Makinoi (18 chromosomes) x C. Decaisneanum (72 chromosomes) gave an F_1 with 72 chromosomes, while C. Makinoi (18 chromosomes) x C. japonese (54 chromosomes) produced an F_1 with 63 chromosomes.

In his studies of twenty closely related garden varieties Shimotomai secured chromosome numbers for the somatic tissue of 53, 54, and 55. In another group of 40 distinct varieties he secured chromosome numbers of 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, and 63.

Emsweller et al. (1937) reported a hybrid C. marginatum (90 chromosomes) x C. morifolium (54 chromosomes) that was highly fertile and contained 144 chromosomes.

Bleier (1934) reported on the crossing of different species of plants. He cited Shimotomai's work on chrysanthemums. In most cases the hybrids between different chrysanthe-

mum species formed bivalents in the meiotic division, but in some cases univalents were noted. Trivalents and quadrivalent association of the chromosomes in meiotic division was noted in a few cases.

Univalent, trivalent, and quadrivalent association of chromosomes leads to irregular inheritance and ratios quite different from the expected diploid association of chromosomes. A discussion of monosomic, trisomic and tetrasomic inheritance is too large a study to include in this work. Sansome and Philp (1932) gave a good discussion on this subject. Thus from the cytogenetic point of view, the frequent occurrence of aneuploids and euploids among chrysanthemum species suggests that in C. hortorum, which has a high chromosome count, there would be expected variations occasionally from the expected diploid ratios and that there would be evidence of polymeric factors.

Genetics of Chrysanthemum

There is very little scientific work published in this country on the inheritance of characteristics in chrysanthemum. Shimotomai has done considerable genetic work on the Japanese types but most of the work is published in Japanese bulletins unaccessible to this writer.

Emsweller et al. (1937) wrote that one of the greatest difficulties encountered by the chrysanthemum breeder is the

failure of many fine varieties to set seed. In some cases this is due to actual sterility and in others it is due to extreme doubleness of the flower. Smith (1913) found that in some of the improved varieties further improvement is prevented owing to the pistils or styles being abortive. In others the staminate florets provide little or no pollen.

Mulford (1937a) reported that the type of chrysanthemum flower greatly influences seed setting. The florets are of two types, disk which are perfect and ray which are pistillate. The disk florets are in the center of the head and in general their number is correlated with the degree of singleness of the entire head. In the double and extreme double types their number is usually greatly reduced. The ray or pistillate florets occur in the outer edge of the flower head and as they are pistillate they will set seed only when pollinated by pollen from other florets. The disk or perfect florets in chrysanthemums are so constructed that under optimum conditions self-fertilization is very high unless some sort of incompatibility is present. The style is completely surrounded by a column of anthers, which in turn are enclosed by a tightly folded corolla. Just prior to and during anthesis the style elongates, pushing the stigma up through the dehisced anthers. In some instances the elongation of the style may precede dehiscence and the flower may not be pollinated. It has been observed that some pistillate stigmas were pollinated by adjacent disk florets, but in

general as the number of disk florets increases there is a greater number of seed per head. Extreme doubles may have ten seeds and singles may have 250 seeds.

Laurie and Poesch (1939) considered color, size, form, fullness of bloom and manner of growth, are the important characteristics with which the breeder deals in the improvement and production of new varieties. Dwarfness and tallness, size and texture of the foliage are the characters that lend themselves most readily to the operators' will. It is possible to begin with pompons and increase their size gradually by using larger flowering types. Small baby pompon types like "Baby Doll" are the result of using the original variety known as Baby as the pistillate parent and moderately small pompons as staminate parents.

In general, better results are obtained when the crosses are made between plants of similar characteristics. Violent crosses are not nearly so reliable because of the increased amount of variation in the resultant seedlings. Hybridizing for color presents many difficulties. There are a number of variable factors concerned that may be so linked as to make a definite combination impossible.

Smith (1913) felt that it is beyond all human power to obtain exact results in uniting or mixing the colors of petals. There is more assurance of obtaining desired colors when varieties of that same color are crossed.

Smith and Laurie (1928) stated that earliness and late-

ness are best secured when varieties which mature at similar periods are used for parents. Breeding for proper texture of the stem is of considerable importance. Some varieties possessing excellent flower characteristics have weak stems, while others have strong and woody stems. Seedlings from weak stemmed varieties show this characteristic to a marked degree and often the characteristic is much more pronounced than in the original.

Mulford (1935) wrote that since early varieties are very limited for outdoor growth in the northern states, work was started by the United States Department of Agriculture to find suitable varieties. The work started by testing many varieties and seedlings for hardiness. Seedlings were raised from the ten earliest varieties. One hundred of the earliest plants were selected from this group. Selection was continued for several years and it was found that the percentage of early blooming seedlings increased each year. A good range of color in various types was secured. Mulford (1939) reported that in 1937 twelve seedlings that had shown promise for hardiness were introduced to the trade.

Mulford (1937b) placed 24 clonal lines under cloth cages for self-pollination. Only eight lines gave viable seed and only four clones gave enough seed for study. One single was homozygous for singleness, one single gave 93.33 per cent single, and 6.67 per cent double. One single gave 86.93 per cent single, 6.42 per cent semi-double and 6.65 per cent double.

The double gave 50.91 per cent singles, 14.54 per cent semi-doubles, 32.72 per cent doubles, and 1.82 per cent extreme doubles. The seedlings exhibited a wide range in size but usually averaged smaller than the parents. The parent with the largest flowers gave none as large, while the other gave some larger than the parents. The color varied within the selfed line. Clone one which has deep pink flowers gave 60 per cent rose, 13.33 per cent pink, 13.33 per cent white, 6.66 per cent yellow and 6.66 per cent red. Clone two which has white petals gave 69.09 per cent white, 12.73 per cent blush, 10.91 per cent pink, 3.64 per cent rose, and 3.64 per cent yellow. Clone 12 which is pink gave 40.14 per cent white, 21.79 per cent pink, 21.56 per cent blush, 10.55 per cent rose, 3.67 per cent yellow, 1.15 per cent bronze and 1.15 per cent deep pink. Clone 21 which is pink gave 36.17 per cent deep pink, 21.28 per cent pink, 19.15 per cent white, 10.64 per cent bronze, 8.51 per cent yellow and 4.25 per cent blush.

Mulford (1938) obtained a wide variation in the clone in time of blooming. Three varieties showed no significant variation in time of bloom from year to year. A few showed no significant variation between two of the three years under study, while the other showed a great difference in time of blooming from year to year.

Cumming (1939) gave a few objectives for plant breeding in garden chrysanthemums as follows: added hardiness, early

flowering varieties capable of resisting hot weather and of producing flowers throughout the season, a tough foliage texture to better resist insects, better flower substances or texture to withstand early frosts, dwarf types suitable for edging, bordering and rock gardens, larger double varieties that will respond to disbudding and resist bad weather conditions, added fragrance, and new solid colors or combinations of colors.

Genetics of China Aster

Many of the forms, sizes and colors of chrysanthemums are also found in the China aster. China asters have the same chromosome unit number as chrysanthemums and belong to the same plant family. Asters have a 2n number of 18 chromosomes and are readily propagated by seed, usually breeding true. Therefore, since there has been little scientific work done on chrysanthemum it was thought desirable to include work done on China asters. Wit (1937) has published a comprehensive report on China aster (Callistemma chinensis).

It was found that the inheritance of type of flower could be explained by assuming four genes in a system as follows:

Quilled	DDTTOORR
Single	DDttOORR
Sunshine	DDTTooRR
Single Ostrich Plume	DDttooRR
Common Double	ddttooRR
Ray	ddttoorr

Growth habits of the plant seemed to be controlled by three sets of genes, thus:

Wild type or tall	PPNNCC
Dwarf type or Nana	PPnnCC
Pyramid type or Pyramidalis	ppNNCC
Compact type or Compacta	PPNNcc
Nana pyramidalis	ppnnCC

Color is controlled by various factors. W gives the standard amounts of pigment. $w^d w^d$ gives dilute colors and ww gives no anthocyanin. I is incompletely dominant to i and darkens the color making purple and red shades more blue. S is incompletely dominant to s and influences the resistance of colors to bleaching and the sunlight, so colors are fast and intense. Pa determines the amount of pigment, pa pa plants are pale. M determines the glucoside types of the anthocyanin. The M types have two sugar residues attached at the anthocyanidin molecule, while all m m types have only one. The diglycosidin type is dominant and the color slightly bluer and deeper. R is the dominant one of the three allels, R-r'-r which causes the differences between the blue, purple and red shades. Flowers of RR, Rr', and Rr are blue or violet, r'r' and r'r have lilac or purple colors, while rr plants bear pink or red flowers.

Aster colors seem to fall in the following groups:

WRMPaIS	Violet blue	Wr'MPaIS	Purple
WRMPaIs	Violet	Wr'MPaIs	Violet purple
WRMPaiS	Blue	Wr'MPaiS	Lilac
WRMpaiS	Pale purple	Wr'MPais	Purple lilac
WRmPaIS	Fading violet	Wr'MpaiS	Pale lilac
WRmPaIs	Brown violet	Wr'mPaIS	Fading purple
WRmPaiS	Slaty blue	Wr'mPaIs	Brown purple
w^dRMPaiS	Dilute blue	Wr'mPaiS	Slaty lilac
w^dRmpaiS	Dilute purple	w^dr'MPaiS	Dilute lilac
w^dRmPaiS	Dilute slaty		
WrMpaIS	Carmine		
WrMPaIs	Deep carmine		
WrMPaiS	Deep pink		
WrMPais	Salmon pink		
WrMpaiS	Shell pink		
WrmPaIS	Scarlet pink		
WrmPaIs	Scarlet		
WrmPais	Red		
w^drMPaiS	Dilute pink		
w^drMpaiS	Dilute shell		
w^drmPaiS	Dilute salmon		

Color Inheritance

That flowers may be conveniently divided into the three color classes, white, yellow, and red and blue was reported by Crane and Lawrence (1938). Variation within these classes comprises intensification, dilution, increase in redness, or increase in blueness. In recent years collaboration between geneticists and biochemists has yielded accurate information concerning the chemical basis of floral pigmentation and the parts played by the genes in determining the nature and amounts of the substances responsible. The great majority of such substances are either anthocyanins, anthoxanthins, or plastid pigments.

Anthocyanins. The anthocyanins are responsible for the scarlet, red and blue shades that predominate among flowers. They occur in the plant as sap-soluble glucosides, that is, they are compound molecules of true coloring matter plus one or more molecules of a sugar.

Anthoxanthins. Crane and Lawrence (1938) remarked that anthoxanthins are closely related chemically to the anthocyanins, but differ in color, ranging from pale ivory to deep yellow. They are sap-soluble and usually occur as glucosides. Structural variation is greater than in the case of the anthocyanidins, but the majority are analogous and fall into two classes, the flavones and flavonols.

The four ways in which anthoxanthins may be concerned with flower color are:

(a) In flowers which have no anthocyanin the anthoxanthin may be directly responsible for all the color.

(b) If a yellow flower anthoxanthin occurs together with an anthocyanin, the resultant color is a blend if the color is in the same cell, but if the pigments are in different cell layers there is a background effect.

(c) In the presence of anthocyanins, ivory anthoxanthins do not contribute independently to the color, but do so indirectly by their "copigmenting" action. Copigments are substances which when present in the same solution as the anthocyanins form weak additive complexes that are much bluer than the anthocyanins alone. It is possible

that 70 per cent of the garden flowers are copigmented, to some extent at least.

(d) The structural similarity of the anthocyanins and the anthoxanthins suggests that their synthesis in the plant may be correlated. Evidence from dahlia suggests that the two classes of substances are formed from the same starting material which is limited in quantity. Thus the presence of much anthoxanthin may lead to almost complete suppression of anthocyanin producing delicately flushed flowers, and if there is copigmentation the result may be a modification of color as well as intensity.

Scott-Moncrieff (1936) reported that in the salmon varieties of Papaver rhoeoes, Lathyrus odoratus and other flowers, the flavone also appears to protect the unstable anthocyanins from bleaching, shrivelling, or "burning" in the sunlight.

Plastid Pigments. Lawrence and Price (1940) wrote that although there are no chemical or genetical data on the inheritance of the non-sap-soluble flower pigments, some mention of these must be made. They comprise a number of yellow or orange substances, xanthophylls and carotins, which are carried by plastids or are dissolved in oils. In the absence of the anthocyanins the non-sap-soluble flower pigments are either solely responsible for flower colors, or are supplemented by yellow anthoxanthins.

MATERIAL AND METHODS

The Commercial Floriculture class at Kansas State College in 1939 made 19 crosses involving 15 varieties of chrysanthemums. All of the plants were grown in the Horticulture Department Greenhouse. In 1940, 16 of these crosses, comprising a total of almost 600 plants, were found suitable for genetical study. Detailed records were kept on the flowers, time of blooming, defects and perfections of each of the plants. Forty-one seedlings were selected for future trial. During 1940, the Ridgeway Color Standards (1912) were used as a guide for color determinations, but in 1941 the process was simplified by using a sheet based on Ridgeway's color terms. Seed from additional crosses, self-pollinated plants and open-pollinated plants were secured for 1941. Cuttings of each of the 41 seedlings were made and grown for pot and bed trials. All the seedlings and pot plants were started in the greenhouse, transferred to the cloth house during the summer and then returned to the greenhouse in September. All cuttings planted in the bed were started in sand and placed in pots until ready for the bed in July. Over 1,000 plants were studied in 1941. Twenty-two of the 1940 selections were saved in 1941 along with 25 from seedlings of the 1940 crosses.

Technique of Crossing. Chrysanthemums are very easily crossed and full instructions can be found in most books on chrysanthemums.

The plants used as the female parent were grown in four inch pots filled with soil of medium fertility. These plants were kept in a house of low relative humidity and watered sparingly. Flowers partially open were selected and all of the perfect florets in the center were removed. Since the stigmas which receive the pollen are hidden by the petals, the petals were cut off with a razor just above the stigma. The flower was then covered with a paper or light cellophane bag to keep away foreign pollen. As the flowers developed the stigmas protruded above the cut petals and became receptive. A camel hair brush was used to transfer pollen from the desired male to the stigmas. The brush was dipped in 95 per cent alcohol after each cross to kill the pollen as more than one cross was made with the same brush. Pollen was added daily whenever the sun shone enough to cause the pollen to be shed. Plants were pollinated between 10 A. M. and 3 P. M. depending upon the availability of pollen. Most of the double flowers were receptive over a ten day period, and were pollinated often to secure best results.

After the seed was set the plants were watered sparingly until the seed matured, which took almost two months. Seed was then taken from the plant, cleaned, and stored.

In the early spring about March 1, the seeds were planted in a sandy loam soil of low to medium fertility. The seeds were covered lightly with sand, and watered from the bottom. The seed flats were placed in a cool room until germination was complete. The seed flats were watered sparingly, but were never allowed to dry out. In about two weeks the seedlings emerged and about ten days later were ready to place in two inch pots.

During the summer the seedlings were transplanted twice and finally allowed to flower in five inch pots. The plants in pots were transferred to the cloth house for the summer and were returned to the greenhouse October 1. The seedlings were usually watered twice daily. From June 15 to September 1 they were fed every two weeks with a fertilizer of 10-20-0 using one ounce to the gallon of water. The plant tops were pinched out every two weeks from June 1 to September 1 to secure a bushy growth. Plants were sprayed regularly to control insects.

Cuttings from 1940 Selections. From the 41 selected seedlings the tops were cut off in the fall and the plants placed in a cold house for a dormant period. In the early spring the plants were placed in a warmer house and watered more frequently to secure succulent shoots. These shoots were made into cuttings about four inches long and rooted in sand.

After the cuttings had rooted they were transferred to

two and one-half inch pots and later shifted to four inch pots if used for bed stock and five inch pots if used for pot stock. The pot stock was placed in the cloth house during the summer and received the same treatment as the seedlings.

The bedding stock was grown in pots on a greenhouse bench until July and was then planted in a raised bed. They received almost the same care with respect to fertilizing, watering and pinching as did the seedlings and pot plants.

