

Inheritance of plant and tuber traits in diploid potatoes

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Abstract

Inheritances of morphologic plant and tuber traits were studied at the greenhouse and field in Peru. The traits considered were: Presence of albino seedlings, stem wing shape, flower color, tuber flesh color and depth of eyes.

Thirteen native diploid Peruvian potato cultivars (eight of *Solanum stenotomum* and five of *S. goniocalix*) showing contrasting differences for the traits studied. These clones, from the potato collection of the National Agrarian University, were used as progenitors to obtain 26 hybrid progenies (10 crosses and their reciprocals and six additional one way crosses).

Albinism was controlled by a single *locus* with dominant allele **A** responsible for green color and **a** in homozygous condition, albinism. For the depth of eyes, deep controlled by the allele **Eyd** appeared dominant over shallow, **eyd**. In the remaining traits various types of gene interactions were found. Stem wing shape would be controlled by a two *loci* producing double dominant epistasis. A two *loci* simple recessive epistasis would control flower corolla color. A more complex three *loci* epistasis appeared to control primary tuber flesh color. For secondary color purple, red and yellow colors would be controlled by three *loci*, purple (allele **P**) and red (allele **R**) dominant over yellow (**pprr**) but **P** was epistatic over **R**. No reciprocal effects were found in any of the studied traits.

Keywords: Diploid potatoes, Disomic inheritance, Genetics.

Introduction

Studies of inheritance of various plant and tuber traits traced back to 1910. Often, the few existing reports do not clearly define hereditary patterns and results on some characters are contradictory. In several reports conclusions were based on insufficient number of individuals per progeny, insufficient number of crosses or there was not enough contrast in the traits showed by the parents crossed. Environmental influence on stem, flower, tuber skin and flesh colors were not been reported.

Albinism due to chlorophyll absence preventing photosynthesis is a lethal trait observed in many plant species. Potato albino seedlings of a white or light pink color have an 8 to 12 day short life surviving on endosperm stored reserves.

The objectives of the present study was to determine the inheritances of several morphologic plant and tuber traits studied in a single season at the greenhouse and later at the field at La Molina, Peru. The traits considered were: Presence of albino seedlings, stem wing shape, flower color, tuber flesh color and depth of eyes.

Literature review

Lam and Erickson (1971) found that albinism on *S. chacoense* was controlled by the recessive allele **a**, and normal green color by **A** being the *locus* on chromosome 12. Estrada (1960), studying albinism on diploid and tetraploid species had similar conclusions.

For Howard (1970) pigment distribution on tuber skin and stem was controlled by *locus I*. The *locus E* controlled red color on the periderm, stem and flower color. Authors cited by Bradshaw and Mackay, 1994, proposed that *locus I* controlled pigment distribution on tuber skin and stem (Kelly, 1924 and Howard, 1962). Lunden, 1937 postulated a *locus E* responsible of red color in the periderm, tuber eyes, stem and flowers.

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

Reports on flower color show some agreement. Hermsen (1978), found two complementary dominant genes controlling flower color. Taylor (1978) also cited by Bradshaw and Mackay, (1994) reached similar conclusions but both loci segregating on a random chromatid model.

Salaman (1926) Fruwirth (1912) cited by Howard (1970) and Howard (1978) found that primary tuber flesh color depended on a single *locus*. The dominant allele controlled yellow and its recessive, white. Other genes may be responsible of various yellow tones observed.

Literature reports about inheritance of depth of eyes are contradictory. East (1910) suggested that shallow eyes were dominant over deep. Salaman ((1911) and Nilsson (1913) both cited by Li *et al.* (2005) found that this trait was controlled by one *locus* but deep eyes were dominant over shallow. Huber (1930) cited by Li *et al.* (2005) also agreed that deep eyes were dominant but two complementary genes were responsible for shallow eyes. Finally, Li *et al.* (2005) found that inheritance of this trait was no clear but suggested a one locus control being deep dominant over shallow eyes.

Materials and methods

Crosses among 13 native diploid cultivars with contrasting traits (eight *S. stenotomum* and five *S. goniocalix*) produced 26 progenies (10 crosses and reciprocals and six one way crosses). Albinism was evaluated on seedlings at the greenhouse 10 days after germination. Flower color was evaluated in the field using CIP's pigmentation scale and tuber traits evaluated at harvest. Data were analyzed with the Chi-Square Test for each progeny followed by Chi-Square homogeneity Test. For space reasons, results on the tables only show contrasting segregation ratios found among all progenies considered in the study.

