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SHORT COMMUNICATION

TUBER SKIN COLOUR VARIATION IN THE SEGREGATING POPULATIONS OF POTATOES (*Solanum tuberosum* L.)

S.K. Luthra[1], Vikas Mangal[2], Salej Sood[2] and Dalamu[2]

[1]*ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut – 250 110, Uttar Pradesh (India)*
[2]*ICAR-Central Potato Research Institute, Shimla – 170 001, Himachal Pradesh (India)*
*****e-mail: *vikas90bharatpur@gmail.com*

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ABSTRACT

The skin colour of potato tubers is one of the most noticeable visual characteristics and ranges from white-cream to black in appearance. A study was conducted to understand tuber skin colour variation in potatoes using contrasting parents. A set of 327 segregating progenies of 8 populations, developed by using 'CP 4242' as female (2 crosses) and male (6 crosses) were assessed for tuber skin colour. Based on the presence or absence of colour, the segregating progenies were classified into 5 skin colours *viz*., white-cream, light red, dark red, light purple and dark purple with the help of potato colour chart. The 327 segregating progenies of 8 crosses exhibited a prevalence of 137 (41.9%), 71 (21.7%), 12 (3.7%), 17 (5.2) and 90 (27.5%) in dark purple, light purple, dark red, light red and white-cream tuber skin colours, respectively. In totality 72.48% progenies possessed coloured tuber skin (dark purple, purple, dark red and light red) as compared to 27.52% progenies exhibiting white-cream skin colour, reflecting 3:1 segregation ratio of tuber colour variation in potato breeding population. This reveals the dominance of purple colour over white in the segregating population.

Keywords: Potatoes, segregating population, tuber colour variation

INTRODUCTION

The skin colour of potato tubers is one of the most noticeable visual characteristics while making the selection in potato breeding programme (van Eck, 2007). This characteristic may range from white-cream to black. The colouring matter found in the tubers of many potato varieties is due to the presence of anthocyanin pigments which do not require the presence of light for their development. It means that the presence of colour in tubers when brought to the surface is independent of isolation. Coloured potatoes (red/purple-fleshed) are a rich source of natural antioxidants like anthocyanin, and contain two-/three-fold higher antioxidant potential than yellow-fleshed potatoes (Brown, 2005). The antioxidant properties of anthocyanin also make them effective in protecting the plants against various biotic and abiotic stresses, as well as contribute to human health nutritionally and medicinally (Li *et al*., 2014; Fogelman *et al*., 2015). The potatoes containing high concentration of anthocyanin are considered healthy (Strygina *et al*., 2019).

In India, traditionally, white, cream or yellow skin potatoes are preferred; while in eastern parts of the country red skin potatoes are also liked by consumers (Luthra *et al*., 2018). The skin of potato tubers is composed of two layers, the cortex and the epidermis, also known as phelloderm and periderm, respectively. Three unlinked loci were proposed to explain the phenotypes of purple, red and white tubers by Salaman (1910). The red pigment in tubers is caused by the complementarity between loci D and R, both of which demonstrate dominance. Together with factor P, they give tubers a purple skin colour. Different genetic systems determine the colour of tuber skin, including those that determine the presence and absence of red and purple/blue pigments (Van Eck, 2007). There are loci on potato chromosome X which are responsible for pigmentation in cortex (controlled by locus I_{co}) and/or epidermis (controlled by locus I_{ep}) (Van Eck *et al*., 1994). There is a locus D and P that is dominantly involved in the biosynthesis of red and blue/purple pigments, respectively, throughout the plant. Another locus E regulates the presence of red or purple pigmentation in combination with locus D or P, respectively, in the epidermis of tuber. The locus R regulates the presence of pigmentation in outer layers of cortex of tuber (Lunden, 1960). A dihydroflavonol 4-reductase (DFR) enzyme is needed in plants to produce pelargonidin-based (red) anthocyanin pigments, which are encoded by gene R (Jong *et al.,* 2003).

To gain a better understanding on how the anthocyanin is synthesized in potatoes, high-throughput RNA sequencing was used to compare the transcriptomes of white and purple cultivars (Liu *et al.*, 2015). Purple pigmentation is caused by the P locus, which codes for flavonoid 3',5'-hydroxylase (Jung *et al.,* 2005). Using coloured potato tubers, Zhang *et al*. (2021) identified that StWRKY13 activated StCHS, StF3H, StDFR, and StANS transcription, providing theoretical support the formation of anthocyanin in these tubers. Vulavala *et al*. (2017) reported that a number of genes express preferentially in potato skin so may also be associated with the secondary cell wall and stress-related activities contributing to the protective nature of skin. The present study was undertaken to find the variation and inheritance pattern of tuber skin colour of potatoes.

