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GENETIC RESOURCES

Petunia hybrida: A Short Description of the Action of 91 Genes, Their Origin and Their Map Location

P. de Vlaming, A.G.M. Gerats, H. Wiering, H.J.W. Wijsman

Department of Genetics, University of Amsterdam, Kruislaan 318, 1098 SM Amsterdam, The Netherlands

and

A. Cornu, E. Farcy, D. Maizonnier

Station d'Amelioration des Plantes, I.N.R.A. B.V. 1540, 21034 Dijon Cedex, France

In 1979 a "List of genes" of *Petunia hybrida* was published (Wiering et al., 1979) followed in 1980 by a paper on order and distance of ten genes on chromosome V (Cornu et al., 1980). Since then more genes have been located and new genes were found, some of which were presented by Cornu and Maizonnier (1983).

In the present paper we divide the genes in five groups, corresponding to 5 tables, giving a short description of gene action and place of action in the plant. Moreover, recombination percentages with markers, the type of the crosses and the total number of plants in these crosses are given. Many of the location experiments are two point crosses in which several F2s are in repul-II-F1; III-Ht1; IV-B1; V-Hf2; VI-Rt; VII-An4 (Maizonnier and Moessner, from the data.

The many cultivars of *Petunia hybrida* are the primary source of genetic variation. This variation (mostly in attractive flower colours) is derived from

Offprint or genetic stocks requests to: A.G.M. Gerats or A. Cornu.

the wild progenitor species and from spontaneous mutations (Wijsman, 1983a). The induced mutations, mainly in plant and flower form and chlorophyll synthesis, are very useful for basic research. For each linkage group corresponding to the seven chromosomes, a reference marker was chosen : I-Hf1; II-F1; III-Ht1; IV-B1; V-Hf2; VI-Rt; VII-An4 (Maizonnier and Moessner, 1979). In the tables only references relating to gene location experiments are given.

In Table 1 genes are listed for flower color and flavonoid biosynthesis. This is the most practical group of genes. The genes are expressed only in the flower and with a few exceptions vitality and fertility of the relevant pure lines are not affected by mutations of these genes. Many stable and unstable alleles of the genes An1 and An2 are known (Cornu, 1977; Farcy and Cornu, 1978; Bianchi et al., 1978; Gerats et al., 1983; Doodeman et al., 1983). In addition, instability of the genes An3, An6, An11, Rt and Ph4 has been observed. The flavonoid genes, genes involved in the synthesis of secondary plant substances, are very valuable for studies of regulation of gene expression and physiological work.

In Table 2, genes are listed for plant and flower shape. Many of these mutants show reduced vitality and fertility.

In Table 3, genes are listed for chlorophyll synthesis. These are all nuclear mutants. All show reduced vitality.

In Table 4, genes are listed for lethality and fertility. The data obtained in the crosses do not allow calculation of recombination percentages.

In Table 5, genes are listed involved in synthesis and variation of several isoenzymes as identified by gel electrophoresis. Many of the alleles described are derived from sampling populations of the wild progenitor species.

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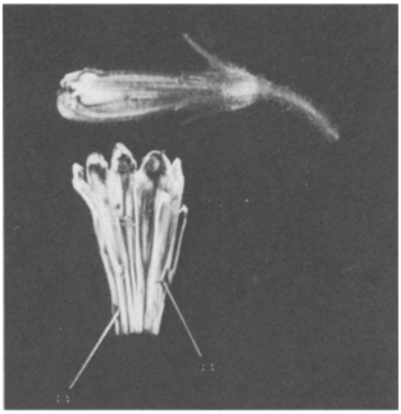

Figure 1. *Petunia hybrida* flower form mutant: phenotype blind, genotype blbl; upper: intact flower, lower: flower folded open.