Results and discussion

Inheritance of Albinism

Hypothesis: One *locus* control with allele **A** controlling green color and **aa**, albino. Segregation of four progenies agreed with the hypothesis with χ^2 values inferior to the critical value $\chi^2_{(1 \text{ df}; \alpha = 0.05)} = 3.84$. Results agreed with Estrada (1960) and Lam and Erickson (1971).

Table 1. Four progeny segregation for green to albino seedlings 10 days after germination

Progenitors		Possible		N° observed seedlings			Ratio	χ^2
Female	Male	Female	Male	Green	Albino	Total		
Pitiquiña	Kulliriñón	Aa	Aa	104	27	131	3/4 : 1/4	1.35
Kulliriñón	Pitiquiña	Aa	Aa	96	31	127	3/4 : 1/4	0.02
Llipiñawi	Kulliriñón	Aa	Aa	118	30	148	3/4 : 1/4	1.77
Llipiñawi	Pitiquiña	Aa	Aa	98	37	135	3/4 : 1/4	0.42

Inheritance of stem wing type

Hypothesis: Two *loci* double dominant epistasis with alleles **C+D** and **C** and **D** = wavy wings (**W**) and **ccdd** = straight wings (**R**). The segregation of the 20 progenies agreed with the hypothesis with χ^2 values inferior to the critical value $\chi^2_{(1 \text{ df}; \alpha = 0.05)} = 3.84$.

Table 2. Observed stem wing segregation ratios observed on 20 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ² test
Female	Male		Wavy	Straight	Total		
Ccdd (W)	ccdd (S)	3	118	128	246	1/2 : 1/2	2.30ns
Ccdd (W)	Ccdd (W)	6	296	126	422	3/4 : 1/4	2.96ns
CcDd (W)	Ccdd (W)	3	205	24	229	7/8 : 1/8	0.42ns
CCDd (W) (W)	CcDd (W)	8	653	0	653	All : 0	0.00ns

Results disagreed with those of a single *locus* control proposed by Choudhury (1944) and Taylor (1987) cited by Bradshaw and Mackay (1994).

Inheritance of flower corolla color

Hypothesis: Two *loci* showing simple recessive epistasis would control this trait. In the first *locus*, dominant allele **C** = Pigment synthesis and **cc** = no synthesis (white) and in the second, **M** = purple tones and **mm** = red tones. Recessive **cc** epistatic over **M** and **m** alleles. All 17 calculated χ^2 values were inferior to the critical $\chi^2_{(2\text{ df}; \alpha = 0.05)} = 5.99$, showing the agreement of the experimental results with the proposed hypothesis.

Table 3. Observed flower color segregation ratios on 17 progenies

Suggested genotypes		N° of crosses	N° plants observed				Expected ratio	Homogeneity ² test
Female	Male		Purple	Red	White	Total		
CcMm (P)	CcMm (P)	6	256	71	107	434	9 : 3 : 4	7.98ns
ccmm (W)	CcMm (P)	2	25	30	53	108	1 : 1 : 2	0.23ns
ccmm (W)	Ccmm (R)	3	0	86	79	165	0 : 1 : 1	4.34ns
CcMm (P)	CCMM (P)	2	133	0	0	133	All : 0 : 0	0.00
CcMm (P)	Ccmm (R)	4	96	96	61	253	3 : 3 : 2	4.07ns

The results agreed with Hermsen (1978) and Taylor (1978), both cited by Bradshaw and Mackay (1994) who proposed two complementary dominant genes controlling this trait. We also observed that environmental factors, particularly temperature and light intensity, influence the expression of color intensity.

Inheritance of primary tuber flesh color

Hypothesis: Results suggested that this trait would be controlled by three *loci*. The **C** allele controls Xanthophyll synthesis and **cc** = No Xanthophyll synthesis (white). In the other two *loci*, **A + B** = yellow, **A** and **B** alone = cream and **aabb** = white. Due to difficulty to distinguish yellow and cream, data of these two colors were consolidated to differentiate from white. All 22 χ^2 values were inferior to the critical $\chi^2_{(1\text{ df}; \alpha = 0.05)} = 3.84$.