MATERIALS AND METHODS

The material used in the present study comprised of 327 segregating progenies of eight breeding populations developed using 'CP 4242' as female (2 crosses) and male (6 crosses). The tuber of all the parents was planted in Modipuram (Uttar Pradesh) during *rabi* 2018 in crossing block. The progenies were generated from 8 crosses using the standard procedure of emasculation and pollination (Luthra *et al.,* 2006). The true potato seeds (TPS) from hybrid berries were extracted and planted in next *rabi* season in nursery. The 25 days old seedlings were transplanted to field and tuber were harvested from individual plants separately. Tuber skin colour was observed at the time of harvest. The parent 'CP 4242' produces dark purple oblong tubers with fleet eyes and dark purple flesh colour, whereas the other seven parents namely CP2340, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Himsona, Kufri Himalini and MS/8-1148 produced white/cream/round/ovoid/ oblong tubers with the fleet to medium eyes and white to cream flesh colour as given under:

Crosses	Tuber skin colour of the parent	
	Female	Male
CP 4242 x Kufri Chipsona 3	Dark purple	White
CP 4242 x CP 2340	Dark purple	Yellow
Kufri Chipsona 1 x CP 4242	White-cream	Dark purple
Kufri Chipsona 3 x CP 4242	White	Dark purple
Kufri Chipsona 4 x CP 4242	White-cream	Dark purple
Kufri Himalini x CP 4242	White-cream	Dark purple
Kufri Himsona x CP 4242	White-cream	Dark purple
MS/8-1148 x CP 4242	White-cream	Dark purple

All the offspring obtained from different cross combinations were analysed for tuber skin colour and categorized into different categories at ICAR-CPRI, Regional Station, Modipuram, Meerut. Based on the presence or absence of colour, the crossed progenies were classified into five categories *viz.,* white-cream, light red, dark red, light purple and dark purple). All the calculations were done using Microsoft excel and different skin colour progenies were converted into percentage values for comparison.

RESULTS AND DISCUSSION

In present study, 327 segregating progenies obtained from 8 cross combinations were examined for tuber skin colour. Five kinds of colours were recognised reflecting 137 (41.90%), 71 (21.71%), 12 (3.67%), 17 (5.20) and 90 (27.52%) as dark purple, light purple, dark red, light red and white cream tuber skin colours, respectively (Plate. 1; Table 2). This revealed the dominance of purple colour over white in cross combinations. In total, 72.48% of progenies possessed coloured tuber skin (dark purple, purple, dark red and light red) as compared to 27.52% of progenies exhibiting white-cream skin colour, reflecting the 3:1 segregation ratio of tuber colour variation in the potato breeding population.

Plate 1: Variation in tuber skin colour in potatoes

Plate 2: Segregating progenies of cross CP 4242 × CP 2340

***1. CP 4242 × Kufri Chipsona 3**:* The tuber skin colour of female and male parents was dark purple and white, respectively. Among the 16 progenies obtained, 12 (75%), 3 (18.75%) and 1 (6.25%) had dark purple, light purple and white-cream tuber skin colour, respectively which indicates the dominance of purple colour over white in this cross combination. The 15:1 ratio of coloured vs white progenies exhibited duplex gene action.

2. CP 4242 × CP 2340: The tuber skin colour of female and male parents was dark purple and yellow, respectively (Plate 2). Among the 33 progenies obtained, 12 (36.36%), 8 (24.24%), 2 (6.06%), 3 (9.09) and 8 (24.24%) were dark purple, light purple, dark red, light red and white-cream tuber skin coloured, respectively. The 3:1 ratio in this cross indicated simplex gene action for tuber skin colour.

3. Kufri Chipsona 1 × CP 4242: The tuber skin colour of female and male parents was white cream and dark purple, respectively. Among the 80 progenies obtained, 35 (43.75%), 19 (23.75%), and 26 (32.50%) had dark purple, light purple, and white-cream tuber skin colours, respectively. The ratio of coloured vs white progenies in this cross combination was near 3:1 ratio, revealing simplex gene action.

4. Kufri Chipsona 3 × CP 4242: The tuber skin colour of female and male parents was white and dark purple, respectively. Among the 22 progenies obtained, 2 (9.09%), 2 (9.09%), 7 (31.82%), and 11 (50%) showed dark purple, light purple, dark red, and white cream tuber skin colours, respectively, indicating the dominance of white colour over purple in this cross combination. However, taking into account coloured vs non-coloured tubers, it also reflects the equal contribution of both colours in the progenies. The gene action could not be ascertained in this cross.

5. Kufri Chipsona 4 × CP 4242: The tuber skin colour of female and male parents was white-cream and dark purple, respectively. Among the 67 progenies obtained, 29 (43.28%), 14 (20.90%), 1 (1.49%), 5 (7.46) and 18 (26.87%) showed dark purple, light purple, dark red, light red and white-cream tuber skin colours, respectively. indicating the dominance of purple colour over white in this cross combination and the ratio indicated simplex gene action.

