Plant and tuber trait inheritance in autotetraploid potatoes (4x)

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Abstract

Inheritance of various morphologic plant and tuber traits in 4x potatoes was studied at the greenhouse and the field at La Molina, Peru. Traits considered were: Seedling and adult plant stem pigmentation stem wing type, tuber primary flesh color, eye depth and knobbiness.

A group of 32 progenies from crossing and selfing 12 native Peruvian cultivars (*Solanum tuberosum* L. ssp. *andigena*) of the National Agrarian University's potato germplasm and four commercial hybrids of the ssps. *andigena* x *tuberosum* of *S. tuberosum* L.were studied.

Seedling and adult plant stem color was controlled by a single *locus* with allele **P** (pigmented) dominant over **p** (green). However, in adult plant color distribution the same **P** allele showed dosage effects: **PPPP** with solid pigmentation while **pppp** green. **PPPp, PPpp** and **Pppp** with mixed proportions of pigmented to green areas based on the number of **P** alleles.

Stem wing shape was controlled by two *loci* showing double dominant epistasis. Tuber knobbiness and presence of eyebrows were controlled by single *loci* showing complete dominance. The inheritance of the other listed traits would be controlled by two or three *loci* showing different types of epistasis.

Primary tuber flesh color appears under control of two *loci* showing complete dominance. Alleles **A + B =** Yellow, **A** and **B** individually = Cream and **aaaabbbb =** White flesh. Tuber eye depth would depend on one *locus* with allele **S** = Semi deep and deep and **s** = shallow. Finally, tuber knobbiness might be controlled by one *locus* where allele **K** = normal tuber shape and the recessive *nulliplex* genotype, **kkkk**, would produce knobby tubers.

Keywords: Genetics, Tetrasomic inheritance, Autotetraploid potatoes.

Introduction

Despite of morphologic trait genetic research on tetraploid potatoes started in 1910, existing information on inheritance of some traits is limited, unclear and some times contradictory. Several reports did not include either sufficient number of observed individuals per progeny or sufficient contrasting characters in the progenitors used in these studies.

Importance of environment effects has not been reported neither its influence on traits such as stem pigmentation and flower, tuber skin and tuber flesh colors.

Literature Review

Kumikura (1967), in Bradshaw y Mackay (1994) suggest that stem pigmentation might be due to a single dominant gene while Howard (1970) suggested that stem color may depend on four *loci* but without showing experimental evidence.

Kelly, (1924) and Howard, (1962) (in Bradshaw and Mackay, 1994) proposed one *locus* **I** that controlled the distribution of the pigments in the tuber skin and stem. Also, Lunden (1937) postulated a *locus* **E** responsible of red color in the periderm, tuber eyes, stem and flowers.

Taylor (1978) in Bradshaw and Mackay (1994) found that wing stem type was controlled by one gene with crenulated (C-) dominant to straight (cc).

Salaman (1926) and Fruwirth (1912) cited by Howard (1970) and Howard (1978) considered that primary flesh color depended on a single *locus* with a dominant allele controlling yellow and its recessive, white.

Extensive literature review by Bradshaw y Mackay (1994) indicates that deep tuber eyes are dominant over shallow and that dosage effects might be responsible of deepness.

Materials and methods

A group of 34 progenies from selfings and crosses of 12 native Peruvian 4x cultivars (*Solanum tuberosum* L. ssp. *andigena*) of the National Agrarian University's potato collection and four commercial hybrids of ssps. *andigena* x *tuberosum* of *S. tuberosum*) were studied. Stem color was evaluated at flowering using CIP´s pigmentation scale. Tuber skin and flesh color, shape eye depth were evaluated at harvest. Data on all traits for individual progenies were analyzed with the χ^2 test followed by a homogeneity test for individual χ^2 values.

Results and discussion

Inheritance of seedling stem color

Hypothesis: Results on 10 tetraploid progenies suggested that stem pigmentation (pigmented *vs* green) was controlled by a single *locus* with dominant allele **P** = pigmented while recessive **p** = green.

Table 1. Observed seedling stem color segregation ratios on 10 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ^{2} test
Female	Male		Purple	Green	Total		
pppp	Pppp	3	365	337	702	1/2 : 1/2	**2.65ns**
Pppp	Pppp	1	170	50	220	3/4 : 1/4	**0.61ns**
pppp	PPpp	2	383	96	479	5/6 : 1/6	**0.03ns**
Pppp	PPpp	2	421	41	462	11/12 : 1/12	**2.87ns**
PPpp	PPpp	2	453	17	470	35/36 : 1/36	**0.00ns**

Tetrasomic inheritance segregation ratios modified the phenotypic frequencies obtained with disomic inheritance. Results of the present research agreed with those of Kumikura (1967) but strongly disagreed with Howard (1970) who postulated a three gene control of this trait.

