Genetic inheritance of fruit traits and seed coat colour in bitter gourd (Momordica charantia)

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ABSTRACT

The present experiment on genetic inheritance of fruit traits (ridgeness, tubercles and curviness) and seed coat colour of bitter gourd (*Momordica charantia* L.) was carried out at experimental farm of Division of Vegetable Science, ICAR-IARI, New Delhi in 2014–16. The study provides genetic information for development of new varieties and hybrids as per the consumer preference. The classical Chi-square (χ^2) test was used to estimate the inheritance pattern of qualitative traits using six generations (P_1 , P_2 , F_1 , F_2 , BC₁P₁ and BC₁P₂; F_3 generation as F_2 for seed coat colour). Inheritance of fruit traits like continuous ridges (Cr: in DBGS-54 × DBGS-2 and DBSS-54 × Pusa Vishesh; χ^2 = 0.09; P = 0.76 and χ^2 = 0.50; P = 0.48, respectively), tubercles (Tb: DBGS-54 × DBGS-2 and DBSS-54 × Pusa Vishesh; χ^2 = 0.50; P = 0.48and χ^2 = 0.01; P = 0.92, respectively), fruit curviness (Cf: DBGS-54 × DBGS-2; χ^2 = 0.02; P = 0.89) and black seed coat colour (Bs: Pusa Aushadhi × DBGS-54 and DBGS-54 × DBGS-2; χ^2 = 0.73; P = 0.39 and χ^2 = 0.02; P = 0.89, respectively) were found to be controlled by single dominant gene. Simple inheritance of these fruit traits will enable the bitter gourd breeder to incorporate these traits in hybrids. The black seed coat colour will act as a morphological marker for hybrid seed purity test too.

Keywords: Bitter gourd, Fruit curviness, Genetic inheritance, *Momordica charantia*, Ridges, Seed coat colour, Tubercles

Bitter gourd (*Momordica charantia* L.) is an important vegetable crop that belongs to the family Cucurbitaceae (De Wilde and Duyfjes 2002). Indian bitter gourd has wide phenotypic variation with respect to growth habit, maturity, fruit shape, size, colour and surface texture (Robinson *et al.* 1997, Rathod *et al.* 2021b) and sex expression (Behera *et al.* 2006). Fruits and seeds of bitter gourd are consumed at immature stage and possess several medicinal properties due to the presence of charantin, momorcharin, momordicoside A and B. Bitter gourd possesses high concentrations of ascorbic acid and iron compared to other cucurbitaceous vegetable crops (Behera 2004).

Cultivated bitter gourd and its wild species (*M. charantia* var. *muricata*) are grown in different parts of the tropics; preferences vary from region to region with respect to fruit colour, length, diameter, shape, size and tubercles (Rathod *et al.* 2019). Seed coat is considered diacritical in the taxonomy of the *Momordica* genus (Aguoru and Okoli 2008). Since immature fruits are sliced during the preparation of various Asian meals, exceptional

¹ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi. *Corresponding author email: tusar@rediffmail.com internal fruit quality and uniform green peel colour are desirable. Fruit colour decides its marketability; long and dark green to glossy green fruits are preferred in northern India, white fruits are preferred in southern India whereas in eastern parts of the country, small and dark green fruits are preferred (Behera et al. 2010). Besides gynoecious trait, fruit length has significant contribution in enhancement of yield of bitter gourd (Rao et al. 2018). The knowledge regarding genetics of different fruit and seed traits is helpful in formulating appropriate breeding programme for developing need based crop varieties. Keeping this in view, the present investigation was carried out to study the genetic inheritance of fruit traits and seed coat colour in bitter gourd. The study will pave the way for development of new varieties and hybrids with different fruit surface as per the consumer's preference.