6. Kufri Himalini × CP 4242: The tuber skin colour of female and male parents was white-cream and dark purple, respectively. Among the 33 progenies obtained, 11 (33.33%), 5 (15.15%), 2 (6.06%), 6 (18.18) and 9 (27.27%) had dark purple, light purple, dark red, light red and white-cream tuber skin colour, respectively. The ratio of coloured vs white progenies showed simplex gene action with dominance of purple colour over white.

7. Kufri Himsona × CP 4242: The tuber skin colour of female and male parents was white-cream and dark purple, respectively. Among the 26 progenies obtained, 11 (42.31%), 11 (42.31%), 1 (3.85%) and 3 (11.54%) showed dark purple, light purple, light red and white-cream tuber skin colours, respectively. The genic control could not be inferred from the ratio of coloured vs white progenies however, the results showed the dominance of purple colour over white in this cross combination.

8. MS/8-1148 × CP 4242: The tuber skin colour of female and male parents was white-cream and dark purple, respectively. Among the 50 progenies obtained, 25 (50%), 9 (18%), 2 (4%) and 14 (28%) showed dark purple, light purple, light red and white-cream tuber skin colours, respectively. The ratio of coloured vs white progenies indicated simplex gene action and the dominance of purple colour over white in this cross combination.

Table 2: Distribution of tuber skin colour categories in 8 segregating progenies of potatoes in the seedling stage at Modipuram, Meerut (India)

Cross combination	Tuber colour						% of tuber colour				
	WC	LR	DR	LP	DP	Total	WC	LR	DR	LP	DP
CP 4242 x Kufri Chipsona 3	1	0	0	3	12	16	6.25	0.00	0.00	18.75	75.00
CP 4242 x CP 2340	8	3	2	8	12	33	24.24	9.09	6.06	24.24	36.36
Kufri Chipsona 1 x CP 4242	26	0	0	19	35	80	32.50	0.00	0.00	23.75	43.75
Kufri Chipsona 3 x CP 4242	11	0	7	2	2	22	50.00	0.00	31.82	9.09	9.09
Kufri Chipsona 4 x CP 4242	18	5	1	14	29	67	26.87	7.46	1.49	20.90	43.28
Kufri Himalini x CP 4242	9	6	2	5	11	33	27.27	18.18	6.06	15.15	33.33
Kufri Himsona x CP 4242	3	1	0	11	11	26	11.54	3.85	0.00	42.31	42.31
MS/8-1148 x CP 4242	14	2	0	9	25	50	28.00	4.00	0.00	18.00	50.00
Overall mean	90	17	12	71	137	327	27.52	5.20	3.67	21.71	41.90

Abbreviations: WC- white-cream, LR- Light red, DR- dark red, LP- light purple, DP- Dark purple

The relative proportions of coloured and white skin tubers in seedlings varied considerably in different crosses. We observed purple tuber skin in the majority of progenies in all the crosses, except Kufri Chipsona 3 × CP 4242. Based on this observation, it is clear that the purple-tuber potatoes, when crossed, produce the majority of purple-tuber offspring. It can, therefore, be inferred that in general, skin colour in potato tubers is dominant to its absence. Kukimura (1972) observed the segregation of brown skin from colourless skin in Spartaan × Maris Piper, which suggested that brown tuber skin is dominant. Light or dark red skin tuber, seem to be obtained by bringing together two different colour factors by hybridisation, and there are also indications that the red colour factor may rest in a white or purple tuber variety in a suppressed stage. In later case, a reassortment of factors by crossing two different varieties permits the expression of colour factor. The results also revealed reciprocal differences in tuber skin colour. In purple × white crosses (CP 4242 × Kufri Chipsona 3), maximum number of offspring exhibited purple phenotype (15 out of 16) but white × purple (Kufri Chipsona 3 × CP 4242) cross combination showed maximum white phenotype (11 out of 22).

In conclusion, nearly 72.48% progenies possessed coloured tuber skin (dark purple, purple, dark red and light red) as compared to 27.52% white-cream skin colour progenies, showing 3:1 segregation ratio (simplex gene action) of tuber colour variation in potato breeding populations. However, in a few crosses we observed duplex gene action for tuber skin colour. Further, two crosses could not infer the genetic control based on the ratio of coloured vs. white progenies. Overall, the results appear inconclusive to ascertain the genetic control of tuber skin colour in different cross combinations, as the polyploid nature of crop might alter the normal ratios as observed in diploid crop. We suggest growing large population of progenies to determine the genetic control of tuber skin colour and verification using backcrosses with recessive parents.

Author contributions. VM and SS: Conceptualisation and Writing-original draft; SKL and Dalamu: Supervision. All authors have read and approved the final document.

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