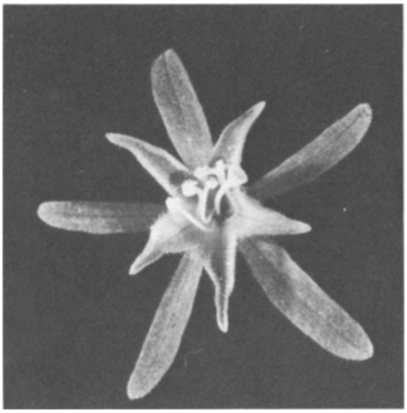

Figure 2. *Petunia hybrida* flower form mutant: phenotype green petals, genotype gpgp.

Figure 3. *Petunia hybrida* flower form mutant: phenotype phoenix, genotype pxpx.

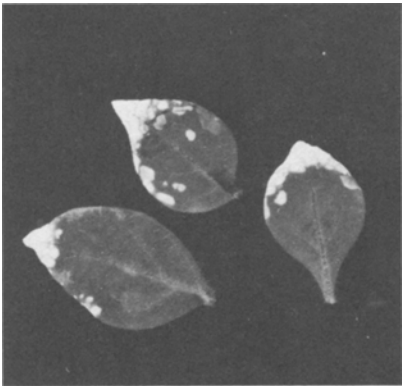

Figure 4. *Petunia hybrida* plant form mutant: phenotype ustulata, genotype usus.

Figure 5. *Petunia hybrida* flower form mutant: phenotype choripetalous with split pistil and acute leaves, genotype ch 1 ch 1.

Figure 6. *Petunia hybrida* flower form mutant: phenotype ears, genotype eaea.

Figure 7. Left: *Petunia hybrida* chlorophyll mutant: phenotype dark green leaves, small plant, genotype dg5dg5. Right: normal green plant, genotype Dg5-.

TABLE I. *Genes for flower colour and flavonoid synthesis in Petunia hybrida.*

Allele	*No or diminished synthesis in a*	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
		Anthocyanin genes							
An1		With anthocyanin		Test		2630	Rt 0	VI	Maizonnier & Moessner, 1979
an1	l t p	Without anthocyanin	Sensation						
An2		With anthocyanin	Pendula Cyanea	Test		1863	Rt 8	VI	Maizonnier &
an2	l	Without anthocyanin or weakly coloured				682 586	Rt 0.2[d] Rt 6		Moessner 1979 Cornu & Farcy subm.
An3		With anthocyanin and flavonol		F2	R	996	Dwl 0.10	IV	
an3-1	l t	Synthesis of flavonol in the flower limb decreased; no or little synthesis of anthocyanin in the flower tube	Rose of Heaven						
an3	l t p	Without anthocyanin or weakly coloured Without flavonol	Blender						
An4		With anthocyanin					marker	VII	Maizonnier & Moessner, 1979
an4	t p	Less anthocyanin between veines of tube; without anthocyanin in pollen	Celestial x Blue Bedder						
An6		With anthocyanin		Test		2178	Bl 27	IV	Cornu & Farcy subm.
an6	l t p	Without anthocyanin; female sterile	Spontenaeous in an unstable stock	F2	R	914	Dw1 0		
An8		With anthocyanins		Test		1008	Gf 24	V	Cornu et al., 1980
an8	t	Anthocyanin synthesis in tube decreased	Deep Blue						