PRESENTATION OF THE DATA

Detailed data on 11 characteristics and general data on six characteristics were recorded on approximately 1,600 blooming chrysanthemum plants during the fall season in 1940 and 1941. Tables 1 and 2 give most of these data except those for color of blossoms which are presented in the body of the thesis. To facilitate analysis of the data, the tables were divided into sections and each part was studied and discussed separately. Where a genetical system could be worked out, a hypothesis was postulated and the expected ratio compared with the observed ratio but no statistical analysis for goodness of fit was attempted. Besides the seedlings from crosses under tiral, selections of suitable new commercial types were made and described, a few self-pollinated and open-pollinated plants were studied, chromo-

some counts made, and mutations and chimeras recorded and described. All of these data are presented and discussed in the pages which follow.

In 1940 pictures were taken of some of the chrysanthemums under study. Plate I shows flowers that illustrate part of the terms used in this text. Plate II shows several of the parent varieties used in the study. Plate III shows the parents of the cross Yellow Doty X Varsity and nine of their offspring. Plate IV shows the parents of the cross Ethyl X Peggy Ann Hoover and a selection of the progeny. Plate V shows the parents of Ethyl X Early White Hardy along with a selection of different types of their offspring. Plate VI shows the parents of Mrs. Tricker X Crimson Splendor and most of the segregates obtained.

Table 1. Summary of most of data collected on chrysanthemum crosses under study in 1940.

Variety	Type						Size				Base			Top			
	Single	Semi-double	Double	Super-double	Anemone	Super-anemone	Baby	Small	Medium	Large	Flat	Reflex	Twisted	Flat	Semi-flat	Mound	Semi-mound
Mrs. Tricker			X						X			X					X
Ethyl				X				X				X					X
Peggy Ann Hoover			X							X	X					X	
Graceland					X				X		X				X		
Crimson Splendor		X							X			X			X		
Early White Hardy			X						X			X				X	
Norma						X			X		X				X		
Yellow Izola						X			X			X			X		
Champaigne Red	X								X		X			X			
Yellow Doty			X						X			X				X	
Ohio State					X				X		X				X		
Pink Doty				X					X			X				X	
Varsity				X			X					X				X	
Baby				X			X				X					X	

Crosses	No. plants	Percentage															
Ethyl X Peggy Ann Hoover	34		6	19	75				100		78	19	3	35	24	12	29
Ethyl X Graceland	51		31	45	20		4	14	86		53	47		45	16	21	18
Ethyl X Crimson Splendor	26		46	50	4			4	96		65	27	8	19	31	4	46
Ethyl X Crimson Splendor	49		40	30	30			12	88		33	67		14	8	23	55
Ethyl X Early White Hardy	79		4	16	80		1.3	81	18		39	60	1.3	14	10	52	24
Norma X Early White Hardy	60		8	38	52		2	20	80		55	43	2	23	2	42	33
Norma X Champaigne Red	71	4	85	5.5	5.5			7	93		64	12	24	21	11	9	59
Mrs. Tricker X Crimson Splendor	18	11	22	28	39		28	38	28	6	67	33		50		44	6
Yellow Doty X Pink Doty	34		16	18	66		8	60	32		68	32		18	16	53	13
Yellow Doty X Varsity	9			100			22	11	67		67	22	11	11	11	45	33
Yellow Doty X Champaigne Red	20	25	65	10					100		50	35	15	45	10	5	40
Yellow Doty X Ohio State	20		50	50				20	80		85	15		15	20	10	55
Yellow Doty X Early White Hardy	8		25	25	50			13	87		62	38		62	13	25	
Yellow Izola X Graceland	44	10	12	2	2	16	58	8	84	8	52	27	21	2	63	8	27
Yellow Izola X Champaigne Red	49	8	29	2		18	43	6	94		78	16	6	31	38		31
Ohio State X Baby	11	9	55	36				27	73		55	27	18	18	9	9	64

Table 1 (concl.).

Variety	Fades					Petals					Eye	Time of blooming		
	Early	Late	To purple veins	To lighter	Waxy	Ragged	Quilled	Petals reverse over eye	Twisted	Show	Anemone	Petals in eye	Early	Medium	Late
Mrs. Tricker							1/2			X				X	
Ethyl	X			X			1/4						X		
Peggy Ann Hoover	X			X			X			X			X		
Graceland		X	X								X		X		
Crimson Splendor	X			X						X			X		
Early White Hardy	X		X				1/4			X			X		
Norma		X		X	X		1/4		X		X				X
Yellow Izola		X									X			X	
Champaigne Red		X		X						X			X		
Yellow Doty		X		X			1/2		X	X			X		
Ohio State		X		X							X			X	
Pink Doty	X			X			1/4	X					X		
Varsity	X			X			1/4							X	
Baby							1/2								X

Crosses	No. plants	Percentage													
Ethyl X Peggy Ann Hoover	34	10	5	12	3		6	70	56		10		3	41	53	6
Ethyl X Graceland	51	6	61	47	20	4		8	47		65	4	31	33	67	
Ethyl X Crimson Splendor	26	19	81		100		4	4	69	8	69		35	61	31	8
Ethyl X Crimson Splendor	49	41	55		96		14	10	77		39		14	29	48	23
Ethyl X Early White Hardy	79	90		86	4		6	14	29		11		1.3	42	45	13
Norma X Early White Hardy	60	23	58	81		45	3	33	28		40	1.7		75	25	
Norma X Champaigne Red	71	14	70	3	81	21		9	27	26	90		18	10	61	29
Mrs. Tricker X Crimson Splendor	18	17	22	17	22	22		50	22		61				83	17
Yellow Doty X Pink Doty	34	32	16	11	37	8	8	29	66	3	29		3	32	52	16
Yellow Doty X Varsity	9					44		30	22		100			67	33	
Yellow Doty X Champaigne Red	20	30	55	20	65			5	5	30	100				100	
Yellow Doty X Ohio State	20		30	10	20	90		5	15		95		50		90	10
Yellow Doty X Early White Hardy	8	13	50	63		25		13			38		13		100	
Yellow Izola X Graceland	44	5		2	3	5	8	14	16	27	20	74	10	45	39	16
Yellow Izola X Champaigne Red	49	22	2		24	6	2	4	4	8	39	61			14	86
Ohio State X Baby	11		36	36		9	9	9	27	9	90		18		100	

Table 2. Summary of most of data collected on chrysanthemum crosses under study in 1941.

Variety	Type						Size				Base			Top				
	Single	Semi-double	Double	Super-double	Anemone	Super-anemone	Baby	Small	Medium	Large	Flat	Reflex	Twisted	Flat	Semi-flat	Mound	Semi-mound	Ring around the eye
Varsity				X			X					X				X		
Champaigne Red	X								X		X			X				
9-6			X				X									X		
9-3			X						X								X	
Graceland					X				X		X				X			
Baby				X			X				X				X			
Ethyl				X				X				X					X	
Sol D'Orr			X							X			X				X	
Pasadena		X							X				X		X			X
Pink Doty				X					X			X				X		

Crosses	No. plants																	
Varsity X 9-3	8			13	87				38	62			38	62			25	25	50	
Varsity X Champaigne Red	47		13	78	9				2	90	8		25	26	49	32	45	4	19	15
Varsity X 9-6	6				17	83			83	17			100					100		
Varsity X Graceland	3				67	33			100				67	33				67	33	
Varsity X Baby	4					100			75	25				100				100		25
Varsity X Ethyl	10			10	20	70			70	20	10			100			10	50	40	
Ethyl X Sol D'Orr	18			17	50	33			17	28	56		39	22	39		39	22	39	
Ethyl X Pasadena	12			41	41	9		9		33	67			17	83		75		25	41
Ethyl X Graceland	11			45	37	18				37	63		9		91		91		9	27
Pink Doty X Sol D'Orr	4					100			25		50	25	25	50	25			25	75	25

Table 2 (concl.).

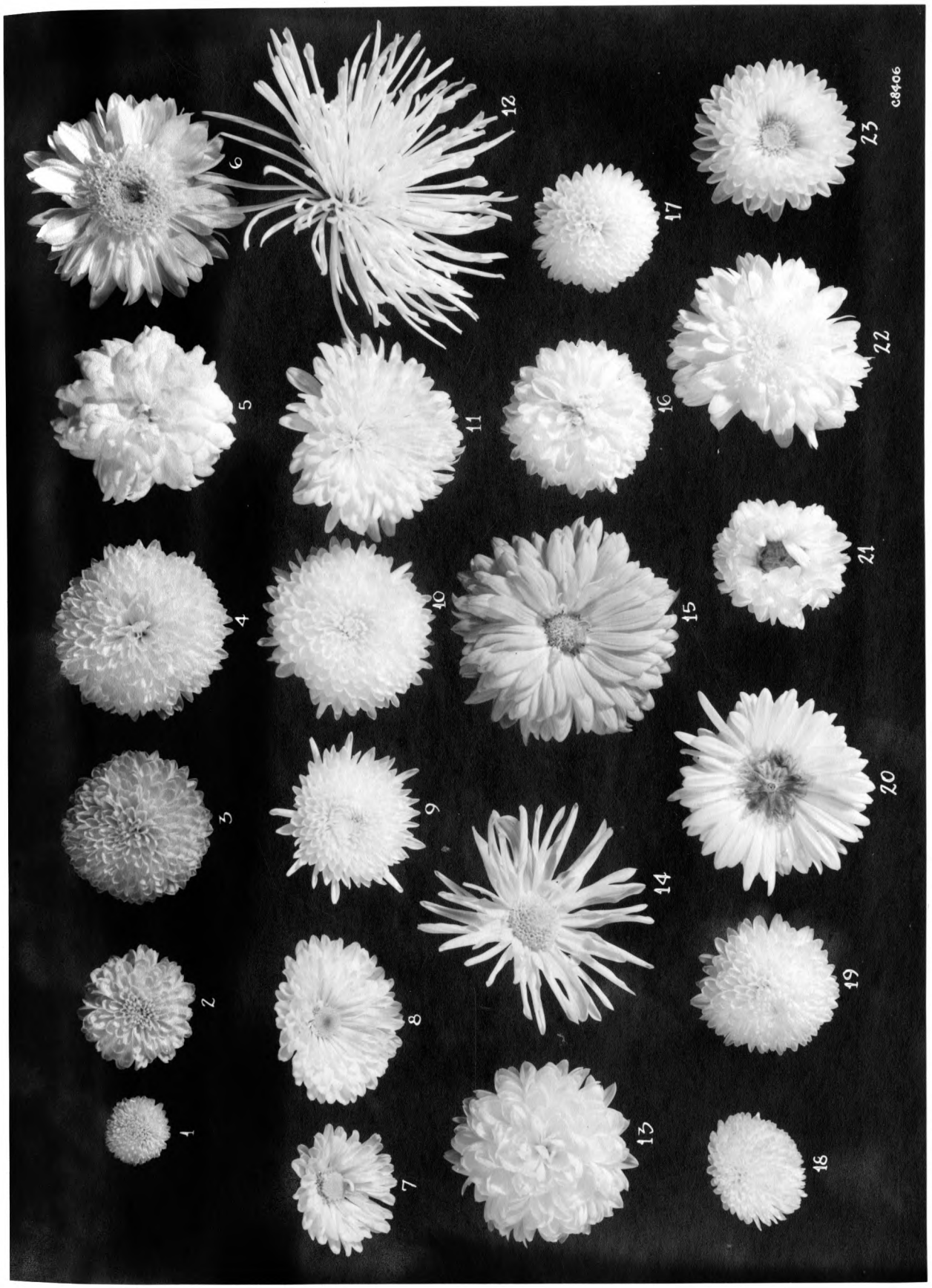
Variety	Fades				Petals					Eye		Time of blooming		
	Early	Late	To purple veins	To lighter	Poor bud	Waxy	Quilled	Petals reverse over eye	Twisted	Show	Anemone	Petals in eye	Early	Medium	Late
Varsity	X			X			1/2							X	
Champaigne Red		X		X									X		
9-6		X		X		X	1/4			X			X		
9-3		X		X		X	1/2	X		X			X		
Graceland		X	X								X		X		
Baby							1/2								X
Ethyl	X			X			1/4						X		
Sol D'Orr	X			X			1/4	X	X	X				X	
Pasadena	X	X	X	X						X		X			X
Pink Doty	X			X			1/4						X		

Crosses	No. plants	Percentage													
Varsity X 9-3	8	25	75	38	62		25	75	25		100			25	75	
Varsity X Champaigne Red	47	51	43	53	41			39	6	55	98		15	28	70	2
Varsity X 9-6	6	50	33	50	50	17		83			67		13	50	17	33
Varsity X Graceland	3		33		33			33	33		67				67	33
Varsity X Baby	4		25		25	25	25	50	25						100	
Varsity X Ethyl	10	60	10	40	50		10	80	70		30			80	10	10
Ethyl X Sol D'Orr	18	61	22	44	50	6		33	84	39	44		22	17	84	
Ethyl X Pasadena	12	41	50	33	75			9	50	83	67	9	33	41	50	9
Ethyl X Graceland	11	54	45	63	45				45	91	81		54	45	55	
Pink Doty X Sol D'Orr	4	25	50	25	50			50	75	25				50		50

EXPLANATION OF PLATE I

Fig. 1. Baby pompon less than three-fourths inch in diameter.
Fig. 2. Small pompon three-fourths inch to one and three-fourths inches in diameter.
Fig. 3. Medium pompon one and three-fourths inches to two and three-fourths inches in diameter.
Fig. 4. Medium size, petals three-fourths quilled.
Fig. 5. Regular flower, medium size.
Fig. 6. Super-anemone of medium size.
Fig. 7. Single quill.
Fig. 8. Semi-double quill.
Fig. 9. Super-double quill with a flat top.
Fig. 10. Super-double quill with a mound top.
Fig. 11. Spoon type quill.
Fig. 12. Large quill over two and three-fourths inches in diameter.
Fig. 13. Japanese reflex.
Fig. 14. Single, twisted petals, twisted base, eye show, and semi-flat top.
Fig. 15. Semi-double, eye show, with petals in the eye.
Fig. 16. Double, eye show, semi-mound top.
Fig. 17. Super-double.
Fig. 18. Flat top.
Fig. 19. Mound top.
Fig. 20. Flat base.
Fig. 21. Reflex base.
Fig. 22. Petals which reverse over the eye.
Fig. 23. Waxy flower.

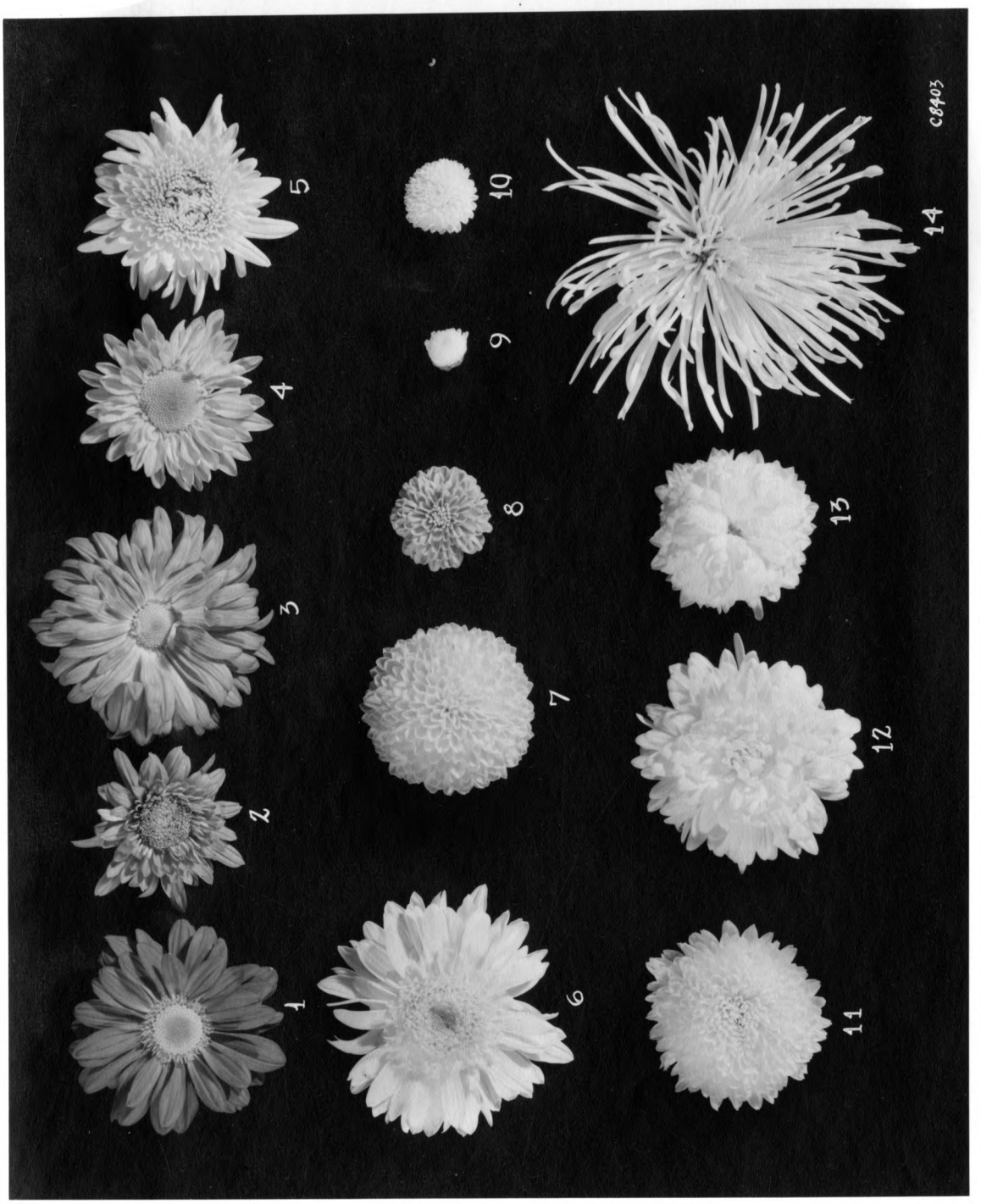
PLATE I



EXPLANATION OF PLATE II

Fig. 1. Champaigne Red - medium sized, single.
Fig. 2. Yellow Izola (half open) - medium sized, super-anemone.
Fig. 3. Crimson Splendor - medium sized, semi-double.
Fig. 4. Norma (half open) - medium sized, super-anemone.
Fig. 5. Dream - medium sized, double, petals which reverse over the eye.
Fig. 6. Graceland - medium sized, anemone.
Fig. 7. Pink Doty - medium sized, super-double, petals which reverse over the eye.
Fig. 8. Ethyl - small, super-double, petals which reverse over the eye.
Fig. 9. Baby - baby, super-double.
Fig. 10. Varsity - baby, super-double.
Fig. 11. Yellow Doty - medium sized, double.
Fig. 12. Mrs. Tricker - medium sized, super-double.
Fig. 13. Early White Hardy - medium sized, double.
Fig. 14. Peggy Ann Hoover - large, quilled, double, eye show.