MATERIALS AND METHODS

Four genetically diverse inbreds of bitter gourd maintained by selfing at IARI, viz. Pusa Vishesh (PV), Pusa Aushadhi (Pre-Gy-1), DBGS-54 (S-54; Pusa Rasdar), DBGS-2 (S-2) along with their three cross combinations, i.e. Pusa Aushadhi × DBGS-54, DBGS-54 × DBGS-2 and DBGS-54 × Pusa Vishesh were found to be good cross combinations with high specific combining ability effects (*sca*). All the traits under study in desirable direction

were used to study the genetic inheritance of fruit traits (ridgeness, tubercles and curviness) and seed coat colour. The genotypes were inter crossed to raise the F_1 plants during rainy season (June-October), 2014. The F₂ and backcross (BC₁P₁ and BC₁P₂) populations were obtained by selfing and backcrossing of F₁ plants, respectively, during spring-summer (February-May), 2015. Comparative field trial including six basic populations of each hybrid (parents, F₁, F₂ and backcross populations) was conducted during spring-summer (February-May) 2016 in a randomized complete block design with three replications. Seedlings were planted on both sides of the channels (90 cm width) in well prepared hills with a spacing of 2 m in between the channels and 60 cm between the hills. The observations on individual plants were recorded. All the recommended fertilizer doses, cultural practices as well as plant protection measures were followed to raise a successful crop in the experimental plots.

The goodness of fit of the observed segregation ratio for the segregation of fruit surface (ridgeness), tubercles, fruit curviness and seed coat colour traits expected for a single gene, was tested using the classical Chi-square (χ^2) test as suggested by Panse and Sukhatme1985. The χ^2 value

was calculated using the formula given below.

$$\chi^2 = \frac{\text{(Observed number - Expected number)}^2}{\text{Expected number}}$$

RESULTS AND DISCUSSION

Inheritance pattern of fruit surface (ridgeness pattern) was investigated in bitter gourd in crosses DBGS-54 (continuous ridge; cr cr) × DBGS-2 (discontinuous ridge; Cr Cr) and DBSS-54 (continuous ridge; cr cr) × Pusa Vishesh (discontinuous ridge; Cr Cr). In both crosses, the F₁ generations had all fruits with discontinuous ridges (Cr cr), which indicated it as dominant trait (Table 1). Out of total 130 plants in F₂ population of cross DBGS-54 (continuous ridge) × DBGS-2 (discontinuous ridge), 99 plants had discontinuous ridge fruits and 31 plants had continuous ridge fruits. The observed frequency of F₂ plants fitted well in the expected ratio of 3 discontinuous ridges: 1 continuous ridge as evident from the non-significant χ^2 values of 0.09 (P = 0.76). The BC₁P₁ population segregated into 17 discontinuous ridges and 13 continuous ridges fruited plants. The observed frequency of BC₁P₁ plants fitted well

Table 1 Chi square (χ^2) analysis of F_2 population for studying inheritance pattern of fruit surface (ridgeness) and tubercles in bitter gourd

Parent/Cross	Dis-continuous	Continuous	Expected ratio	χ ² value	P-value
Inheritance of fruit surface (ridgeness)					
S-54	0	20			
S-2	20	0			
Pusa Vishesh	20	0			
$S-54 \times S-2 (F_1)$	30	0			
S-54 × Pusa Vishesh (F_1)	30	0			
$(S-54 \times S-2) \times S-54 (BC_1P_1)$	17	13	1:1	0.53	0.47
$(S-54 \times Pusa \ Vishesh) \times S-54 \ (BC_1P_1)$	16	14	1:1	0.13	0.72
$(S-54 \times S-2) \times S-2 (BC_1P_2)$	30	0			
$(S-54 \times Pusa \ Vishesh) \times Pusa \ Vishesh (BC_1P_2)$	30	0			
$S-54 \times S-2 (F_2)$	99	31	3:1	0.09	0.76
S-54 × Pusa Vishesh (F ₂)	101	29	3:1	0.50	0.48
Inheritance pattern of tubercles					
Parent/Cross	Present	Absent	Expected ratio	χ²- value	P-value
S-54	0	20			
S-2	20	0			
Pusa Vishesh	20	0			
$S-54 \times S-2 (F_1)$	30	0			
S-54 × Pusa Vishesh (F ₁)	30	0			
$(S-54 \times S-2) \times S-54 (BC_1P_1)$	16	14	1:1	0.13	0.72
$(S-54 \times PusaVishesh) \times S-54 (BC_1P_1)$	17	13	1:1	0.53	0.47
$(S-54 \times S-2) \times S-2 (BC_1P_2)$	30	0			
(S-54 × Pusa Vishesh) × Pusa Vishesh (BC ₁ P ₂)	30	0			
$S-54 \times S-2 (F_2)$	101	29	3:1	0.50	0.48
S-54 × PusaVishesh (F_2)	98	32	3:1	0.01	0.92