Table 4. Observed primary tuber flesh color segregation ratios observed on 22 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ² test
Female	Male		Y + C	White	Total		
CcAaBb (Y)	CCAabb (C)	9	684	87	771	7/8 : 1/8	10.00ns
CcAaBb (Y)	ccAaBb (W)	2	87	92	179	15/32 : 17/32	0.46ns
ccAaBb (W)	ccAabb (W)	2	0	174	174	0 : All	0.00
CCAaBb (Y)	CcAaBb (Y)	4	334	13	347	31/32 : 1/32	6.68ns
CCAabb (C)	ccAabb (W)	5	289	103	392	3/4 : 1/4	3.88ns

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. On the other hand, results agreed with their suggestion that other genes may be involved on the various yellow tones observed.

Inheritance of secondary tuber flesh color

Hypothesis: Results suggested that purple, red and yellow would be controlled by three epistatic *loci* with complete dominance. . In the first, **A** = Anthocyanin synthesis induction and **aa** = no induction (yellow), in the second, allele **P** = purple and **pp** = no color and in the third, **R** = red and **rr** = no color and **P** epistatic over **R**. All 20 calculated individual χ^2 values were inferior to the critical one $\chi^2_{(1 \text{ df}; \alpha = 0.05)} = 3.84$.

Table 5. Observed primary tuber flesh color segregation ratios observed on 20 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ² test
Female	Male		Purple	Red	Total		
AAppRR (R)	Aapprr (Y)	8	0	32	32	0 : All	0.00
AAPpRR (P)	Aapprr (Y)	7	21	21	42	1/2 : 1/2	0.00
aaPprr (Y)	AAPpRR (P)	3	32	7	39	3/4 : 1/4	1.03

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** were kept independent. Results of 18 progenies for depth of eyes strongly suggested that in diploid potatoes this trait was controlled by three independent *loci* S, T and U each showing complete dominance of deep and semi – deep over shallow eyes. All 18 calculated individual χ^2 values were inferior to the critical one $\chi^2_{(1 \text{ df}; \alpha = 0.05)} = 3.84$.

Table 6. Observed Depth of eyes segregation ratios observed on 18 progenies

Suggested genotypes		N° of crosses	N° plants observed			Expected ratio	Homogeneity ² test
Female	Male		SD + D	Shallow	Total		
SsTtuu (SD)	SsTtUu (D)	4	347	4	351	32/31 : 1/32	0.78 ns
Ssttuu (SD)	SsTtUu (D)	9	751	37	788	15/16 : 1/16	10.68 ns
Ssttuu (SD)	SsTtuu (SD)	5	374	50	424	7/8 : 1/8	1.28 ns

These results agreed with previous results about dominance of deep over shallow eyes but strongly disagree with a single *locus* control of the trait Segregation data on 18 crosses clearly show a three loci control. Also, contrary to other author's suggestions about strong environmental influence over this trait, we believe that depth of eyes is one of the most constant potato traits and that environmental effects are not significant.

Conclusions

1. Albinism would be controlled by one *locus* with two alleles **A** = green and **a** = albino.
2. Stem wing type would be controlled by 2 *loci* showing a double dominant epistasis where **C + D** together and, **C** and **D** individually = wavy wings and **ccdd** = straight wings.
3. Two epistatic *loci* would control flower color. In the first *locus*, allele **C** = presence of pigment and **cc** = absence of pigment (white) and the second, **M** = purple tones and **mm** = red tones, being the recessive **cc** epistatic over the **M** and **m** alleles.

4. Primary flesh color would be controlled by 3 *loci* where **C** = Xanthophyll synthesis and **cc** = no synthesis (white). In the 2nd and 3rd *loci*, dominant **A** and **B** alleles control cream color and both together (**A + B**) produce yellow while the recessive genotype **aabb**, controls white.
5. Secondary flesh color would be controlled by three alleles. In first *locus*, **A** = anthocyanin synthesis and **aa** = no synthesis (yellow). In the 2nd and 3rd *loci*, alleles **P** = purple and **R** = red and **pprr** doesn't show secondary flesh color. At the same time **P** is epistatic over **R**.
6. Depth of eyes appears controlled by three *loci* showing complete dominance. Allele **S**, **T** and **U** would produce deep and semi deep eyes while the recessive **ssttuu** would be the only with shallow eye phenotype.
7. Heterozygosis of most of the progenitors used in this research is evident as indicated for the wide segregation in all studied traits.
8. In spite of the significant number of reciprocal crosses were studied, no maternal effects are evident in any of the studied traits.

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