PLATE II



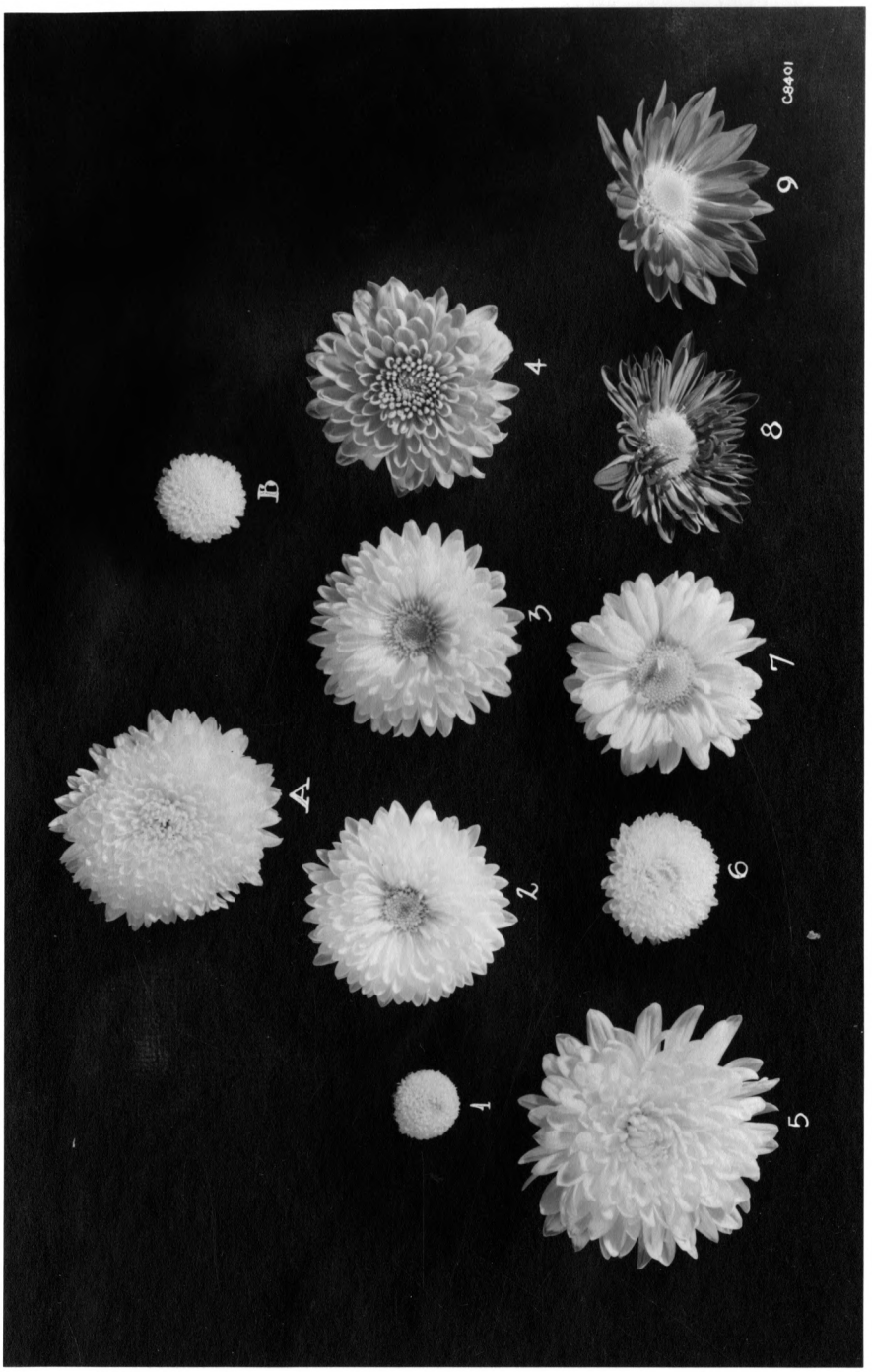
EXPLANATION OF PLATE III

Fig. A. Yellow Doty.

Fig. B. Varsity.

Fig. 1-9. Yellow Doty X Varsity progeny.

PLATE III



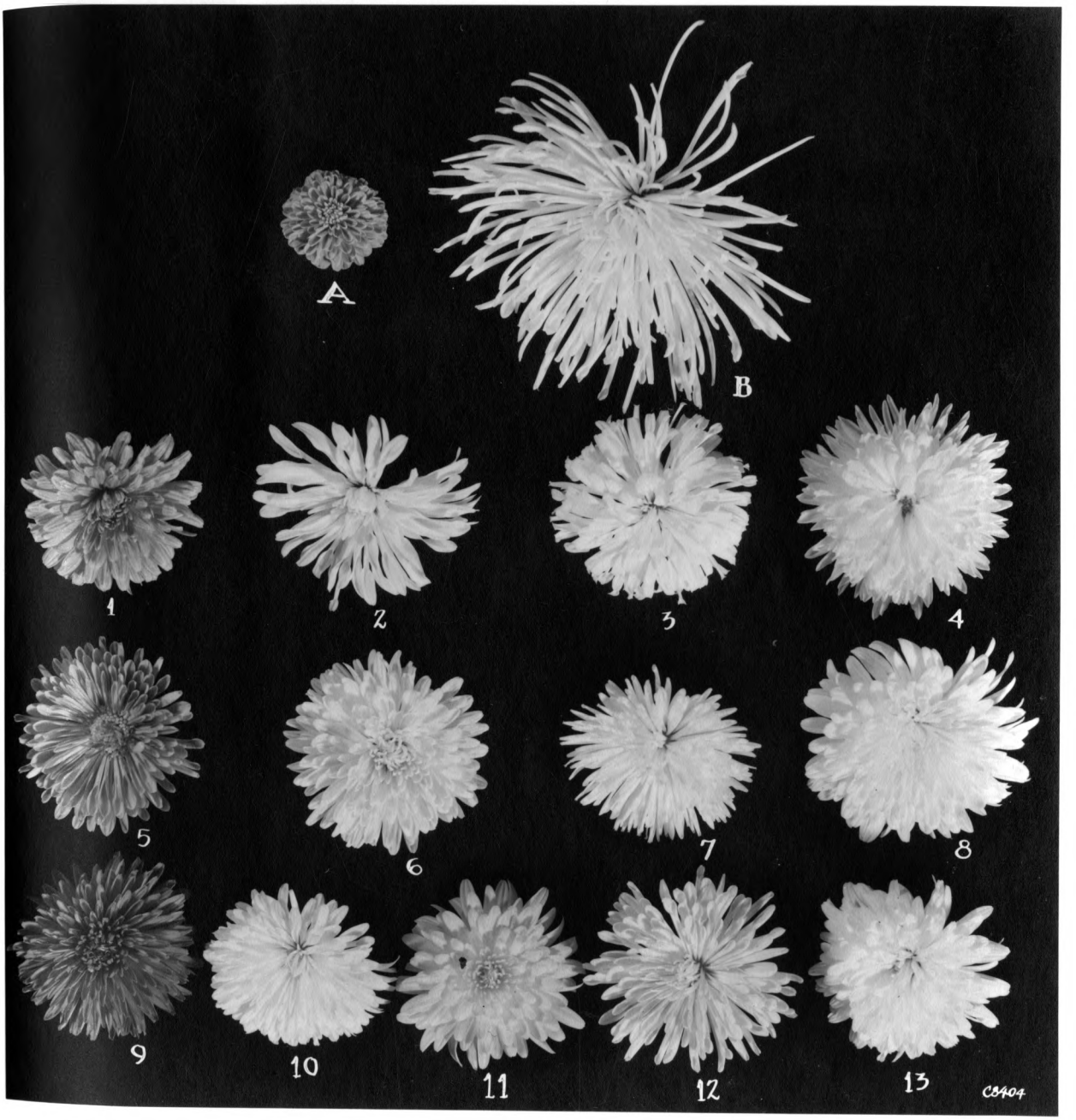
EXPLANATION OF PLATE IV

Fig. A. Ethyl.

Fig. B. Peggy Ann Hoover.

Figs. 1-13. Selections from Ethyl X Peggy Ann Hoover.

PLATE IV



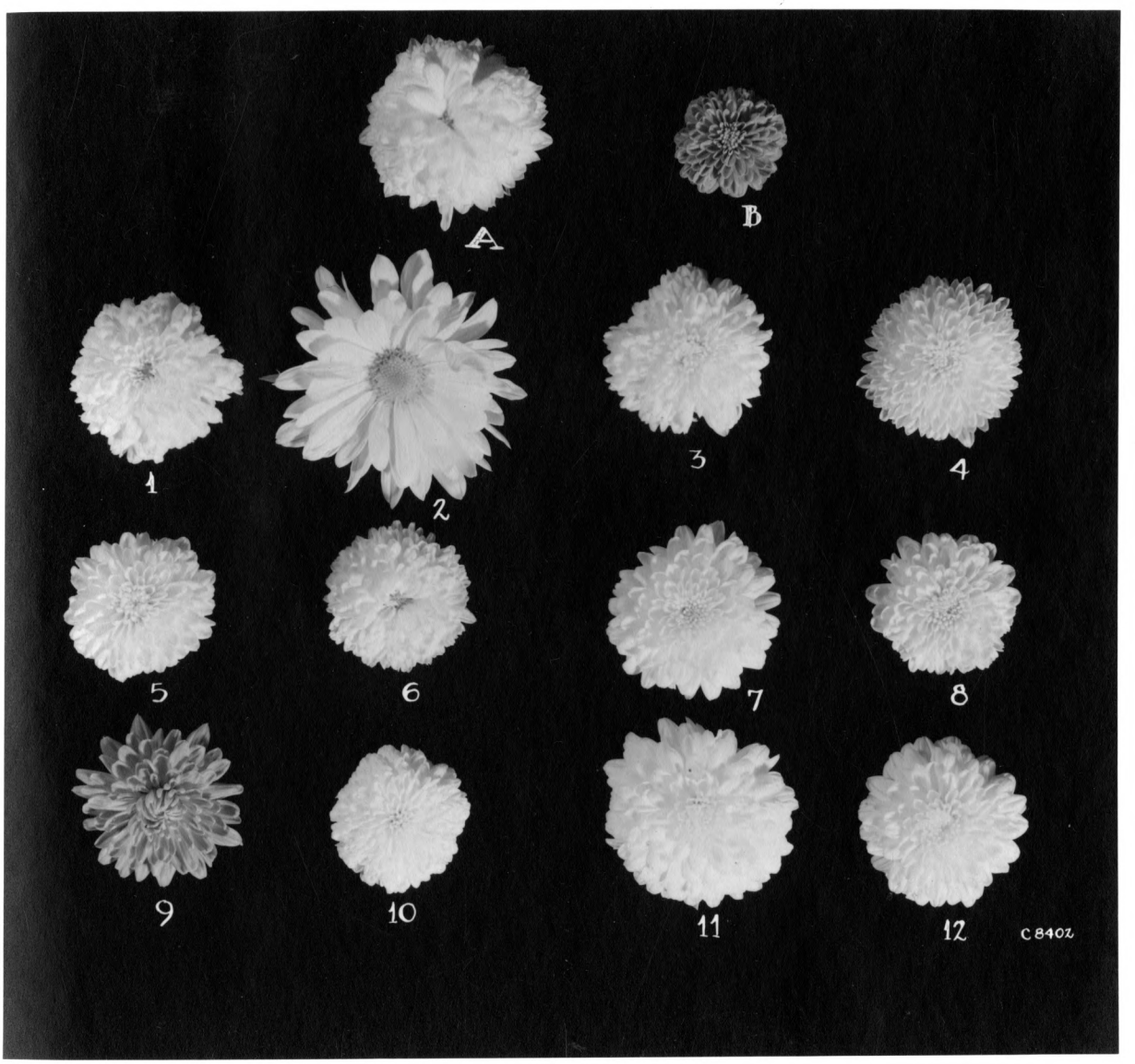
EXPLANATION OF PLATE V

Fig. A. Early White Hardy.

Fig. B. Ethyl.

Figs. 1-12. Selections from Early White Hardy X Ethyl.

PLATE V



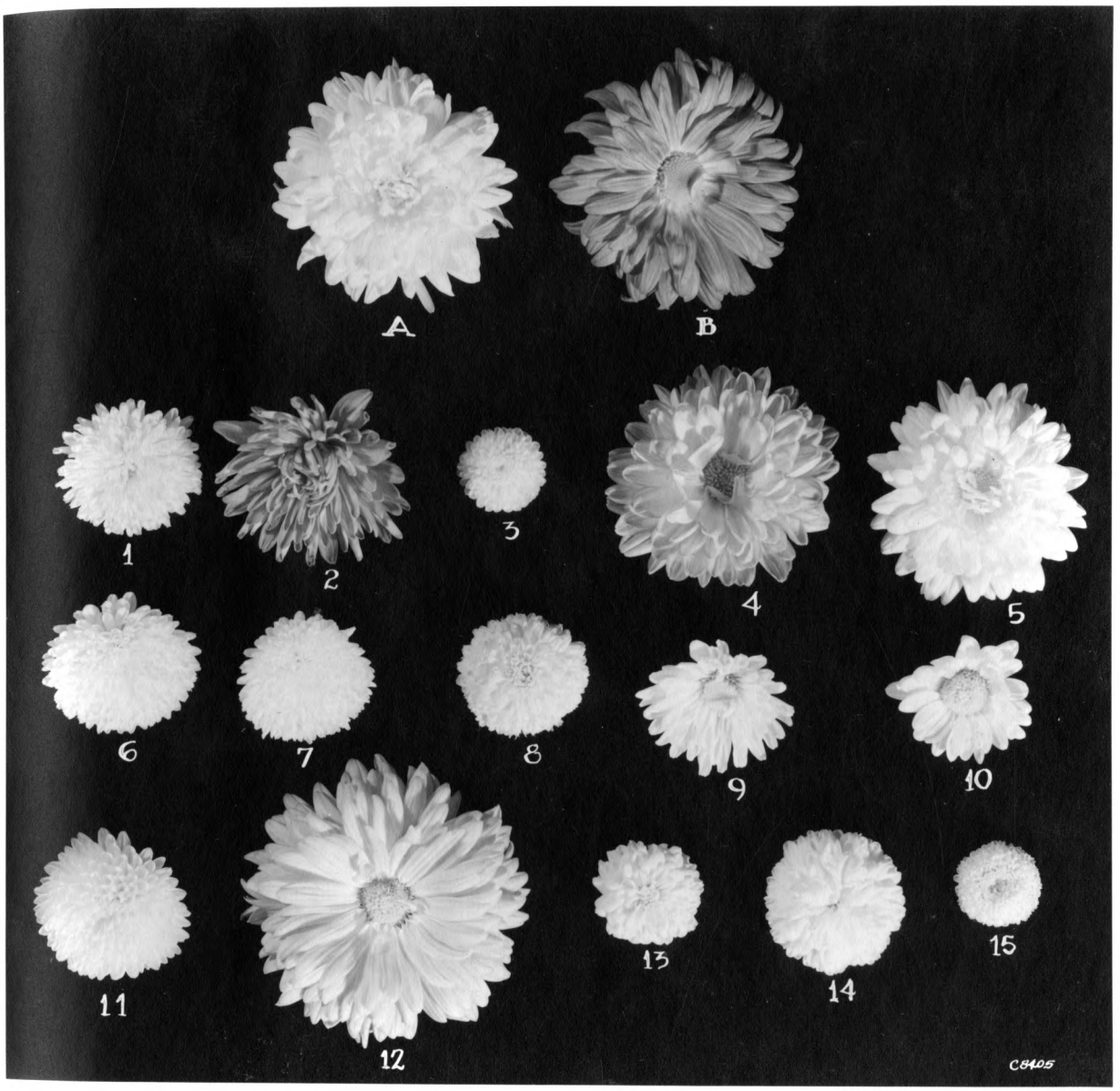
EXPLANATION OF PLATE VI

Fig. A. Mrs. Tricker.