TABLE I. *continued*

Allele	*No or diminished synthesis in a*	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
An9		With anthocyanin		Test		968	Hf1 0.2	I	
an9	l t p	Without anthocyanin or weakly coloured	Spontaneous in M1 × M31						
An10		With anthocyanin and flavonol	EMS induced mutation in TLh2						
an10	l	Without or few anthocyanin and flavonol							
An11		With anthocyanin		F2	R	181	Htl 0-16	III	Doodeman et al., 1983
an11	l t p	Without anthocyanin	Spontaneous in unstable An1						
		Hydroxylation genes							
Ht1		With quercetin and cyanidin or peonidin (3'hydroxylation)					= marker	III	Maizonnier & Moessner, 1979
ht1	l t p	With kaempferol; small amounts of cyanidin or peonidin	Admiral						
Ht2	l p	With quercetin and cyanidin or peonidin (3'hydroxylation)		Test		88	Hfl 27	I	
ht2	l t p	With kaempferol; without cyanidin and peonidin	Gottfried Michaelis						
Hf1		With delphinidin, petunidin or malvidin (3'5'hydroxylation)	Red Velvet				= marker	I	Maizonnier & Cornu, 1971
hf1-1	l	With delphinidin or petunidin (3'5'hydrolxylation)	Rose of Heaven						
hf1	l t p	Only small amounts of delphinidin, petunidin or malvidin	Fire Chief						

Hf2	t p	With delphinidin, petunidin or malvidin *(3'5' hydroxylation)*	Flaming Velvet			= marker	V	Cornu et al., 1980 semi dominant
hf2	l t p	Only small amounts of delphinidin, petunidin or malividin						
		Glycosylation genes						
Rt		With anthocyanin-3-rutinoside (3rhamnosylation)				= marker	VI	Smith et al., 1975
rt	l t p	With anthocyanin-3-glucoside	Fire Chief Salmon Gem					
Gf		With acylated anthocyanin-3-rutinoside-5-glucoside		Test	202	Un 28	V	Cornu et al., 1980
gf	l t p	With anthocyanin-3-rutinoside	Grandiflora nana Karminrosa (4x)					
		Methylation genes						
Mt1		3' position of anthocyanin methylated		Test		Ht1	III	
mt1	l t p	3' position of anthocyanin not methylated	Pendula Cyanea					
Mt2		3' position of anthocyanin methylated		Test	1933	Hf2 0.9	V	Cornu et al., 1980
mt2	l t p	3' position of anthocyanin not methylated	Pendula Cyanea					
Mf1	t p	3' and 5' positions of anthocyanin methylated		Test	493	Ht1 11	III	Wiering and de Vlaming 1977
mf1	l t p	3' and 5' positions of anthocyanin not methylated	Flaming Velvet					
Mf2	t p	3' and 5' positions of anthocyanin methylated		Test	945	Hf2 0,5[d]	V	Cornu et al., 1980
mf2	l t p	3' and 5' positions of anthocyanin not methylated		Test	673	Hf2 12		

TABLE I. *continued*

Allele	*No or diminished synthesis in a*	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
		Acylation genes							
Ac	t p	Other form of p-cumaroyl acylation of anthocyanin	Silvery blue						
ac	l t p	p-cumaroyl acylation on position 4 of rhamnose							
		Flavonol genes							
Fl		Flavonol synthesis stimulated, reduced synthesis of anthocyanin	Pendula Cyanea				= marker	II	Maizonnier & Moessner, 1979
fl-1		Flavonol synthesis only in hflhfl, reduced synthesis of cyanidin and peonidin	Admiral						
fl	l t	Only small amounts of flavonol, synthesis of anthocyanin normal							
		Veining genes							
Fn		Limb with thick veins, tube brown by anthocyanin synthesis							
fn	l t	Limb with fine veins, tube pale		Test		3807	Hf2 0.2	V	Cornu et al., 1980
		Intensity genes							
Fa	l	Color fades during flowering	Royal Ruby						
fa		No fading of color							