Inheritance of Adult Plant Stem Color

Hypothesis: Results on segregation for adult plant stem color of 28 progenies suggested a single *locus* control with the dominant allele **P** = pigmented and the recessive **p** = green.

Table 2. Observed adult plant stem color segregation ratios on 28 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ^{2} test
Female	**Male**		**Purple**	**Green**	**Total**		
pppp	Pppp	3	235	229	464	1/2 : 1/2	**0.88ns**
Pppp	Pppp	4	349	125	474	3/4 : 1/4	**1.79ns**
pppp	PPpp	6	564	78	642	5/6 : 1/6	**3.84ns**
Pppp	PPpp	8	822	56	878	11/12 : 1/12	**6.12ns**
PPpp	PPpp	7	727	19	746	35/36 : 1/36	**3.18ns**

Data on Tables 1 and 2 show marked genotypic differences at that *locus* among parents. In addition, stem color showed two additional components, **(a).**Distribution, and **(b).** Intensity.

Differences in stem pigment distribution suggest dosage effects. The expected genotypic array upon selfing a *duplex* is **1/36 PPPP: 8/36 PPPp: 18/36 PPpp: 8/36 Pppp: 1/36 pppp** with a phenotypic array: **35/36 P_ _ _ (pigmented): 1/36 pppp (green)**. However, among the 35/36 pigmented there were distinct levels in the variables **(a).** and **(b).** mentioned before.

(a). Color distribution would depend on number of **P** alleles per genotype. A q*uadruplex* (PPPP) was fully pigmented, and a *duplex* (PPpp) has more pigment distribution than a *simplex* (Pppp). **(b).** Stem pigment intensity could have a variable expressivity of the P allele related to the environment, mainly light intensity and temperature. Under greenhouse conditions, Llama Senqa and Ayllu Papa stems were near to black while in the field's lower light intensity and temperature, stems still were black but showed greens areas throughout.

Inheritance of stem wing type

Hypothesis: Results on 14 progenies suggested that this trait is controlled by two *loci* showing double dominant epistasis with alleles **C + D** and **C** and **D** individually = Wavy while alleles **ccccddd =** Straight Wings.

Table 3. Observed stem wing type segregation ratios on 14 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ^{2} test
Female	**Male**		**Purple**	**Green**	**Total**		
ccccdddd	Ccccdddd	1	34	28	62	1/2 : 1/2	**0.58ns**
ccccdddd	CcccDddd	6	527	141	668	3/4 : 1/4	**5.77ns**
CcccDddd	Ccccdddd	2	141	26	167	7/8 : 1/8	**0.06ns**
CcccDddd	CcccDddd	5	615	41	656	15/16 : 1/16	**3.28ns**

Results disagreed with those of Taylor (1978), in Bradshaw y Mackay (1994) who found that this trait was controlled by a single *locus* with wavy (W) dominant over straight (S).

Inheritance of primary tuber flesh color

Hypothesis: Results on 34 progenies suggested that this trait is controlled by two *loci* showing complete dominance with alleles **A + B =** Yellow and A and B individually = Cream while alleles **aaaabbbb =** White. Due to difficulty to distinguish yellow and cream, data of these two colors were consolidated to differentiate from white. All 34 χ^2 values were inferior to the critical $\chi^2_{(1\,df;\ \alpha = 0.05)}$ **= 3.84.**

Table 4. Observed primary tuber flesh color segregation ratios on 34 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ^{2} test
Female	Male		Y + C	White	Total		
aaaabbbb (W)	aaaabbbb (W)	2	0	241	241	0 : All	**0.00**
aaaabbbb (W)	Aaaabbbb (C)	1	93	72	165	1/2 : 1/2	**2.67ns**
aaaabbbb (W)	AaaaBbbb (C)	3	390	115	505	3/4 : 1/4	**2.37ns**
AAaabbbb (C)	aaaabbbb (W)	4	532	113	645	5/6 : 1/6	**1.00ns**
AaaaBbbb (C)	Aaaabbbb (C)	3	408	66	474	7/8 : 1/8	**1.66ns**
AAaabbbb (C)	Aaaabbbb (C)	4	523	43	566	11/12 : 1/12	**1.36ns**
AaaaBbbb (C)	AaaaBbbb (C)	5	794	46	840	15/16 : 1/16	**3.43ns**
AAaaBBbb(Y)	Aaaabbbb (C)	10	1597	27	1624	71/72 : 1/72	**15.12ns**
AAaaBBbb(Y)	AAaaBBbb(Y)	2	294	0	294	++	**0.23ns**

$^{++}$**1295/1296 : 1/1296**

These results disagreed with Salaman (1926) and Fruwirth (1912) cited by Howard (1970) and Howard (1978) who considered that primary flesh color depended on a single *locus* with a dominant allele controlling yellow and its recessive, white.