Fig. B. Crimson Splendor.

Fig. 1-15. Selections from Mrs. Tricker X Crimson Splendor.

PLATE VI



Since no genetical work has heretofore been published on the breeding of chrysanthemums giving standard terms and factors, those used in the text have been set up to fit the results obtained.

Due to the high chromosome numbers and heterozygosity of the parents, it is difficult to secure accurate genetical results with chrysanthemums. Had inbred parents been available for making the initial crosses in this study, more satisfactory results probably would have been obtained. Most of the results fitted nicely into the hypotheses given as an explanation for the results obtained but larger numbers are necessary for accurate results. In most cases all of the expected classes were represented even though the per cent obtained in each class was more or less variable. The number of crosses and the number of plants per cross were too few in most instances and more work with crossed and self-pollinated plants is necessary.

Inheritance of Blossom Size

There is a general range of size of chrysanthemums from the baby type to the large blossoms. For this work only chrysanthemums whose blooms averaged less than three-fourths inch in diameter were classified as baby, from three-fourths inch to one and three-fourths inches was called small, one and three-fourths inches to two and three-fourths inches

were medium and over two and three-fourths inches was termed large. The sizes are not sharply defined and possibly a plant might be classified as medium under certain conditions and as large under more favorable conditions of growth. In the cross Ethyl X Peggy Ann Hoover all of the plants were classified as medium in 1940, while in the study of cuttings in 1941 of the three plants selected from this cross, one was classified as large and the other two medium.

Size of blossoms appeared to be controlled by four pairs of dominant factors called $\underline{A}^1$, $\underline{A}^2$, $\underline{A}^3$, and $\underline{A}^4$. $\underline{A}^1\text{-}\underline{A}^2\text{-}\underline{A}^3\text{-}\underline{A}^4\text{-}$, i.e., four genes in the dominant condition, seem to lead to the expression of the baby size. $\underline{A}^1\text{-}\underline{A}^2\text{-}\underline{A}^3\underline{a}^4\underline{a}^4$, or any three sets of genes in the dominant condition, give the small size. $\underline{A}^1\text{-}\underline{A}^2\text{-}\underline{a}^3\underline{a}^3\underline{a}^4\underline{a}^4$, or any two sets of genes in the dominant condition give the medium size. $\underline{A}^1\text{-}\underline{a}^2\underline{a}^2\underline{a}^3\underline{a}^3\underline{a}^4\underline{a}^4$ or $\underline{a}^1\underline{a}^1\underline{a}^2\underline{a}^2\underline{a}^3\underline{a}^3\underline{a}^4\underline{a}^4$ or one or no pairs of dominants are present then the large size is obtained. At least, such an hypothesis was the best one found to explain the results secured in these cultures.

The various sizes are illustrated on Plate I, figures 1, 2, 3, and 12.

Plate VI shows a distribution of sizes in the cross Mrs. Tricker X Crimson Splendor. Both parents are medium in size. Assuming the genetical formulae of $\underline{A}^1\underline{a}^1\underline{a}^2\underline{a}^2\underline{a}^3\underline{a}^3\underline{A}^4\underline{a}^4$ and $\underline{a}^1\underline{a}^1\underline{A}^2\underline{a}^2\underline{A}^3\underline{a}^3\underline{a}^4\underline{a}^4$ respectively, then when crossed, these

should segregate to give 12.5 per cent baby, 37.5 per cent small, 37.5 per cent medium, and 12.5 per cent large. From the 18 plants available, the following percentages were observed: 28 per cent baby, 38 per cent small, 28 per cent medium, and 6 per cent large. Baby seemed partially dominant to large and appeared to be dependent upon the presence of four dominants.

From the data the different varieties could have the following genetical composition:

Variety	Size	Genetic formula for size
Yellow Doty	Medium	$a^1a^1A^2a^2A^3A^3a^4a^4$
Varsity	Baby	$A^1a^1A^2a^2A^3a^3A^4A^4$
Ethyl	Small	$a^1a^1A^2a^2A^3A^3A^4a^4$
Pink Doty	Medium	$a^1a^1A^2A^2a^3a^3A^4a^4$
Champaigne Red	Medium	$a^1a^1A^2A^2A^3a^3a^4a^4$
Ohio State	Medium	$a^1a^1a^2a^2A^3a^3A^4a^4$
Early White Hardy	Medium	$A^1A^1a^2a^2A^3A^3a^4a^4$
Graceland	Medium	$a^1a^1a^2a^2A^3a^3A^4a^4$
Baby	Baby	$A^1a^1A^2a^2A^3A^3A^4a^4$
Norma	Medium	$a^1a^1A^2a^2A^3A^3a^4a^4$
Mrs. Tricker	Medium	$A^1a^1a^2a^2a^3a^3A^4a^4$
Crimson Splendor	Medium	$a^1a^1A^2a^2A^3a^3a^4a^4$
Peggy Ann Hoover	Large	$a^1a^1a^2a^2a^3a^3a^4a^4$
9-3	Medium	$a^1a^1A^2A^2A^3A^3a^4a^4$
9-6	Baby	$A^1a^1A^2A^2A^3a^3A^4a^4$
Sol D'Orr	Large	$A^1a^1a^2a^2a^3a^3a^4a^4$

Pasadena	Medium	$a^1a^1A^2a^2A^3a^3a^4a^4$
Yellow Izola	Medium	$a^1a^1A^2a^2A^3A^3a^4a^4$

Below are presented the genetical ratios using the above hypothesis for each variety. The observed and expected ratios are given in per cent along with the number (in parentheses) of plants observed in each cross.

1940 data		Baby	Small	Medium	Large
		per cent			
Yellow Doty X Varisty					
expected		37.5	50	12.5	
observed	(9)	22	11	67	
Yellow Doty X Pink Doty					
expected			50	50	
observed	(34)	8	60	32	
Yellow Doty X Champaigne Red					
expected				100	
observed	(20)			100	
Yellow Doty X Ohio State					
expected			25	50	25
observed	(20)		20	80	
Yellow Doty X Early White Hardy					
expected			50	50	
observed	(8)		13	87	
Yellow Izola X Graceland					
expected			25	50	25
observed	(44)		8	84	8
Yellow Izola X Champaigne Red					
expected				100	
observed	(44)		6	94	
Ethyl X Peggy Ann Hoover					
expected			25	50	25
observed	(34)			100	
Ethyl X Graceland					
expected			37.5	50	12.5
observed	(51)		14	86	

1940 data		Baby	Small	Medium	Large
		per cent			
Ethyl X Crimson Splendor					
	expected		37.5	50	12.5
	observed (26)		4	96	
	observed (49)		12	88	
Ethyl X Early White Hardy					
	expected	25	50	25	
	observed (79)	1	81	18	
Norma X Early White Hardy					
	expected		50	50	
	observed (60)		20	80	
Norma X Champaigne Red					
	expected			100	
	observed (71)		7	93	
Mrs. Tricker X Crimson Splendor					
	expected	12.5	37.5	37.5	12.5
	observed (18)	28	38	28	6
Ohio State X Baby					
	expected	18.75	43.75	31.75	6.5
	observed (11)		27	73	
1941 data					
Varsity X Champaigne Red					
	expected	37.5	50	12.5	
	observed (47)	2	90	8	
Varsity X 9-6					
	expected	56.25	37.5	6.25	
	observed (6)	83	17		
Varsity X 9-3					
	expected	50	50		
	observed (8)	38	62		
Varsity X Graceland					
	expected	18.75	43.75	31.25	6.25
	observed (3)	100			
Varsity X Baby					
	expected	56.25	37.5	6.25	
	observed (4)	75	25		
Varsity X Ethyl					
	expected	37.5	50	12.5	
	observed (10)	70	20	10	

1941 data		Baby	Small	Medium	Large
		per cent			
Ethyl X Sol D'Orr					
	expected	12.5	37.5	37.5	12.5
	observed (18)	17	28	56	
Ethyl X Pasadena					
	expected		37.5	50	12.5
	observed (12)		33	67	
Pink Doty X Sol D'Orr					
	expected		25	50	25
	observed (4)	25		50	25
Ethyl X Graceland					
	expected		37.5	50	12.5
	observed (11)		37	63	

As can be seen from the above tabulation, good agreement exists between expected and observed classes in most of the crosses although the percentages deviate widely from expected. The latter of course is not surprising in view of the small number of plants available in each cross.

Inheritance of Flower Type

There are many different types of chrysanthemums. In this study the single, semi-double, double, and super-double types were found to work into a genetical formula using a four factor hypothesis.

On Plate I, figures 7, 8, 9, 10, 14, 15, 16, and 17 illustrate the single, semi-double, double, and super-double types. On Plate II, figure 6 shows an anemone and figure 2 shows a super-anemone in which the anemone eye is not fully opened.

All types of flowers can have either plain or quilled outer petals.

A single flower has one or two rows of petals around a plain eye of perfect florets, a semi-double has three to ten rows of petals around a plain eye of perfect florets, a double has over ten rows but has enough perfect florets in the center that the eye shows, the super-doubles usually have some perfect florets in the center but not enough to form an eye. An anemone has two rows of outer petals around a quilled center of perfect flowers, while a super-anemone has more than two rows of petals around a quilled center of perfect flowers.

$\underline{T}^1\text{-}\underline{T}^2\text{-}\underline{T}^3\text{-}\underline{T}^4\text{-}$, i.e., four genes in the dominant condition, seem to lead to the expression of the single type. $\underline{T}^1\text{-}\underline{T}^2\text{-}\underline{T}^3\underline{t}^4\underline{t}^4$, or any three sets of genes in the dominant condition, give the semi-double type. $\underline{T}^1\text{-}\underline{T}^2\text{-}\underline{t}^3\underline{t}^3\underline{t}^4\underline{t}^4$, or any two sets of genes in the dominant condition give the double type. $\underline{T}^1\text{-}\underline{t}^2\underline{t}^2\underline{t}^3\underline{t}^3\underline{t}^4\underline{t}^4$ or $\underline{t}^1\underline{t}^1\underline{t}^2\underline{t}^2\underline{t}^3\underline{t}^3\underline{t}^4\underline{t}^4$ or one or no pairs of dominants are present then the super-doubles are obtained. At least, such an hypothesis was the best one found to explain the results secured in these cultures.

Plate VI shows a distribution of types that were obtained in the cross Mrs. Tricker X Crimson Splendor. Mrs. Tricker is a double and could be $\underline{T}^1\underline{t}^1\underline{t}^2\underline{t}^2\underline{T}^3\underline{t}^3\underline{t}^4\underline{t}^4$ and Crimson Splendor is a semi-double and could be

$\underline{t}^1\underline{t}^1\underline{T}^2\underline{t}^2\underline{T}^3\underline{T}^3\underline{T}^4\underline{t}^4$. When these two are crossed the expected percentage would be 6.75 per cent single, 25 per cent semi-double, 37.5 per cent double, and 31.75 per cent super-double. The following percentage was observed: 11 per cent single, 22 per cent semi-double, 28 per cent double, and 39 per cent super-double.

Larger numbers are necessary for accurate results but from the data the different varieties could have the following genetical formulae.

Variety	Type	Genetic formula for type
Peggy Ann Hoover	Double	$t^1t^1T^2t^2T^3t^3t^4t^4$
Graceland	Anemone	$t^1t^1T^2t^2T^3t^3T^4T^4$
Ethyl	Super-double	$t^1t^1t^2t^2t^3t^3T^4t^4$
Crimson Splendor	Semi-double	$t^1t^1T^2t^2T^3T^3T^4t^4$
Early White Hardy	Double	$T^1t^1T^2t^2t^3t^3t^4t^4$
Mrs. Tricker	Double	$T^1t^1t^2t^2T^3t^3t^4t^4$
Yellow Doty	Double	$T^1T^1t^2t^2T^3t^3t^4t^4$
Pink Doty	Super-double	$t^1t^1T^2t^2t^3t^3t^4t^4$
Varisty	Super-double	$t^1t^1t^2t^2T^3t^3t^4t^4$
Champaigne Red	Single	$T^1T^1T^2t^2T^3t^3T^4t^4$
Ohio State	Anemone	$T^1t^1T^2t^2T^3T^3t^4t^4$
Norma	Super-anemone	$t^1t^1T^2t^2T^3T^3t^4t^4$
Baby	Super-double	$t^1t^1t^2t^2t^3t^3T^4t^4$
9-6	Double	$t^1t^1t^2t^2T^3t^3T^4t^4$
9-3	Double	$t^1t^1T^2T^2t^3t^3T^4t^4$

Variety	Type	Genetic formula for type
Sol D'Orr	Double	$t^1t^1T^2t^2T^3t^3t^4t^4$
Pasadena	Semi-double	$t^1t^1T^2t^2T^3t^3T^4T^4$

Below are presented the genetical ratios using the above hypothesis for each variety. The observed and expected ratios are given in per cent along with the number (in parentheses) of plants observed in each cross.