In1	l	Color paler	Roter Vogel							
in1		Color darker								
In2		Color darker								
in2		Color paler	Pendula Cyanea							
		pH genes								
Ph1		Reddish hue		Test		4793	Hf1	0.4	I	Cornu and Farcy, subm.
						1071	Hf1	1.0[d]		
						1532	Hf1	4.9		
ph1	l	Bluish hue	Admiral							
Ph2		Reddish hue							IV	Maizonnier & Moessner, 1979
ph2	l	Bluish hue	Dark purple							
Ph3		Reddish hue		F2	R	199	An4	0-10	VII	
ph3	l	Bluish hue; female sterile	Peach Satin × Gypsy							
Ph4		Reddish hue		F2	R	1355	Ht1	26	III	
ph4	l	Bluish hue	Royal Ruby							
Ph5		Reddish hue								
ph5	l	Bluish hue; female sterile	EMS induced mutation						I	
		Genes for colour of pollen								
Po	P	Without yellow pigment in pollen		Test		1952	Hf2	23[d]	V	Cornu et al., 1980
						3807	Hf2	0.6		
po		With yellow pigment (2',4,4',6' tetrahydroxy chalcone) in pollen	Pendula Cyanea							

[a] l = limb of corolla; t = tube of corolla; p = pollen
[b] in cases where no origin is given this type is very frequent
[c] C = coupling; R = repulsion
[d] considerable variation is found

TABLE II. *Genes for plant and flower shape in Petunia hybrida*

Allele	*Blocking of gene action in a*	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
Bl		Flower limb normal					= marker	IV	Maizonnier & Moessner, 1979
bl	f	Flower limb very short, blocking the entrance of the tube (blind)	Royal Ruby						
Ch1		Petals, leaves and pistils normal		F2	R	1801	Ph1 6	I	
ch1	le f	Petals not fused (choripetalous), leaves narrow and acute, pistils mostly reduced	Pace Setter						
Ch2		Flower limb normal		Test		199	Ph4 20	III	
ch2	f	Flower limb with strong incisions between the petals	Royal Ruby						
Ch3		Petals, leaves and pistils normal		F2	R	193	Ht1 0-20	III	
ch3	le f	Petals not fused, leaves narrow and acute, pistils reduced	(Celestial × Red Statin)× Red Joy						
Co		Plant normal							
co	st	Young plant with short internodes	EMS induced mutation in R69						
Cr		Flower limb normal		Test		1074	Fl 0.4	II	
cr	f	Flower limb crumpled	EMS induced mutation in M7						

Do1		Flower with increased number of petals and stamens	All double Multiflora Cardinal			444	An4 0	VII	
do1	f	Flower with normal number of petals and stamens							
Do2		Flower normal		F2	C	156	Fl 1.8	II	
do2	f	Flower parts increased in number and strongly reduced, flower head-shaped, female sterile	Red Joy						
Dw1		Plant normal		F2	R	579	Bl 14	IV	
dw1	st le f	Plant with short internodes, small dark green leaves and small flowers	Spontaneous mutation in M1 × Vu1						
Dw2		Plant normal		F2	C	344	Rt 1.5	VI	
dw2	st le	Plant with short internodes, small leaves with necrotic spots	EMS induced mutation in R69						
Dw4		Plant normal		Test		204	An4 45	VII	Maizonnier and Moessner 1979
dw4	le f	Plant small, leaves spoon shaped, flowers small	γ-rays induced in TL-h1 × Sf-la						
Dw5		Plant normal							
dw5	st le f	Plant small, leaves curled, small flowers	EMS induced mutation in R82						
Dw7		Plant normal		F2	C	220	Fl 5	II	Bennink and de Vlaming, 1981
dw7	st le f	Short internodes, small leaves, small flowers; gibberellic acid sensitive	EMS induced mutation in R82						

TABLE II. *continued*

Allele	*Blocking of gene action in a*	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
Ea		Flower normal		Test		195	Hf1 6	I	
ea	f	Earshaped projections at outer surface of corolla between the petals; male sterile	EMS induced mutation in R69						
Fu		Leaf normal		F2	C	141	Ht1 9	III	
fu	st	Leaf edge folded up	EMS induced mutation in R82						
Gp		Flower normal		F2	R	375	Dw1 0-20	IV	
gpgp	f	Petals with shape and colour as sepals	Spontaneous mutation; EMS induced mutation in R82; γ-rays induced mutation in TL-h1 × Sf-1a						
Ls		Flower normal		Test		106	An4 22	VII	
lsls	f	Flower with long style	Spontaneous						
Px		Flower normal		Test		195	Fl 1	II	
px	f	With a twist in the flower tube; sometimes a new flower proliferates from the receptacle	Spontaneous mutation in instable An1						
St1	le f	Flower normal							
st1		Flower flat, with short tube, leaves, flat and round	γ-rays induced mutation in TL-h1 × Sf-1a						