Inheritance of depth of eyes

Hypothesis: Because of difficulty to clearly distinguish semi deep and deep phenotypes, both classes were consolidated as **SD + D** and only shallow, **S** was kept independent. Results of 19 progenies for depth of eyes suggested that in 4x potatoes this trait was controlled by one *locus* with dominant allele **S** = Semi deep and Deep eyes while **s** be responsible for shallow eyes. All 19 calculated individual χ^2 values were inferior to the critical one $\chi^2_{(1\ df;\ \alpha\ 0.05)} = 3.84$.

Table 5. Observed primary tuber flesh color segregation ratios on 34 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ^{2} test
Female	Male		SD + D	S	Total		
ssss (S)	ssss (S)	1	0	147	147	0 : All	**0.00**
Ssss (SD)	ssss (S)	3	229	218	447	1/2 : 1/2	**1.75ns**
Ssss (SD)	Ssss (SD)	8	930	313	1243	3/4 : 1/4	**11.44ns**
SSss (D)	Ssss (SD)	2	270	19	289	11/12 : 1/12	**0.89ns**
SSss (D)	SSss (D)	1	169	8	177	35/36 : 1/36	**1.99ns**
SSss (D)	SSSs (D)	4	642	6	648	All : 0	**0.15ns**

Results on segregation of 19 progenies agreed with previous reports about dominance of deep over shallow eyes on 4x potatoes. However, in a few progenies observed results did not fit with the expected according to the hypothesis which might be due to difficulty to separate semi deep and deep phenotypes. Also, data suggest a possible dosage effect of the **S** allele in the expression of eye depth as suggested in literature.

Inheritance of tuber knobbiness

Hypothesis: Tuber knobbiness is a rare trait observed in the cultivar Allkachokllo, among the progenitors utilized. Segregation of four progenies from crossing normal shaped cultivars (Amarilis, Canchan, Yungay and Ccompis) to Allkachokllo suggested that this trait depends on a single *locus* with dominant allele K = Normal shape and the recessive k = Knobby tuber**.**

Table 6. Observed tuber knobbiness segregation ratios on four progenies

Pedigree		Possible genotype		N° observed plants			Ratio	^{2}
Female	**Male**	**Female**	**Male**	**Normal**	**Knobby**	**Total**		
Amarilis	Allkachokllo	KKkk	kkkk	147	34	181	5/6 : 1/6	0.58ns
Canchan	Allkachokllo	Kkkk	kkkk	92	76	168	1/2 : 1/2	1.52ns
Yungay	Allkachokllo	Kkkk	kkkk	104	81	185	1/2 : 1/2	2.86ns
Ccompis	Allkachokllo	Kkkk	kkkk	54	57	111	1/2: 1/2	0.08ns

Conclusions

9. Seedling and adult plant stem pigmentation appears controlled by one *locus* with alleles **P** = pigmented and **p** = green. In adult plants, stem pigment distribution would involve dosage effects of P allele with complete cover in *quadruplex* genotypes (PPPP) with gradual decrease on *triplex* (PPPp), *duplex* (PPpp), and *simplex* (Pppp).
10. In adult plant stems**,** pigmentation intensity appears to be influenced by environment factors mainly light intensity and temperature.
11. Stem wing type might be controlled by two *loci* with double dominant epistasis. **C + D** together and **C** and **D** individually = wavy wings and **ccdd** = straight wings.
12. Primary tuber flesh color appears under control of two *loci* showing complete dominance. Alleles **A + B =** Yellow, **A** and **B** individually = Cream and **aaaabbbb =** White flesh**.**
13. Eye depth might depend on one *locus* with allele **S** = Semi deep and deep and **s** = shallow.
14. The tuber knobbiness might be controlled by one *locus* where allele **K** = normal tuber shape and the recessive *nulliplex* genotype, **kkkk**, would produce knobby tubers.

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