in the expected ratio of 1 discontinuous ridge: 1 continuous ridge fruited plant with non-significant χ^2 values of 0.53 (P=0.47). In another cross, DBGS-54 (continuous ridge) × Pusa Vishesh (discontinuous ridge), the F₂ population segregated into discontinuous ridge and continuous ridge fruiting plants in the ratio of 101: 29 fitting well in the expected ratio of 3 discontinuous ridge: 1 continuous ridge fruited plants ($\chi^2 = 0.50$; P = 0.48). Out of 30 plants in BC₁P₁, 16 showed discontinuous ridge fruits and remaining 14 had discontinuous ridge fruits. The observed frequency fitted well into expected ratio of 1 discontinuous ridge: 1 continuous ridge fruited plant ($\chi^2 = 0.13$; P = 0.72). This study confirmed the earlier reports (Srivastava and Premnath 1972, Dalamu et al. 2012).

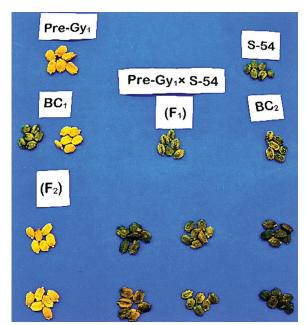
Inheritance pattern of tubercles was investigated in bitter gourd in crosses DBGS-54 (no tubercles; tb tb) × DBGS-2 (tubercle; Tb Tb) and DBGS-54 (no tubercles; $tb \ tb) \times PusaVishesh$ (tubercle; $Tb \ Tb$). In both crosses, the F_1 generations had all fruits with tubercles ($Tb \ tb$), which, indicated it as dominant trait (Table 1). Out of total 130 plants in F₂ population of DBGS-54 (no tubercles) × DBGS-2 (tubercle), 101 plants were tubercle fruited and 29 plants had no prominent tubercles on fruits. The observed frequency of F₂ plants fitted well in the expected ratio of 3 prominent tubercles: 1 non-prominent tubercles as evident from the non-significant χ^2 values of 0.50 (P = 0.48). The BC₁P₁ population segregated into 16 prominent tubercles and 14 non-prominent tubercles fruited plants. The observed frequency of BC₁P₁ plants fitted well in the expected ratio of 1 prominent tubercle: 1 non-prominent tubercle fruited plant with non-significant χ^2 values of 0.13 (P = 0.72). In another cross, DBGS-54 (no tubercles) × PusaVishesh (tubercle), the F2 population segregated into prominent tubercle and non-prominent tubercle fruited plants in the ratio of 98: 32



Fig 1 F₂ segregated population of cross DBGS-54 × DBGS-2 showed curved fruits.

fitting well in the expected ratio of 3 prominent tubercles: 1 non-prominent tubercle fruited plants ($\chi^2 = 0.01$; P = 0.92). Out of 30 plants in BC₁P₁, 17 showed prominent tubercle, fruits and remaining 13 had non-prominent tubercle fruits. The observed frequency fitted well in the expected ratio of 1 prominent tubercle: 1 non-prominent tubercle fruited plant ($\chi^2 = 0.53$; P = 0.47). This is also supported by the earlier studies (Vahab 1989, Kumari et al. 2015).

Inheritance pattern of fruit curviness was investigated in bitter gourd in cross DBGS-54 (straight; cf cf) × DBGS-2 (curved; Cf Cf). All F₁ plants showed curved fruits (Cf cf), indicating its dominant nature. Out of total 90 plants in F₂ population, 68 segregated as curved and 22 as straight fruits fitting into the expected ratio of 3 curved: 1 straight $(\chi^2 = 0.02; P = 0.89; Table 2; Fig 1)$. The BC₁P₁ population segregated into 17 curved and 13 straight fruited plants. The observed frequency of BC₁P₁ plants fitted well in the expected ratio of 1 curved: 1 straight fruited plant ($\chi^2 = 0.53$;



cross [Pusa Aushadhi (Pre-Gy-1) \times DBGS-54] in F_2 population.

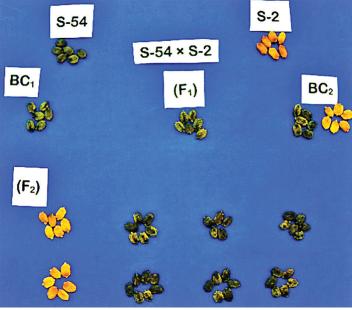


Fig 2a Segregation for seed coat colour (Bs) in bitter gourd Fig 2b Segregation for seed coat colour (Bs) in bitter gourd cross (DBGS- $54 \times DBGS-2$) in F₂ population.