St2			Plant normal							
st2	st	f	Plant small, greenish yellow, flowers small	γ-rays induced mutation in TL-h1 × Sf-1a						
Tu	le	f	Flower trumpet-shaped	EMS induced mutation in Pa-3 × RL-y	Test		971	Rt 24	VI	
tu			Flower normal							
Un	le	f	Flower limb and calyx undulated, leaves yellowish green	Admiral	Test		1436	Hf2 2	V	Cornu et al., 1980
un			Flower limb and calyx flat, leaves green		Test		469	Hf2 21[d]		
Us			Leaf normal		F2	C	167	Hf2 3	V	
us	le		Leaf with necrotic spots	Spontaneous mutation in V22 × Ml; χ- rays induced mutation in Blue Bedder						
Wi			Plant normal		F2	C	245	Hf1 1	I	
wi	le		Early withering of leaf	EMS induced mutation in R82						

[a] st = stem; le = leaf; f = flower
[b] in cases where no origin is given this type is very frequent
[c] C = coupling; R = repulsion

TABLE III. *Genes for chlorophyll synthesis in Petunia hybrida*

Allele	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
Dg1	Leaf normal green		F2	R	330	Rt 0-20	VI	
dgl	Leaf dark green and small, plant small	χ-rays induced mutation in Blue Bedder						
Dg2	Leaf normal green		F2	R	153	B1 27	IV	
dg2	Leaf dark green, lumpy	EMS induced mutation in R69						
Dg4	Leaf normal green						IV	
dg4	Leaf dark green and round	χ-rays induced mutation TL × Sg						
Dg5	Leaf normal green							
dg5	Leaf dark green, small and soft	Spontaneous mutation in unstable An1						
Dg6	Leaf normal green							
dg6	Leaf dark green and small	Spontaneous mutation in unstable An1						
Lg1	Plant normal		Test		469	Hf1 16	I	
lg1	Plant pale green	χ-rays induced mutation in TL-h1 × S-h2						

Lg2	Plant normal					Fl	II	
lg2	Plant becoming diffuse pale green	χ-rays induced mutation in TL-h1 × S-h2						
Lg3	Plant normal							
lg3	Leaves pale green, concave	χ-rays induced mutation in TL-h1 × S-h2						
Lg4	Plant normal							
lg4	Leaves fading pale green	Spontaneous mutation in RL-S						
Lg5	Plant normal		F2	R	153	An4 0-20	VII	
lg5	Plant pale green	Spontaneous mutation in R69						
Lu1	Plant normal					Fl 0,05	II	
lu1	Homozygous lethal; Lu1lu1: leaves yellow	EMS induced mutations in various strains	Test		7858			
Sp1	Plant normal		Test		710	Hf2 40	V	Maizonnier & Moessner, 1979
sp1	Leaves with dark green spots	χ-rays induced mutation in TL-h1 × S-h2						
Sp2	Plant normal							
sp2	Leaves with dark green spots	Spontaneous mutation in unstable An1						