1940 data	Single	Semi-double	Double	Super-double
		per cent		
Ethyl X Peggy Ann Hoover				
expected		12.5	37.5	50
observed (34)		6	19	75
Ethyl X Graceland				
expected		25	50	25
observed (51)		31	45	20
		4 (were super-anemone)		
Ethyl X Crimson Splendor				
expected		37.5	50	12.5
observed (26)		46	50	4
observed (49)		40	30	30
Ethyl X Early White Hardy				
expected		12.5	37.5	50
observed (79)		4	16	80
Mrs. Tricker X Crimson Splendor				
expected	6.75	25	37.5	31.75
observed (18)11		22	28	39
Yellow Doty X Pink Doty				
expected		25	25	50
observed (34)		16	18	66
Yellow Doty X Varisty				
expected			100	
observed (9)			100	
Yellow Doty X Champaigne Red				
expected	25	50	25	
observed (20)	25	65	10	

1940 data	Single	Semi-double	Double	Super-double
		per cent		
Yellow Doty X Ohio State				
expected	25	50	25	
observed (20)		50	50	
Yellow Doty X Early White Hardy				
expected		25	25	50
observed (8)		25	25	50
Norma X Early White Hardy				
expected		18.75	43.75	37.5
observed (60)		8	38	52
		2(were super-anemone)		
Norma X Champaigne Red				
expected	28	38	18	16
observed (71)	4	85	5.5	5.5
Ohio State X Baby				
expected	12.5	37.5	37.5	12.5
observed (11)	9	55	36	
1941 data				
Varsity X Champaigne Red				
expected	12.5	37.5	37.5	12.5
observed (47)	13	78	9	
Varsity X 9-6				
expected			50	50
observed (6)			17	83
Varsity X 9-3				
expected		50	50	
observed (8)		13	87	
Varsity X Graceland				
expected		37.5	50	12.5
observed (3)			67	33
Varsity X Baby				
expected			37.5	62.5
observed (4)				100
Varsity X Ethyl				
expected			37.5	62.5
observed (10)		10	20	70
Ethyl X Sol D'Orr				
expected		25	50	25
observed (18)		17	50	33

1941 data	Single	Semi-double	Double	Super-double
		per cent		
Ethyl X Pasadena				
expected	25		50	25
observed (12)	41		41	9
	9(were super-anemone)			
Ethyl X Graceland				
expected	25		50	25
observed (11)	45		37	18
Pink Doty X Sol D'Orr				
expected			37.5	62.5
observed (4)				100

There are various kinds of anemone eyes but all may be classified into the following four types: small anemone eye which is barely distinguishable from the plain eye, large anemone eye with good mound, large anemone eye but flat like Norma, and large anemone eye with upright quilled mound. The anemone eye factors act upon the four-factor type described above. The anemone eye is usually recessive. Anemone plants seem to carry the dominance of the type factor, discussed above, of a single or semi-double, plus the recessive factor common for that particular type of anemone, and super-anemone plants seem to carry the type factor for a double or super-double plus the recessive factor for that particular type of anemone which it carries. An anemone eye would be $\underline{T}^1\text{-}\underline{T}^2\text{-}\underline{T}^3\text{-}\underline{t}^4\underline{t}^4$ plus recessive anemone genes or $\underline{T}^1\text{-}\underline{T}^2\text{-}\underline{T}^3\text{-}\underline{T}^4\text{-}$ plus recessive anemone genes while a super-anemone could be $\underline{T}^1\text{-}\underline{T}^1\text{-}\underline{t}^2\underline{t}^2\underline{t}^3\underline{t}^3$ plus recessive anemone genes or $\underline{T}^1\text{-}\underline{t}^2\underline{t}^2\underline{t}^3\underline{t}^3\underline{t}^4\underline{t}^4$ plus recessive anemone genes. Champaigne Red is a single but must be heterozygous for the

anemone factor of Yellow Izola and when crossed with Yellow Izola gives about as high a percentage of anemone and super-anemone eyes as when an anemone is crossed with a super-anemone. Champaigne Red when crossed with the Norma type anemone eye gives few anemones. On certain mutant strains some flowers may have the anemone eye while others on same plant may be non-anemone. Considerable work must be done on the anemone eye factor before more definite rules can be given. The following results were obtained.

Cross	Single	Semi-double	Double	Super-double	Anemone	Super-anemone
			per cent			
Ethyl X Graceland		31	45	20		4
Norma X Early White Hardy		8	38	52		2
Norma X Champaigne Red	4	85	5.5	5.5		
Yellow Izola X Graceland	10	12	2	2	16	58
Yellow Izola X Champaigne Red	8	29	2		18	43
Ohio State X Baby	9	54	36			
Ethyl X Pasadena		41	41	9		9

Inheritance of Flower Base

In this work there were three different kinds of flower base. Some flowers had a flat base, some a reflex base, and some a twisted base due to twisted petals. Some flowers were

hard to classify and could be placed in one of two classifications, while other flowers were definite in their classification.

The three types of base are illustrated on Plate I by figures 14, 20, and 21.

The genetical scheme that seemed to fit the best was similar to that used for size and type. $\underline{B}^1\text{-}\underline{B}^2\text{-}\underline{B}^3\text{-}$, or any three sets of genes in the dominant condition may give the twisted base, $\underline{B}^1\text{-}\underline{B}^2\text{-}\underline{b}^3\underline{b}^3$, or any two sets of genes in the dominant condition may result in the flat base and $\underline{B}^1\text{-}\underline{b}^2\underline{b}^2\underline{b}^3\underline{b}^3$ or $\underline{b}^1\underline{b}^1\underline{b}^2\underline{b}^2\underline{b}^3\underline{b}^3$ or with one or no sets of genes in the dominant condition a reflex base may be obtained.

Norma X Champaigne Red gave a good distribution of base types. Norma has a flat base and its formula could be $\underline{B}^1\underline{b}^1\underline{B}^2\underline{b}^2\underline{b}^3\underline{b}^3$ and Champaigne Red a flat base and its formula could be $\underline{B}^1\underline{B}^1\underline{b}^2\underline{b}^2\underline{B}^3\underline{b}^3$. Using this system the expected ratio would be 25 per cent twisted, 50 per cent flat and 25 per cent reflex base, while the observed ratio was 24 per cent twisted, 64 per cent flat and 12 per cent reflex base.

The number of plants observed especially in 1941 was too small to give accurate results.

From the data the different varieties could have the following genetical formulae.

Variety	Kind of base	Genetic formula for base
Yellow Doty	Reflex	$b^1b^1B^2b^2b^3b^3$
Varisty	Reflex	$b^1b^1b^2b^2B^3b^3$
Ethyl	Reflex	$b^1b^1b^2b^2B^3b^3$
Pink Doty	Reflex	$b^1b^1b^2b^2B^3B^3$
Champaigne Red	Flat	$B^1B^1b^2b^2B^3b^3$
Ohio State	Flat	$b^1b^1B^2b^2B^3b^3$
Early White Hardy	Reflex	$B^1B^1b^2b^2b^3b^3$
Graceland	Flat	$B^1b^1B^2B^2b^3b^3$
Baby	Flat	$B^1b^1B^2b^2b^3b^3$
Norma	Flat	$B^1b^1B^2b^2b^3b^3$
Mrs. Tricker	Reflex	$b^1b^1b^2b^2B^3b^3$
Crimson Splendor	Reflex	$b^1b^1B^2B^2b^3b^3$
Peggy Ann Hoover	Flat	$b^1b^1B^2B^2B^3b^3$
9-6	Flat	$b^1b^1B^2B^2B^3B^3$
9-3	Flat	$b^1b^1B^2b^2B^3b^3$
Sol D'Orr	Twisted	$B^1b^1B^2b^2B^3b^3$
Pasadena	Twisted	$B^1b^1B^2b^2B^3b^3$
Yellow Izola	Reflex	$b^1b^1b^2b^2B^3b^3$

Below are presented the genetical ratios using the above hypothesis for each variety. The observed and expected ratios are given in per cent along with the number (in parentheses) of plants observed in each cross.

1940 data		Twisted	Flat	Reflex
			per cent	
Ethyl X Peggy Ann Hoover				
	expected		75	25
	observed (34)	3	78	19
Ethyl X Graceland				
	expected	25	50	25
	observed (51)		53	47
Ethyl X Crimson Splendor				
	expected		50	50
	observed (26)	8	65	27
	observed (49)		33	67
Ethyl X Early White Hardy				
	expected		50	50
	observed (79)	1	39	60
Norma X Early White Hardy				
	expected		50	50
	observed (60)	2	55	43
Norma X Champaigne Red				
	expected	25	50	25
	observed (71)	24	64	12
Mrs. Tricker X Crimson Splendor				
	expected		50	50
	observed (18)		67	33
Yellow Doty X Pink Doty				
	expected		50	50
	observed (34)		68	32
Yellow Doty X Varisty				
	expected		37.5	67.5
	observed (9)	11	67	22
Yellow Doty X Champaigne Red				
	expected	25	50	25
	observed (20)	15	50	35
Yellow Doty X Ohio State				
	expected		75	25
	observed (20)		85	15
Yellow Doty X Early White Hardy				
	expected		50	50
	observed (8)		62	38

1940 data		Twisted: per cent	Flat :	Reflex
Yellow Izola X Graceland				
	expected	25	50	25
	observed (44)	21	52	27
Yellow Izola X Champaigne Red				
	expected		75	25
	observed (49)	6	78	16
Ohio State X Baby				
	expected	18.75	44.75	37.5
	observed (11)	18	55	27
1941 data				
Varisty X Champaigne Red				
	expected	37.5	50	12.5
	observed (47)	49	25	26
Varisty X 9-6				
	expected		100	
	observed (6)		100	
Varsity X 9-3				
	expected		56.25	43.75
	observed (8)		38	62
Varisty X Graceland				
	expected	25	50	25
	observed (3)		67	33
Varisty X Baby				
	expected	25	50	25
	observed (4)			100
Varsity X Ethyl				
	expected		37.5	62.5
	observed (10)			100
Ethyl X Sol D'Orr				
	expected	18.75	43.75	37.5
	observed (18)	39	39	22
Ethyl X Graceland				
	expected	25	50	25
	observed (11)	91	9	
Ethyl X Pasadena				
	expected	18.75	43.75	37.5
	observed (12)	83		17

1941 data		Twisted: per cent	Flat :	Reflex
Pink Doty X Sol D'Orr				
expected		25	50	25
observed	(4)	25	25	50

Agreement between observed and expected was only fair in this analysis. Other genes, small numbers or factors of the environment may be responsible for this situation.

Appearance of the Top

The appearance of the top is dependent upon many factors including the degree of doubleness, petals which reverse over the eye, petals in the eye, presence or absence of the anemone eye, and twisted petals. Plate I, figure 18 shows a flat top, figure 14 a semi-flat top, figure 16 a semi-mound top, and figure 19 a mound top.

No definite conclusions could be drawn from the data as to factorial make-up of the varieties. Table 3 gives a summary of the results for all crosses studied.

Petals Which Reverse Over the Eye

Some varieties have petals which reverse over the eye. This is a desirable factor because it makes some plants look more double, gives a two color effect or gold eye to varieties such as Ethyl, and having the petals reverse over the eye sometimes covers the undesirable factor of having petals

Table 3. Appearance of top of chrysanthemum flowers.

Cross	Type	Percentage			
		Flat	Semi-flat	Mound	Semi-mound
Ethyl X Peggy Ann Hoover	(Semi-mound X mound)	35	24	12	29
Ethyl X Graceland	(Semi-mound X semi-flat)	45	16	21	18
Ethyl X Crimson Splendor	(Semi-mound X semi-flat)	19	31	4	46
Ethyl X Crimson Splendor	(Semi-mound X semi-flat)	14	8	23	55
Ethyl X Early White Hardy	(Semi-mound X mound)	14	10	52	24
Norma X Early White Hardy	(Semi-flat X mound)	23	2	42	33
Norma X Champaigne Red	(Semi-flat X flat)	21	11	9	59
Mrs. Tricker X Crimson Splendor	(Semi-mound X semi-flat)	50		44	6
Yellow Doty X Pink Doty	(Mound X mound)	18	16	53	13
Yellow Doty X Champaigne Red	(Mound X flat)	45	10	5	40
Yellow Doty X Varsity	(Mound X mound)	11	11	45	33
Yellow Doty X Ohio State	(Mound X semi-flat)	15	20	10	55
Yellow Doty X Early White Hardy	(Mound X mound)	62	13	25	
Yellow Izola X Graceland	(Semi-flat X semi-flat)	2	63	8	27
Yellow Izola X Champaigne Red	(Semi-flat X flat)	31	38		31
Ohio State X Baby	(Semi-flat X mound)	18	9	9	64
Varsity X Champaigne Red	(Mound X flat)	32	45	4	19
Varsity X 9-6	(Mound X mound)			100	
Varsity X 9-3	(Mound X semi-mound)		25	25	50
Varsity X Graceland	(Mound X semi-flat)			67	33
Varsity X Baby	(Mound X mound)			100	
Varsity X Ethyl	(Mound X semi-mound)		10	50	40
Ethyl X Sol D'Orr	(Mound X semi-mound)		39	22	39
Ethyl X Pasadena	(Mound X semi-flat)		75		25
Ethyl X Graceland	(Mound X semi-flat)		91		9
Pink Doty X Sol D'Orr	(Mound X semi-mound)		25	75	

in the eye. This characteristic appeared to be controlled by two dominant factors both of which have to be present if the character is expressed. Letters O and P were used to denote the factors.

From the data the different varieties could have the following genetical formulae.

Variety	Petals which reverse over the eye	Genetic formula
Yellow Doty	No	Oopp
Varsity	No	ooPp
Ethyl	Yes	OoPp
Pink Doty	Yes	OoPP
Champaigne Red	No	oopp
Ohio State	Anemone	ooPp
Early White Hardy	No	oopp
Graceland	Anemone	OOpp
Baby	No	Oopp
Norma	Anemone	OoPp
Mrs. Tricker	No	Oopp
Crimson Splendor	No	ooPP
Peggy Ann Hoover	No	ooPP
9-6	No	oopp
9-3	Yes	OoPp
Sol D'Orr	Yes	OoPp
Pasadena	No	ooPP
Yellow Izola	Anemone	OoPp

Below are presented the genetical ratios using the above hypothesis for each variety. The expected ratio of petals reversed over the eye is given in per cent along with the results observed.

Cross	Expected:Observed per cent	
Ethyl X Peggy Ann Hoover	50	56
Ethyl X Graceland	50	47
Ethyl X Crimson Splendor	50	69
Ethyl X Early White Hardy	25	29
Norma X Early White Hardy	25	28
Norma X Champaigne Red	25	27
Mrs. Tricker X Crimson Splendor	25	22
Yellow Doty X Pink Doty	75	66

Cross	Expected:Observed per cent	
Yellow Doty X Varsity	25	22
Yellow Doty X Champaigne Red	0	5
Yellow Doty X Ohio State	25	15
Yellow Izola X Graceland	50	16
(74 per cent had anemone eye)		
Yellow Izola X Champaigne Red	25	4
(61 per cent had anemone eye)		
Ohio State X Baby	25	27
Varsity X Champaigne Red	0	6
Varsity X 9-3	37.5	25
Varsity X 9-6	0	0
Varsity X Graceland	50	33
Varsity X Baby	25	25
Varsity X Ethyl	37	70
Ethyl X Sol D'Orr	75	84
Ethyl X Pasadena	50	50
Ethyl X Graceland	50	45
Pink Doty X Sol D'Orr	75	75

In two of the crosses involving Champaigne Red, plants were observed with the character when none was expected. No particular explanation is offered here.

Petals in the Eye

Petals in the eye is an undesirable characteristic and not many of the commercial varieties have this defect except as mutations. Pasadena was found to have a few petals in the eye while Crimson Splendor had a few as a mutation. This appears to act as a two factor ratio in which both factors have to be dominant for the character to be expressed. R and S were used to denote the factors.

From the data the different varieties could have the following genetical composition for petals in the eye.

Variety	Genetic formula
Ethyl	Rrss
Peggy Ann Hoover	rrss
Graceland	rrSS
Crimson Splendor	rrSs
Early White Hardy	rrss
Norma	rrSs
Champaigne Red	Rrss
Mrs. Tricker	rrss
Yellow Doty	RRss
Pink Doty	rrss
Varsity	rrss
Ohio State	rrSs
Yellow Izola	Rrss
Baby	Rrss
9-6	rrSs
9-3	rrss
Sol D'Orr	rrSs
Pasadena	RrSs

Below are presented the genetical ratios using the above hypothesis for each variety. The observed and expected ratios are given in per cent.

Cross	Expected:Observed per cent	
Ethyl X Peggy Ann Hoover	0	3
Ethyl X Graceland	50	31
Ethyl X Crimson Splendor	25	35
		14
Ethyl X Early White Hardy	0	1.3
Norma X Early White Hardy	0	0
Norma X Champaigne Red	25	18
Mrs. Tricker X Crimson Splendor	0	0
Yellow Doty X Pink Doty	0	3
Yellow Doty X Varsity	0	0
Yellow Doty X Champaigne	0	0
Yellow Doty X Ohio State	50	50
Yellow Doty X Early White Hardy	0	13
Yellow Izola X Graceland	50	10
Ohio State X Baby	25	18
Varsity X Champaigne Red	0	15
Varsity X 9-6	0	13
Varsity X 9-3	0	0
Varsity X Graceland	0	0
Varsity X Baby	0	0

Cross	Expected:Observed per cent	
Varsity X Ethyl	0	0
Ethyl X Sol D'Orr	25	22
Ethyl X Pasadena	37.5	33
Ethyl X Graceland	50	54
Pink Doty X Sol D'Orr	0	0

In six of the crosses petals appeared in the eye when none was expected, otherwise the hypothesis agrees fairly well with the results obtained.

Inheritance of Waxy Flowers

Some chrysanthemum plants have flowers which appear to be waxy. The petals stand out and have a glazed appearance. Not many chrysanthemum plants in this study had waxy flowers. A waxy flower is illustrated on Plate I, figure 23.

Norma was the only waxy parent used in 1940, while 9-6 and 9-3 were waxy parents used in 1941. A two factor scheme, using L and M in which both have to be present in the dominant condition before the factor is expressed, seemed to give at least a partial fit to the genetical results.

From the data the different varieties could have the following genetical set-up.

Variety	Genetic formula
Norma	LlMm
Early White Hardy	llMm
Champaigne Red	llMm
Mrs. Tricker	Llmm
Crimson Splendor	llMm
Yellow Doty	Llmm
Ohio State	llMM
Varsity	llMm
9-6	LlMm
9-3	LlMm

Below are presented the genetical ratios in per cent using the above hypothesis for each variety.

Cross	Expected:Observed per cent	
Norma X Early White Hardy	37.5	45
Norma X Champaigne Red	25	21
Mrs. Tricker X Crimson Splendor	25	22
Yellow Doty X Ohio State	50	90
Varsity X 9-3	37.5	25
Varsity X 9-6	37.5	0
Yellow Doty X Early White Hardy	25	25
Yellow Doty X Varsity	25	44

In several other crosses a small percentage (5 to 10 per cent) was observed. No explanation for this was secured.

Quilled Petals

On Plate I, figure 12 shows a fully quilled plant, figure 8 shows one three-fourths quilled, figure 11 shows one one-half quilled, figure 17 is one-fourth quilled and figure 13 in non-quilled. The amount of quilling refers to the degree of quilling of individual petals.

There was not enough material available for a full genetical study on quilling. One-fourth quilled x non-quilled averaged 9 per cent quilled, while non-quilled x non-quilled averaged 9 per cent. One-half quilled x non-quilled gave 0 to 50 per cent quilling but an average of 20 per cent. One-fourth quilled x quilled gave 70 per cent quilled, and one-fourth quilled x one-fourth quilled gave from 14 to 50 per cent quilled but an average of 32 per cent quilled. One-fourth quilled x one-half quilled gave from 13 to 83 per cent quilled but an average of 47 per cent quilled. In two crosses of one-fourth x one-half quilled there was an average of 63 per cent quilled. To secure a majority of non-quilled varieties the parents should be non-quilled or at least one should be non-quilled. To secure a majority of quilled varieties quilled parents should be crossed.

Results by crosses are given in per cent as follows:

Cross		Per cent
Ethyl X Peggy Ann Hoover	1/4 quilled x quilled	70
Ethyl X Graceland	1/4 quilled x non-quilled	8
Ethyl X Crimson Splendor	1/4 quilled x non-quilled	4
Ethyl X Crimson Splendor	1/4 quilled x non-quilled	10
Ethyl X Early White Hardy	1/4 quilled x 1/4 quilled	14
Norma X Early White Hardy	1/4 quilled x 1/4 quilled	33
Norma X Champaigne Red	1/4 quilled x non-quilled	9
Mrs. Tricker X Crimson Splendor	1/2 quilled x non-quilled	50
Yellow Doty X Pink Doty	1/2 quilled x 1/4 quilled	29
Yellow Doty X Varsity	1/2 quilled x 1/4 quilled	30
Yellow Doty X Champaigne Red	1/2 quilled x non-quilled	5
Yellow Doty X Ohio State	1/2 quilled x non-quilled	5
Yellow Doty X Early White Hardy	1/2 quilled x 1/4 quilled	13
Yellow Izola X Graceland	Non-quilled x non-quilled	14

Cross		Per cent
Yellow Izola X Champaigne Red	Non-quilled x non-quilled	4
Ohio State X Baby	Non-quilled x 1/2 quilled	9
Varsity X Champaigne Red	1/2 quilled x non-quilled	39
Varsity X 9-6	1/2 quilled x 1/4 quilled	83
Varsity X 9-3	1/2 quilled x 1/2 quilled	75
Varsity X Graceland	1/2 quilled x non-quilled	33
Varsity X Baby	1/2 quilled x 1/2 quilled	50
Varsity X Ethyl	1/2 quilled x 1/4 quilled	80
Ethyl X Sol D'Orr	1/4 quilled x 1/4 quilled	33
Ethyl X Pasadena	1/4 quilled x non-quilled	9
Ethyl X Graceland	1/2 quilled x non-quilled	0
Pink Doty X Sol D'Orr	1/4 quilled x 1/4 quilled	50

Ragged Appearance

None of the parent plants had a ragged appearance but a small percentage appeared in some crosses. All but one of the Ethyl crosses had a few ragged flowered plants. In only one case is the percentage over 10 per cent, hence, this could very easily be due to a series of allelomorphic factors all of which must be in the recessive condition before the factor is expressed. Below are the results secured in 1940. No data were taken in 1941.

Cross	Percentage
Ethyl X Peggy Ann Hoover	6
Ethyl X Crimson Splendor	4
Ethyl X Crimson Splendor	14
Ethyl X Early White Hardy	6
Norma X Early White Hardy	3
Yellow Doty X Pink Doty	8
Yellow Izola X Graceland	8
Yellow Izola X Champaigne Red	2
Ohio State X Baby	9

Time of Blooming

Confusing results were obtained in connection with time of blooming. Since only relatively early greenhouse varieties were used, it is probable that the range of maturity was too narrow to escape environmental variation. Early outdoor varieties and late greenhouse varieties may have to be added to this sort of study before a genetical system can be worked out for inheritance of time of blooming. Results are given in per cent for data obtained.

Cross		Early	Medium	Late
		per cent		
Ethyl X Peggy Ann Hoover	(Early X early)	41	53	6
Ethyl X Graceland	(Early X early)	33	67	
Ethyl X Crimson Splendor	(Early X early)	61	31	8
Ethyl X Crimson Splendor	(Early X early)	29	48	23
Ethyl X Early White Hardy	(Early X early)	42	45	13
Norma X Early White Hardy	(Late X early)	75	25	
Norma X Champaigne Red	(Late X early)	10	61	29
Mrs. Tricker X Crimson Splendor	(Medium X early)		83	17
Yellow Doty X Pink Doty	(Early X early)	32	52	16
Yellow Doty X Varsity	(Early X medium)	67	33	
Yellow Doty X Champaigne Red	(Early X early)		100	
Yellow Doty X Ohio State	(Early X medium)		90	10
Yellow Doty X Early White Hardy	(Early X early)		100	
Yellow Izola X Graceland	(Medium X early)	45	39	16
Yellow Izola X Champaigne Red	(Medium X early)		14	86
Ohio State X Baby	(Medium X late)		100	
Varsity X Champaigne Red	(Medium X early)	28	70	2
Varsity X 9-6	(Medium X early)	50	17	33
Varsity X 9-3	(Medium X early)	25	75	
Varsity X Graceland	(Medium X early)		67	33
Varsity X Baby	(Medium X late)		100	
Varsity X Ethyl	(Medium X early)	80	10	10
Ethyl X Sol D'Orr	(Early X medium)	17	84	
Ethyl X Pasadena	(Early X late)	41	50	9
Ethyl X Graceland	(Early X early)	45	55	
Pink Doty X Sol D'Orr	(Early X medium)	50		50

Color Inheritance

Color seems to be controlled by many factors but definite conclusions could not be obtained from the limited material available for study. The largest percentage of the flowers have a uniform color due to the color of the dorsal side of the petals. Twisted petals, petals which reverse over the eye, color at the tip of the petals, color at the edge of the petals, a yellowish cast around the eye when the flower is opening, and the anemone eye all have been observed to have an effect on the color of the flower. Other factors that affect the color are the time of fading and the kind of fading. Of the colors themselves, they may be intense, regular shade, or dilute and faded even when the flower first opens.

The anemone eye and petals which reverse over the eye have been discussed separately in other sections of this work. Various factors such as color at the tip of the petals, color at the edge of the petals, a yellowish cast around the eye and fading will be noted in this section, but the genetics of the factors were not analyzed completely due to too small numbers in the crosses. Separate crosses and selfs were not made to study these factors.

The various color factors for asters reported upon by Wit (1937), summarized above, seem to apply in chrysanthemums

as well as additional factors concerning veining, fading, cream eye and color at the tip and edge of the petals. However, chrysanthemums lack blue flowers common in asters and possess many shades of yellow and orange not found in asters.

In 1940 the following colors were noted among the plants studied. The colors were classified according to the color standard of Ridgeway (1912).

Yellow and white shades

White
Maize yellow
Picric yellow
Sulphur yellow
Martius yellow
Baryta yellow
Empire yellow
Apricot yellow
Pinard yellow
Light greenish yellow
Pale greenish yellow
Pale green yellow
Lemon yellow
Xanthine yellow
Light orange yellow
Pale orange yellow
Mars yellow
Buff yellow
Lemon chrome
Yellow chrome
Chrome
Yellow ocher
Cream
Creamy white
Cadmium
Light cadmium

Red-orange shades

Orange-buff
Orange rufous
Ochraceous orange
Raw sienna
Mars orange
Yellow orange
Pinkish buff
Dark pinkish buff
Pompeian red
English red
Light English red
Faded English red
Eugenia red
Light eugenia red
Dark eugenia red
Nopal red
Brazil red

Pink-purple shades

Shell pink
Light shell pink
Spinel pink
Amaranth pink
Rose pink
Old rose
Pale flesh
Phlox pink
Light phlox pink
Mallow pink
Light mallow pink
Very light mallow pink
Light pinkish lilac
Rosolane purple
Pomegranate purple
Pale amaranth purple
Phlox purple

Slight Brazil red
Light Brazil red
Dragon blood red
Scarlet red
Begonia red
Hellebore red
Carmine
Bright carmine
Light carmine
Faded carmine
Red rufous
Faded phlox purple
Mallow purple
Light mallow purple
Purple
Rose purple
Pale rose purple
Carmine purple
Aster purple
Light aster purple
Dark aster purple

In 1941 a wide range of colors were noted, but a more simplified system of studying the color was used and so the various color factors as here noted were not recorded.

The following results were obtained in 1940 for each of the crosses available for study.

Ethyl (nopal red) X Peggy Ann Hoover (white with mallow pink veins) gave 34 plants. For the dorsal color there were eight yellow, five white, six red, four purple, one pink, two white with red veins, one white with purple veins, two yellow with red veins, and five yellow with orange veins. For the ventral color there were six white, three purple, four red, ten yellow, two pink, three yellow with orange veins, five yellow with red veins, and one purple with white veins.

Ethyl (nopal red) X Graceland (white) gave 51 plants. For the dorsal color there were 23 white, 17 yellow, two red, one orange, four white with pink veins, two white with purple veins, one white with red veins, and one white with orange veins. For the ventral color there were 20 yellow, 27 white, three white with pink veins, and one white with purple veins.

Ethyl (nopal red) X Crimson Splendor (crimson). The first cross gave 26 plants. For the dorsal color, there were 17

red, three orange, two yellow with dark yellow veins, and four yellow with red veins. For the ventral color there were six yellow, 18 yellow with red veins and two yellow with orange veins.

The second cross gave 49 plants. For the ventral color there were 41 red, three orange, four yellow with red veins and one yellow with orange veins. For the ventral color there were six yellow, 41 yellow with red veins, and two yellow with orange veins.

Ethyl (nopal red) X Early White Hardy (white) gave 79 plants. For the dorsal color there were 45 white, 18 purple, two red, one pink, one yellow, nine white with purple veins, one white with red veins, and two white with pink veins. For the ventral color there were 47 white, nine purple, 17 white with purple veins, three white with pink veins and three yellow with red veins. Twenty-two plants had flowers with a yellowish cast around the eye when the flowers were young.

Norma (white with mallow pink veins) X Early White Hardy (white) gave 60 plants. For the dorsal color there were 55 white, three yellow, one white with pink veins and one white with purple veins. For the ventral color there were 57 white and three yellow. No veining on the ventral was found. Fourteen plants had a yellowish cast around the eye when the flowers were first opening.

Norma (white with mallow pink veins) X Champaigne Red (carmine) gave 71 plants. For the dorsal color there were 48 red, four

yellow, 17 yellow with red veins, one yellow with orange veins, and one plant had flowers that had yellow petals with the edge of the petal red. For the ventral color there were 14 yellow, 55 yellow with red veins - one of which had the veins only half way down, and two yellow with orange veins.

Mrs. Tricker (lemon yellow) X Crimson Splendor (crimson) gave 18 plants. For the dorsal color there were 11 yellow, one pink, four yellow with red veins, and two yellow with orange veins. For the ventral color there were 15 yellow, one pink and two yellow with red veins.

Yellow Izola (lemon yellow) X Champaigne Red (carmine) gave 49 plants. For the dorsal color there were 16 purple, 25 red, two white, two yellow with red veins, two white with purple veins, one white with pink veins, and one yellow with red tips.

Yellow Izola (lemon yellow) X Graceland (white) gave 44 plants. For the dorsal color there were seven yellow, 24 white, one yellow with red veins, nine white with purple veins, one white with purple veins half way down, and three white with tip of petal having purple veins. For the ventral color there were seven yellow, 23 white, one yellow with red veins, ten white with purple veins, one white with purple veins half way down, and two white with the tip of petals having purple veins.

Yellow Izola (lemon yellow) X Champaigne Red (carmine) gave 49 plants. For the dorsal color there were 16 purple, 25

red, two white, two yellow with red veins, two white with purple veins, one white with pink veins, and one yellow with red tips. For the ventral color there were two white, two red, 24 yellow with red veins, 18 white with purple veins, one white with pink veins, and two yellow with red tips.

Ohio State (lemon yellow) X Baby (lemon yellow) gave 11 plants. For the dorsal color there were nine yellow, one pink and one red. For the ventral color there were eight yellow, one yellow with dark yellow veins, and two yellow with red veins.

Yellow Doty (lemon yellow) X Ohio State (lemon yellow) gave 20 plants. For the dorsal color there were six white, eight yellow, three red, one purple, and two yellow with red veins. One plant had white flowers with a yellowish cast around the eye when the flower first opened. For the ventral color there were eight yellow, six white, one purple, two yellow with red veins, three yellow with red veins half way down.

Yellow Doty (lemon yellow) X Champaigne Red (carmine) gave 20 plants. For the dorsal color there were eight red, one yellow, one purple, seven yellow with red veins, one yellow with orange veins, one yellow with the edge of the petal red and one yellow with the tip of the petal red. For the ventral color there were two yellow, 15 yellow with red veins, one yellow with orange veins, one yellow with purple veins, one yellow with red at the tip of the petals.

Yellow Doty (lemon yellow) X Varsity (lemon yellow) gave nine plants. For the dorsal color there were three red, four

yellow, one yellow with red veins, and one white with red veins. One flower had a yellowish cast around the eye when it was first opening. For the ventral color there were four yellow, two white, and three yellow with red veins. Yellow Doty (lemon yellow) X Pink Doty (mallow pink) gave 38 plants. For the dorsal color there were 11 purple, four red, nine yellow, four orange, one pink, three yellow with red veins, one white with pink veins, one white with purple veins, one yellow with pink veins, one yellow with orange veins and two yellow with red tips at edge of petals. Three plants had flowers that had a yellowish cast around the eye as the flower first opened. For the ventral color there were 15 yellow, three pink, two white, two orange, seven white with purple veins, two white with pink veins, five yellow with red veins and two yellow with orange veins. Yellow Doty (lemon yellow) X Early White Hardy (white) gave eight plants. For the dorsal color there were seven white and one yellow. Two plants had flowers that had a yellowish cast around the eye when the flower first opened. For the ventral color there were seven white and one yellow. Varisty (lemon yellow) X Champaigne Red (carmine) gave 47 plants. For the dorsal color there were 20 red, five yellow, one pink, 13 yellow with red veins, three yellow with orange veins, four red with yellow tips, and one yellow with orange tips. For the ventral color there were five yellow, one red, 35 yellow with red veins, one white with red veins,

two yellow with pink veins, and three yellow with orange veins.

Varsity (lemon yellow) X 9-6 (white with hellebore red veins) gave 7 plants. One was apetalous. For the dorsal color there were five yellow, one light yellow with dark yellow veins. For the ventral color there were six yellow.

Varsity (lemon yellow) X 9-3 (lemon yellow with light English red veins) gave eight plants. For the dorsal color there were three yellow with orange veins, four yellow with red veins and one crimson. For the ventral color there were two yellow with orange veins, three yellow with red veins, and three yellow.