TABLE III. *continued*

Allele	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
Vs1	Plant normal		Test		430	Hf1 14	I	
vs1	leaves yellow, becoming green (often unstable)	Spontaneous mutation in Satin Rouge						
Vs2	Plant normal							
vs2	Young leaves yellowish, becoming green	χ-rays induced mutation in TL-h1 × S-h2						
Vs3	Plant normal		Test		1004	Bl 25	IV	
vs3	Cotyledons white, young leaves with yellow base	EMS induced mutation in TL-h1 × S-h2						
Vs4	Plant normal		Test		261	Hf1 9	I	
vs4	Rosette with yellow heart (late repair)	χ-rays induced mutation in TL-h1 × S-h2						
Vs5	Plant normal		Test		366	An4 1[d]	VII	
vs5	Plant becoming green, early repair (first leaf)	Spontaneous in a haploid plant			577 834	An4 2 An4 12	VII	Cornu and Farcy, subm
Ws	Plant normal		F2	R	407	Fl 28	II	
ws	Plant with yellow stem and white stigma	χ-rays induced in Blue Bedder						

Yg1 yg1	Plant normal Leaves chlorotic	χ-rays induced mutation in TL-h1 × S-h2	Test		3916	Hf2 2,5	V	Cornu et al., 1980
Yg3 yg3	Plant normal leaves pale green/yellow	Spontaneous mutation in unstable An1	F2	R	432	Ht1 6	III	

[b] in cases where no origin is given this type is very frequent
[c] C = coupling; R = repulsion
[d] considerable variation is found

TABLE IV. *Genes for fertility and lethality in Petunia hybrida*

Allele	*Phenotype*	*Origin*[b]	*Cross*	*Phase*[c]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
Le1	Plant normal		F2			Hf1	I	
le1	Semilethal	Grandiflora nana Karminrosa (4x)						
Le2	Plant normal		F2					
le2	le2le2 : lethal	Roter Vogel				An1	VI	
Le3	Plant normal		F2					
le3	Semilethal	Royal Ruby				Hf1	I	
Rf1	Gene restoring fertility in cytoplasmic male sterile plant							
rf1	Gene maintaining sterility in cytoplasmic male sterile plant	Material originated from Dr. Frankel (Israel)						
Rf2	Gene maintaining sterility in cytoplasmic male sterile plant					Rt	VI	
rf2	Gene restoring fertility in cytoplasmic male sterile plant	Material originated from Dr. Frankel (Israel)						

[b] in cases where no origin is given this type is very frequent
[c] C = coupling; R = repulsion

TABLE V. *Genes involved in synthesis and variation of isoenzymes in Petunia hybrida as identified in gel electrophoresis*

Allele	*Organ*[a]	*Phenotype*	*Cross*[b]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
		Peroxidase					
prxA	le f		Test 3p	189	Ht1 35	III	v.d. Berg and
				189	Mf1 29		Wijsman, 1982a
			Test				
prxB	le f r		F2	50	Hf1 12	I	v.d. Berg and
			Test	126	Hf1 0		Wijsman, 1982b
prxC	le f r		Test	304	Dw1 22	IV	v.d. Berg et al., 1982
			F2	209	Bl 50		
			F2	212	An3 24		
prxD	le		Test 3p	124	Ht1 27	III	
				124	Mf1 20		
prxF	f		Test (trisomic)	81	An4 14	VII	
			Test	31	gpiB 29		
prxG	r		Test 3p	118	An4 9	VII	
				65	lapB 6		v.d. Berg et al., 1984
				44	gpiB 7		
prxH	r		Test	31	gpiB 26	VII	
			Test	186	prxF 11		
			Test	48	An4 36		

TABLE V. *continued*

Allele	*Organ*[a]	*Phenotype*	*Cross*[b]	*Total number of plants*	*% of recombination with marker*	*Chromosome*	*References and remarks*
		Glucose phosphate isomerase					
gpiB	le f		Test 3p	109	An4 8	VII	Wijsman and v.d. Berg, 1982
		Leucine aminopeptidase					
lapB	le		Test 3p	109	An4 2	VII	Wijsman and v.d. Berg, 1982
		Shikimate dehydrogenase					
sdh	le		F2	[75	Hf2 9		
				[90	Po 15		

[a] le = leaf; f = flower; r = root.
[b] 3p = three point cross.
[c] Lines harboring different alleles have been tabulated in Wijsman, 1983 b.

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