Varsity (lemon yellow) X Graceland (white) gave three plants. For the dorsal color there were one yellow and two yellow with red veins. For the ventral color there were one yellow and two yellow with red veins.

Varsity (lemon yellow) X Baby (lemon yellow) gave four plants. For the dorsal color there were three yellow and one red. For the ventral color there were three yellow and one yellow with red veins.

Varsity (lemon yellow) X Ethyl (nopal red) gave ten plants. For the dorsal color there were three red, three yellow with red veins, one yellow with orange veins and three yellow with red tips. For the ventral color there were two yellow, five yellow with red veins, and three yellow with red tips.

Ethyl (nopal red) X Sol D'Orr (light orange yellow with nopal

red veins) gave 18 plants. For the dorsal color there were five red, two yellow, six yellow with red veins, two yellow with orange veins, one yellow with red tips, one red with yellow tips, one yellow with edge of petals red. For the ventral color there were three yellow, 13 yellow with red veins and two yellow with orange veins.

Ethyl (nopal red) X Pasadena (lemon yellow with nopal red veins) gave 12 plants. For the dorsal color there were four red, one white, one yellow, two yellow with red veins, two yellow with orange veins, one orange with red veins, one red with tips of petals yellow. For the ventral color there were one yellow, one white, eight yellow with red veins, two yellow with orange veins.

Ethyl (nopal red) X Graceland (white) gave 11 plants. For the dorsal color there were four yellow, one white, two purple, two light yellow with dark yellow veins, one yellow with red veins, one white with purple veins. For the ventral color there were four yellow, two white, three yellow with red veins, one white with pink veins, and one white with purple veins.

Pink Doty (mallow pink) X Sol D'Orr (light orange yellow with nopal red veins) gave four plants. For the dorsal color there were one yellow, one light pink with dark pink veins, one white with pink veins, and one yellow with red veins. For the ventral color there were two white with pink veins, one yellow and one yellow with red veins.

Fading Factors

The time and amount of fading has a large influence on the color of the flower and its commercial value. Crimson Splendor seems to be dominant for the lighter color fading factor in that most of its offspring faded to a lighter color. Early White Hardy seems to carry a dominant factor that causes the petals to have purple veins when old. No definite conclusions could be drawn from the data as to factorial make-up of the other varieties. Table 4 gives a summary of the results for all crosses studied.

Studies on Self-pollinated and Open-pollinated Plants

In 1940 "selfs" were made of a large number of plants to obtain better genetical data and to establish homozygous lines. Flowers were trimmed but were not emasculated. Flowers from the following seedlings or varieties were placed under paper bags and self-pollinated once or twice.

5-4	9-4	A-3	Pink Doty
5-1	9-3	A-2	Graceland
5-8	4-5	A-22	Ethyl
5-2	1-11	A-19	Yellow Doty
5-26	11-28	19-6	Crimson Splendor
5-5	11-21		Marguerite Clark

The seed that formed was stored under good conditions but when planted the following spring it did not germinate

Table 4. Fading of blossoms in chrysanthemum hybrids, 1940 and 1941.

Cross	Time and kind of fading	Percentage fading			
		Early	Late	To purple veins	To lighter shade
Ethyl X Peggy Ann Hoover	Early to light x early to light	10	5	12	3
Ethyl X Graceland	Early to light x late to purple veins	6	61	47	20
Ethyl X Crimson Splendor	Early to light x early to light	19	81		100
Ethyl X Crimson Splendor	Early to light x early to light	41	55		96
Ethyl X Early White Hardy	Early to light x early to purple veins	90		86	4
Norma X Early White Hardy	Late to light x early to purple veins	23	58	81	
Norma X Champaigne Red	Late to light x late to light	14	70	3	81
Mrs. Tricker X Ceimson Splendor	Non fade x early to light	17	22	17	22
Yellow Doty X Pink Doty	Late to light x early to light	32	16	11	37
Yellow Doty X Champaigne Red	Late to light x late to light	30	55	20	65
Yellow Doty X Ohio State	Late to light x late to light		30	10	20
Yellow Doty X Early White Hardy	Late to light x early to purple veins	13	50	63	
Yellow Izola X Graceland	Late to light x late to purple veins	5		2	3
Yellow Izola X Champaigne Red	Late to light x late to light	22	2		24
Ohio State X Baby	Late to light x non fade		36	36	
Varsity X Champaigne Red	Early to light x late to light	51	43	53	41
Varsity X 9-6	Early to light x late to light	50	33	50	50
Varsity X 9-3	Early to light x late to light	25	75	38	62
Varsity X Graceland	Early to light x late to purple veins		33		33
Varsity X Baby	Early to light x non fade		25		25
Varsity X Ethyl	Early to light x early to light	60	10	40	50
Ethyl X Sol D'Orr	Early to light x early to light	61	22	44	50
Ethyl X Pasadena	Early to light x early to light late to purple veins	41	50	33	75
Ethyl X Graceland	Early to light x late to purple veins	54	45	63	45
Pink Doty X Sol D'Orr	Early to light x early to light	25	50	25	50

well and only a few seedlings emerged. One plant was obtained from each of the following selfs: 5-5, A-3, and Pink Doty.

Most writers state that chrysanthemums are easily selfed, but Mulford (1937b) placed four plants each of 24 clonal lines under cloth cages for self-pollination. Only eight lines gave viable seed and only four lines gave enough seed for study. From the eight lines one seedling was obtained from one line, three seedlings from each of three lines and 17, 54, 503, and 53 seedlings from the other four lines under study.

A number of additional self-pollinated plants were made in 1941. These plants had petals cut off and were pollinated using their own pollen or pollen from the same plant five or six times.

From the 37 crosses almost all the seed was plump, and of a good dark brown or black color, while the seed from the 20 self-pollinated plants were almost entirely shriveled and of a light brown color.

From these data and Mulford's (1937a, 1937b), it seemed that there may be self-incompatibility in some varieties. Crane and Lawrence (1938) discussed the various types of incompatibility found in plants.

Seed was selected from the central perfect flowers on some of the seedlings in 1940. These were studied, but due to the parentage not being certain as a result of open-pollination, the results were not analyzed as the other data

were. Six plants were found that were of enough commercial value to warrant future trial. In most cases the range of type, size and other factors was what would be expected if the plant was crossed with some plant of the same characteristics.

The 9-1 open-pollinated line gave several odd types worth discussing. The mother plant or 9-1 occurred in the cross of Yellow Doty X Varsity. It was lemon chrome, baby, double, reflex base and mound top. The flowers were waxy, and the plant bloomed early. The 80 progeny of this open-pollinated plant were very variable, having a complete range of color, size, base, top, quilling, and time of blooming. Some of the plants were waxy. For type, singles, semi-doubles, doubles, anemones, and super-anemones were observed.

No. 22 was apetalous. This was a very sturdy plant but none of the flowers had petals. Some crosses were made to study the genetics of this factor. Another apetalous plant was found in Varsity X 9-6 so evidently the factors were carried in the "9" line.

No. 30 had one row of white outer petals and an anemone eye of perfect flowers.

No. 35 had two rows of short twisted petals around the eye.

No. 38 was a baby that had five rows of quilled petals around the plain eye that looked like No. 43 or 44.

Nos. 43 and 44 were both of baby size that had no outer

petals but had five and seven rows of anemone (perfect) petals around a plain eye. From outward appearance, they looked like No. 38 except all florets were perfect.

No. 39 was a chimera. One-half of the plant was lemon yellow, double with a twisted base and a semi-mound top. The other half of the plant was lemon yellow with crimson veins, semi-double, with a reflex base and semi-mound top.

No. 52 had quilled petals divided into three parts at the top.

No. 7 had no outer petals but did have an anemone eye of perfect flowers.

No. 54 had a variable number of petals. Some flowers were apetalous, others had one and two petals, others one and two rows of petals. A few flowers had three and four rows of petals. The same type and color of flowers occurred in the mixed cross Ethyl X Graceland and Ethyl X Varsity.

Mutations and Chimeras

There were many mutations and chimeras found both in 1940 and 1941. The exact cause and nature of the sports and mutations is not known. Sansome and Philp (1932) and others have discussed these phenomena. A few of those found in connection with the present work are described here.

In 1940 in the cross Ethyl X Crimson Splendor, one

seedling had variable flowers. Part of the plant had flowers with a flat top and part of the plant had flowers with a semi-mound top.

In 1940 two seedlings, numbers 13 and 39, of the cross Ethyl X Graceland showed mutations and these were used to study the inheritance of cuttings from mutations. No. 13 had lemon yellow medium sized super-double flowers with a reflex base and a flat top. Most of the plant blossomed early, but in the medium period a branch developed that had white flowers of medium size, super-double, with a reflex base and semi-mound top. Numerous cuttings were made from this plant and studied in 1941. In the early period one plant had yellow flowers the same description as the yellow part in the original and looked like the original plant. In the medium period eight plants had white flowers the same description as the original white section. In the late period seven plants blossomed with white flowers with the same description. The last plant in the lot blossomed very late. It had lemon yellow flowers of medium size, and a mound top. No. 39 had white flowers of medium size, part of which were super-double and part super-anemone. The plant bloomed in the medium period. Cuttings from this plant were studied in 1941. About half of the plants bloomed early and the other half late. In every case, part of the flowers produced by each cutting were super-double and part were super-anemone. The foliage on the late plants was somewhat dif-

ferent than the foliage on the medium blooming plants.

In the 1941 work, two plants were observed that had a variable number of petals. Some of the flowers had no petals, some flowers a few petals, while others on the same plant had as many as four rows of petals.

Several chimeras were noted in 1941. One was a sectorial type with a yellow quarter in one of the pink flowers of the selection 140539. In the mixed cross of Ethyl X Varsity and Ethyl X Graceland seedling No. 22 had white flowers with Indian lake color in the veins extending three-fourths of the way down. One flower on this plant was half pure white and half white with Indian lake veins. Seedling No. 29 was light orange yellow with nopal red veins, but one flower was part yellow, and the rest of the flower had nopal red veins.

In the cross Varsity X Champaigne Red, seedling No. 36 had flowers that were light orange yellow with coral red veins. Part of the plant had flowers that faded to a lighter color and part faded to a darker color.

In the study of cuttings, 80439 was very variable. Part of the plants under study had flowers that were a lighter shade than the other plants. The light colored flowers were one-fourth quilled and had a lemon yellow anemone eye while the darker colored flowers were one-half quilled and had a cadmium yellow anemone eye. One plant had one-half of the plant with dark flowers and one-half of the plant had light

flowers. One plant of No. 110239 had a branch where the flowers were much darker than the others of that variety. In the selection 110339 the flowers varied in color. The flowers were mallow pink, but some of the plants had flowers with some yellow in the center. The amount of yellow varied with the different plants. In the selections 10139 and 30139 most of the flowers had anemone eyes although some had plain eyes.

Among the commercial varieties, some mutate quite frequently whereas others are more stable. Yellow Garza is particularly unstable. White Garza has white outer petals and white or cream anemone eye while Yellow Garza, a mutation of White Garza, has yellow petals with a yellow anemone eye. In most commercial plantings of Yellow Garza mutations of white may be found. The following flowers were found by the writer in commercial plantings of Yellow Garza at the Kansas State College greenhouse and at the greenhouse of the Manhattan Floral Company. Numerous flowers of Yellow Garza had mutated to white but the yellow anemone eye was maintained. Some flowers were found with one-half of the outer petals white while the other outer petals were yellow. The yellow anemone eye was maintained unaffected. There were many sectorial types of chimeras. Several flowers had half of the flower white and the other half yellow. The white and yellow took in both the outer petals and the anemone eye. Several flowers were found with a quarter of the flower either yellow

or white and the rest of the flower the other color. One flower was pure yellow except for three petals, two of which were located on either side of the third but in a different row. The two petals were half white but the third had a white center with yellow edges. One branch supporting three blossoms was found that had a white flower in the center, a pure yellow flower on one side and a yellow flower with a sectorial chimera of white on the other. Several other intermediate types were found.

Cytological Studies

The Japanese have done cytological work on some species of chrysanthemums but no reference could be found of chromosome counts of C. hortorum or greenhouse varieties grown in the United States.

For this work aceto-carmine smears were made of anthers of some of the varieties and seedlings under study but accurate counts could not be obtained because chrysanthemum chromosomes are very small and when the slides were studied under oil immersion and magnified 1425 times the chromosomes were just a little larger than corn chromosomes with 440 magnifications. The field was crowded so the accuracy of the count may be questioned. Counts of 22 to 36 pairs were noted in different slides and different cells. Most of the counts showed around 27 pairs or 54 chromosomes for

the 2n number. A few cases were noted in late anaphase where an unequal number of chromosomes were being formed in division.

A study of the pollen showed various sizes of pollen grains, especially in some plants. Some pollen grains were noted to be two and three times as large as other pollen grains in the same field. Part of the pollen grains looked plump and well colored while others of the same size looked shriveled and of a slightly different color.

Mulford (1937a) reported that in counts of pollen grains of seedlings and commercial varieties the percentage of good pollen ranged from 11.7 to 100 per cent. Upon selfing these plants under cloth cages he secured 0 to 81 per cent fertility. One seedling that had 100 per cent viable pollen gave 6.5 per cent fertility and one with 92.9 per cent viable pollen gave no fertility. About 50 per cent of the plants under study gave less than 25 per cent fertility, while only about 8 per cent gave over 51 per cent fertility. A considerable variation in size of pollen grains existed between some of the plants and on the same plants. This unequal size of pollen grain is probably due to meiotic irregularities leading to unequal segregation of chromosomes. This would lead to microspores with different number of chromosomes and probably a variability as to size. According to Mulford these irregularities may result from structural hybridity, polyploidy or unfavorable environmental conditions.

Study of Cuttings

There were 41 selections from the 1940 seedling chrysanthemums that were propagated by cuttings for study in 1941. These selections were based on flower characteristics and upon commercial value. Some plants that had good flowers were not saved because they resembled commercial varieties now in existence, and were not superior in any observed characteristics. Twenty-seven of these selections were found to be good enough to warrant future trial and will be grown commercially in the College Greenhouse in 1942 to see if the public will buy them in preference to the commercial varieties now grown. The selections are here described.

Selections from Yellow Izola X Champaigne Red:

40539--Carmine purple, semi-double, medium size, with a twisted base, and semi-flat top. The color fades late to a lighter color, but is still desirable. This is a desirable shade and should work well for bedding stock, but should be cut late as the twisted petals show the white of the veined base until the flower is almost open. It is too tall for pot plants. Blossoms in the medium period or about the time of Varsity.

40239--Carmine, semi-double, medium size, with a twisted base, and semi-flat top. The color fades late to a lighter color. The plant has stiff stems and many flowers to the stem and does well in pots as well as for bedding stock. Blossoms in the medium period or a little later than Varsity.

40339--Carmine purple and looks exactly like 40539 except it blooms ten days later.

40639--Deep rose pink, super-anemone, medium size, with a flat base, and flat top. The color fades late to a little lighter more desirable color. The plant has good placement of flowers and makes a good bedding plant. The anemone eye has an especially good mound, cadmium yellow in color opening to a trace of rose pink. Blossoms in the medium period just a little later than Varsity.

40739--Phlox pink, super-anemone, medium size, with a flat base, semi-flat top, and with quilled petals. The anemone eye is light orange yellow opening to a trace of phlox pink. This is of a different type and one that does not catch the public eye. Not saved. It could be used as a pot plant or bed plant. Blossoms later than Varsity.

40839--Indian lake, super-anemone, medium size, with a flat base, and semi-flat top. The anemone eye is cadmium yellow opening to Indian lake. The flowers fade early to a lighter color. This makes a good plant for bedding stock and can be used as a pot plant if properly staked. Flowers in the medium period or a little later than Varsity.

40939--Indian lake, anemone, medium size, with a twisted base, and semi-flat top. The anemone eye is light orange yellow opening to Indian lake. The flower fades late to light. This makes a good cut flower, but is too tall for pot stock unless properly staked. Blossoms in the medium period a little later than Varsity.

40439--Indian lake, anemone, medium size, with a twisted base, and semi-flat top. The anemone eye is maize yellow opening to a trace of Indian lake. This anemone eye is different from the other flowers in that the quilled petals make an upright center. This plant can be used as a cut flower and a pot plant if properly staked. Flowers in the medium period a little later than Varsity.

40139--Crimson scarlet, super-anemone, medium size, with a reflex base, and a semi-flat top. The anemone is a very good mound of cadmium yellow opening to scarlet. The flowers fade slightly very late. This makes a good cut flower or pot plant variety. Blossoms in the medium period a little later than Varsity.

401039--Dark Indian lake, super-anemone, medium size, with a reflex base, and semi-flat top. The anemone is a very good mound, cadmium yellow opening to dark Indian lake. This makes a very good cut flower when open but shows white due to twisted petals before the flowers are open. As a pot plant it needs good support. Blossoms in medium period a little later than Varsity.

401139--Carmine purple, semi-double, with a twisted base, and semi-flat top. The petals are one-fourth quilled. This makes a good cut flower if cut when flowers are fully open as the petals are twisted when opening. It is too tall for a good pot plant. Blossoms in the medium period a little later than Varsity.

Selections from Mrs. Tricker X Crimson Splendor:

180239--Lemon yellow with coral red veins, double, small size, with a reflex base, and semi-mound top. The petals are reverse over the eye and the eye shows. This selection has a poor bud and is of little value until the flowers are fully open. The flowers fade early to a lighter color. This makes a good cut flower if cut late but is too tall and wiry for a pot plant. Blossoms early but is ready for sale about the same time as Varsity.

180139--Lemon yellow, super-double, baby size, with a reflex base, and mound top. This makes a good cut flower as the flowers are very numerous and they do not fade until very late. Blossoms earlier and is better than Varsity.

Selections from Yellow Doty X Pink Doty:

140439--Nopal red, super-double, medium size, with a reflex base, and a mound top. The flowers fade early to a lighter color. The petals are one-third quilled and have petals which reverse over the eye. This makes a good cut flower but was not saved because of no outstanding characteristics and its fading character. Blossoms early.

140239--Lemon yellow with nopal red veins, super-double, small size, with a reflex base, and semi-mound top. The flowers fade late to a lighter color. The petals are one-half quilled and reverse over the eye. It makes a fair cut flower and pot flower, but it has a poor bud and the flowers are rather bunched at the top of the head so it was not saved. Blossoms early.

140639--Pinard yellow with nopal red veins, super-double, medium size, with a reflex base, and semi-flat top. Fades early to a lighter color. Petals which are reverse over the eye. Makes a good early pot plant but is too short for cut flowers so was not saved.

140339--Lemon yellow with nopal red veins, super-double, small size, with a twisted base, and semi-mound top. Fades late to a lighter color. The petals are twisted and reverse over the eye. This is a good plant for either pot or cut flowers but not enough difference from some of the commercial varieties to be worth saving. Blossoms early.

140539--Rose pink, super-double, small size, with a reflex base, and mound top. The petals are reverse over the eye. The buds open uneven but this makes an excellent flower when more open and it lasts over a month without fading. Has many flowers per stalk and makes a very good cut flower as well as a good pot plant. Blossoms among the earliest but should not be cut much before Varsity.

140739--Pinkish magenta, super-double, medium size, with a reflex base, and a mound top. Petals are one-half quilled and reverse over the eye. The flowers fade early to a lighter color. This variety makes good cut flowers and pot plants, and blossoms as early as Pink Doty. It is considered better than Pink Doty although a little smaller.

140139--Deep rose pink, super-double, small size, with a reflex base, and a mound top. Fades early to a lighter color. The petals are one-third quilled. The petals are reverse over the eye. It makes a good pot plant or cut flower. Blossoms early.

Selections from Ethyl X Peggy Ann Hoover:

110139--Extra deep rose pink, super-double, large size, with a twisted base, and semi-flat top. The petals are one-fourth quilled and reverse over the eye. Makes a very good late pot plant.

110239--Lemon yellow, super-double, medium size, with a twisted base, and semi-mound top. The petals are one-fourth quilled and reverse over the eye. The flowers have excellent placement on the stem and this makes a good cut flower except they are very wiry. Not saved. Blossoms among the earliest.

110339--Mallow pink, double, medium size, with a flat base, and semi-mound top. The petals are three-fourths quilled and petals are reverse over the eye. Fades late to a lighter color. This would make a good early cut flower if it did not have such wiry stems. The color is not fixed within the cuttings as there was a distinct range with varying shades of yellow to pink. Not saved.

Selections from Norma X Early White Hardy:

10139--White, super-anemone, medium size, with a flat base, and semi-mound top. The anemone eye is pinard yellow changing to cream. It would make a good medium blooming pot plant except there were a few petals in the

eye and the flowers fade early to purple veins. Not saved.

10239--White with mallow pink veins and a cream eye. The flowers are double, of medium size, with a reflex base, and mound top. The petals are one-fourth quilled, and reverse over the eye. This makes a good medium blooming cut flower except that it fades early to almost white and later to purple veins. Not saved.

10339--White with cream eye, super-double, medium size, with a flat base, and flat top changing late to a semi-mound top. The petals are quilled and reverse over the eye. This type of flower is different than commercial varieties and while it blossoms in the medium period it fades early to purple veins and was not saved.

Selections from Ethyl X Crimson Splendor:

120239--Carmine, super-double, medium size, with a reflex base, and semi-flat top. The petals are reverse over the eye and are one-fourth quilled. This would make a good early cut flower except it fades very early to a lighter color. Not saved.

120139--Carmine, super-double, medium size, with a twisted base and semi-mound top. The petals are very twisted and reverse over the eye. This makes a good cut flower for the middle period but some of the flowers fade very early while others fade a little later. Not saved.

20139--Nopal red, super-double, medium size, with a twisted base, and semi-flat top. The petals are reverse over the eye. This would make a good early cut flower but it fades very badly to a lighter color. Not saved.

Selections from Ethyl X Graceland:

80139--White, double to super-anemone, medium size, with a twisted base, and semi-flat top. Some of the flowers are double with petals which reverse over the eye, while other flowers have a pinard yellow anemone eye. Flowers fade late to purple veins. Not saved. Blossoms in the early period.

80239--White, super-anemone, medium size, with a twisted base, and semi-flat top. Flower has a good cream anemone eye. Fades late to purple veins. Makes a good pot plant or cut flower. Blossoms in the middle period about the time of Varsity.

80339--Lemon yellow, double to super-anemone, medium size, with a twisted base, and semi-flat top. The plants are variable with some double flowers showing. Parent plants are to be picked only when all anemone. Cadmium yellow anemone eye. Blossoms early or a little later than Ethyl.

80439--Lemon yellow with nopal red veins, super-anemone, medium size, with a twisted base, and semi-mound top. Variable in that some plants are much lighter than others. The light flowers have the petals one-fourth quilled, and have a lemon yellow anemone eye. The dark plants have the petals one-half quilled, and have a cadmium yellow anemone eye with petals in the eye. Not saved for while the variety blooms about the time of Yellow Izola, it is not as good.

Selections from Yellow Doty X Early White Hardy:

70139--White, super-double, medium size, with a flat base, and mound top. The petals are quilled. Fades early to purple veins. Makes a good different pot plant but too short for cut flowers. Blossoms as early as either parent.

70239--White, waxy, super-double, medium size, with a flat base, and semi-mound top. The petals are one-fourth quilled, and reverse over the eye. Blooms in the medium period a little earlier than Varsity. Makes a good cut flower but not as good as White Doty so was not saved.

Selections from Ethyl X Early White Hardy:

30139--White with mallow pink veins, cream eye. Flowers are super-anemone, medium size, with a flat base, and semi-mound top. The cream eye fades early to white and later the whole plant becomes purple veined. Pretty good for early cut flowers but was not saved because of the fading factors.

Selections from Norma X Champaigne Red:

60139--Lemon yellow with nopal red veins, double, medium size, with a twisted base, and semi-mound top. The petals are reverse over the eye. The color fades to a yellow around the eye, regular color center petals, and purple veined outer petals. Makes a good early cut flower, but was not saved because of the fading factors.

60239--Lemon yellow with the edge of the petals nopal red. The flowers are waxy, super-double, medium size, with a twisted base, and semi-mound top. The petals are reverse over the eye until late. There are a few petals in the eye. Blooms in the middle period a little earlier than Varsity. A very desirable early flower for pot plants but needs special care to make a good cut flower.

Selections from Yellow Izola X Graceland:

50139--Lemon yellow, super-anemone, large size, with a reflex base, and a semi-flat top. The anemone eye is lemon yellow and forms an excellent mound. The petals are narrow until the flowers are fully open. The flower fades to purple veins very late. This variety is excellent for pot plants and makes good cut flowers if plants are given good care. Blooms a little earlier than Ohio State and is a much better pot plant.

50239--White, anemone, medium size, with a twisted base, and semi-flat top. The anemone eye is lemon yellow and forms an excellent mound. The petals fade to purple veins late in the season. This variety makes excellent pot plants and makes good cut flowers if the plants are given extra care. Blooms about ten days later than Graceland but is a much better variety.

50339--Crimson, super-anemone, medium size, with a flat base, and semi-flat top. The anemone eye is maize yellow opening to a little crimson. Flowers fade early to a lighter color. Makes a fair cut flower but the stems are wiry and the mound is not very good. Not saved.

Twenty-five selections were made from the 1941 seedlings. These selections were found to have good flower characteristics as well as commercial possibilities. Further work is planned to select the best commercial varieties in the lot.

Selections from Ethyl X Graceland or Ethyl X Varsity:

10140--Pinard yellow with nopal red veins, super-double, baby size, with a flat base, and mound top. The petals were three-fourths quilled. Flowers fade late to a lighter color. Blossoms early.

10240--Cadmium yellow with nopal red veins, super-double, baby size, with a reflex base, and mound top. The petals were reverse over the eye and three-fourths quilled. Flowers fade late to a slightly lighter color. Blossoms in the middle period.

10340--Nopal red with yellow at the tips of the petals. The flowers are super-anemone, medium size, with a twisted base, and semi-flat top. The petals were twisted. The anemone eye was cadmium yellow opening to nopal red. Blossoms in the middle period.

10440--Crimson, super-double, small size, with a reflex base, and a mound top. The petals were reverse over the eye and the center of the flower appeared golden due to this characteristic. The flowers fade late to a slightly lighter color. This is an improved Ethyl in that it is as early as Ethyl but fades much later.

10540--Lemon yellow with a tinge of crimson giving the appearance of salmon color. The flowers are double, baby size, with a reflex base, and semi-mound top. The eye shows a little but is not undesirable. The flowers fade very little. Blossoms very early and looks like a very good pot plant variety.

10640--Scarlet-crimson, super-double, small size, with a reflex base, and a mound top. The petals are one-fourth quilled and form a gold center due to the petals which reverse over the eye. Blooms in the middle period.

Selections from Varsity X Champaigne Red:

20140--Deep rose, single, small size, with a twisted base, and semi-flat top. This is a desirable color that may be worked on more double varieties. The petals all have pinard yellow close to the base forming a gold ring around the eye. Blossoms early.

Selections from Varsity X Ethyl:

70140--Crimson, semi-double, medium size, with a reflex base, and semi-flat top. This is an improved Crimson Splendor and while it blooms earlier than Crimson Splendor it fades very late.

70240--Lemon yellow with scarlet tips. The flowers are super-double, baby size, with a reflex base, and semi-mound top. The petals are one-fourth quilled and are reverse over the eye. The flowers are very good and show

red and gold. Blossoms early.

Selections from Ethyl X Sol D'Orr:

80140--Reddish scarlet, super-double, small size, with a twisted base, and mound top. The petals are three-fourths quilled and reverse over the eye. Fades to a lighter color. Blossoms in the middle period.

80240--Cadmium yellow with the edge of the petals scarlet. The flowers are double, baby size, with a flat base, and mound top. The eye shows. Blossoms in the middle period.

Selections from Ethyl X Graceland:

100140--Dark mallow purple, super-double, medium size, with a twisted base, and semi-flat top. The petals fade to darker purple. The flowers have a semi-cream eye due to the petals which reverse over the eye. There is a white area at the end of the petals making a white ring in the center. Blossoms in the middle period.

Selections from Graceland X Champaigne Red:

110140--Light orange yellow with the back of petals with crimson veins. The flowers are super-double, baby size, with a flat base, and a mound top. The petals are three-fourths quilled. Blossoms in the middle period.

110240--Lemon yellow, super-double, baby size, with a flat base, and a mound top. The petals are one-fourth quilled. Had a poor bud early. Blossoms in the middle period.

Selections from Pink Doty X Sol D'Orr:

140140--Mallow pink with a vein of deep rose pink. The flowers are super-double, medium size, with a reflex base, and semi-mound top. The petals are reverse over the eye. Fades early to a lighter color. Blossoms in the early period.

140240--White with mallow pink veins, super-double, medium size, with a reflex base, and semi-mound top. Blossoms late.

Selections from A-27 open-pollinated:

160140--Light Indian lake, super-anemone, medium size, with a twisted base, and semi-flat top. Not all the flowers have the anemone eye. Blossoms late.

Selections from 6-22 open-pollinated:

170140--Indian lake, super-anemone, large size, with a twisted base, and semi-flat top. The petals are one-fourth quilled. There are a few petals in the eye. The anemone eye is pinard yellow opening to Indian lake. Blossoms in the middle period.

Selections from 9-1 open-pollinated:

190140--Apetalous plant saved to study the genetics of the apetalous factor.

Selections from 9-5 open-pollinated:

200140--Carmine, super-double, medium size, with a flat base, and flat top. The petals were one-half quilled and reverse over the eye. Blossoms in the middle period.

Selections from A-4 open-pollinated:

230140--Crimson, anemone, medium size, with a twisted base, and semi-flat top. The anemone eye is light cream opening to crimson. Blossoms in the middle period.

Selections from 9-6 open-pollinated:

210140--White with mallow pink veins, double, large size, with a flat base, and semi-mound top. Fades to white. A few petals in the eye. Blossoms in the middle period.

Selections from 9-2 open-pollinated:

220140--White with mallow pink veins, semi-double, medium size, with a twisted base and semi-mound top. The petals are twisted. A few petals in the eye. Fades early to white. Blossoms late.

220240--Carmine, anemone, medium size, with a twisted base, and semi-flat top. The petals are twisted. The anemone eye is lemon yellow opening to carmine. Blossoms late.

SUMMARY AND CONCLUSIONS

To discover the manner of inheritance for several characteristics of chrysanthemum and to develop new commercial varieties, over 600 seedlings from 16 crosses were studied in 1940 and over 1,000 plants of crosses, self-pollinated plants, open-pollinated plants, and cuttings of selections were studied in 1941.

As chrysanthemums had not been previously studied genetically, the factor symbols were used here for the first time for chrysanthemums.

While over 1,600 plants were studied, this number was insufficient to give conclusive results on the complex inheritance encountered. From the data available several tentative hypotheses were formulated. Size of blossoms appeared to be controlled by four pairs of dominant factors called $\underline{A}^1$, $\underline{A}^2$, $\underline{A}^3$, and $\underline{A}^4$. Type seemingly was controlled by four pairs of dominant factors called $\underline{T}^1$, $\underline{T}^2$, $\underline{T}^3$, and $\underline{T}^4$. Base was controlled by three pairs of dominant factors termed $\underline{B}^1$, $\underline{B}^2$, and $\underline{B}^3$. Petals which reverse over the eye fitted an hypothesis of two pairs of dominant factors $\underline{O}$ and $\underline{P}$ both of which were necessary for the expression of the character. Waxy petals appeared to

be controlled by two pairs of dominant factors L and M both of which were necessary for the expression of the character. Petals in the eye may be controlled by two dominant factors R and S both of which when dominant lead to the expression of the character.

Color inheritance was especially complex and appeared to be controlled by many factors. The color may be affected by the dorsal color, ventral color, presence or absence of veining on the dorsal and ventral side of the petals, twisted petals, petals which reverse over the eye, color at the tip of the petals, color at the edge of the petals, a yellowish cast around the eye when the flower is opening, the anemone eye and the time and amount of fading. Of the colors themselves some were intense, some regular shades and some dilute or faded even when the flower first opened. Fifty-four different shades of color were found in the 1940 seedlings.

Forty-one selections were made from the 1940 seedlings. Of this number 27 strains were found to be worth further trial as new commercial varieties. Twenty-four selections were made from the 1941 seedlings.

Evidence of self-incompatibility was observed in the self-pollination experiments.

Among the open-pollinated plants several odd types were found, especially in the 9-1 line.

Many mutations and chimeras were found in the seed-

lings and selections under trial.

Most of the chromosome counts showed 27 pairs of chromosomes but counts of 22 and 36 pairs were noted. A large variation in size of pollen grains was noted.

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