Table 2 Chi square (χ^2) analysis of F_2 population for studying inheritance pattern of fruit curviness and seed coat colour in bitter gourd

Parent/Cross	Curved	Straight	Expected ratio	χ ² value	P-value
Inheritance of fruit curviness					
S-54	0	20			
S-2	20	0			
$S-54 \times S-2 (F_1)$	30	0			
$(S-54 \times S-2) \times S-54 (BC_1P_1)$	17	13	1:1	0.53	0.47
$(S-54 \times S-2) \times S-2 (BC_1P_2)$	30	0			
$S-54 \times S-2 (F_2)$	68	22	3:1	0.02	0.89
Inheritance of seed coat colour					
Parent/Cross	Black	Light brown	Expected ratio	χ^{2-} value	P - value
Pusa Aushadhi	0	20			
S-54	20	0			
S-2	0	20			
Pusa Aushadhi × S-54 (F ₁)	30	0			
$S-54 \times S-2 (F_1)$	30	0			
(Pusa Aushadhi \times S-54) \times Pusa Aushadhi (BC $_1$ P $_1$)	11	9	1:1	0.20	0.66
(Pusa Aushadhi × S-54) × S-54 (B C_1P_2)	20	0			
$(S-54 \times S-2) \times S-54 (BC_1P_1)$	30	0			
$(S-54 \times S-2) \times S-2 (BC_1P_2)$	16	14	1:1	0.13	0.72
Pusa Aushadhi \times S-54 (F_2)	64	26	3:1	0.73	0.39
$S-54 \times S-2 (F_2)$	67	23	3:1	0.02	0.89

P=0.47). This result was contradictory to the earlier report (Kumari *et al.* 2015) where curved fruit inherited as recessive trait. This might be due to the fact that fruit curviness may have associated with fruit length. They reported smaller fruit length (10.14 cm) in F_1 when Sel-2 (23.92 cm) was crossed with Pusa Purvi (4.07 cm) and average fruit length of F_2 was 11.71 cm. In the present experiment, greater fruit length in F_1 (16.44 cm) was observed in the cross between DBGS-54 (13.99 cm), DBGS-2 (20.76 cm) and the mean fruit length of F_2 was13.53 cm.

Inheritance pattern of seed coat colour was investigated in bitter gourd in crosses Pusa Aushadhi (light brown; bs bs) × DBGS-54 (black; Bs Bs) (Fig 2a) and DBGS-54 (black; Bs Bs) × DBGS-2 (light brown; bs bs) (Fig 2b). In both crosses, the F₁ generations had all seeds with black colour (Bs bs), indicating that black seed coat colour inherited as a dominant trait (Table 2). Out of total 90 plants in F₂ population of cross Pusa Aushadhi (light brown) × DBGS-54 (black), 64 plants were black seeded and 26 plants had light brown colour seeds. The observed frequency of F₂ plants fitted well in the expected ratio of 3 black: 1 light brown seed colour as evident from the non-significant χ^2 values of 0.73 (P = 0.39). The BC₁P₁ population segregated into 11 dark brown and 9 cream seeded plants. The observed frequency of BC₁P₁ plants fitted well in the expected ratio of 1:1 with non-significant χ^2 values of 0.20 (P = 0.66). In another cross, DBGS-54 (black) × DBGS-2 (light brown), the F₂ population segregated into black and light brown seeded plants in the ratio of 67: 23 fitting well in the expected ratio of 3 black: 1 light brown seeded plants ($\chi^2 = 0.02$; P = 0.89). Out of 30 plants in BC₁P₂, 16 showed black and remaining 14 had light brown seed coat colour. The observed frequency fitted well into expected ratio of 1 black: 1 light brown seeded plant ($\chi^2 = 0.13$; P = 0.72). This study confirmed the earlier report of Srivastava and Premnath (1972), Rathod *et al.* (2021a) and is contrary to Kole *et al.* (2012) who reported digenic (9:7) mode of inheritance.

The present study showed inheritance pattern of fruit surface in bitter gourd; discontinuous ridges (*Cr*), tubercles (*Tb*) curved fruits (*Cf*) and black seed coat colour (*Bs*) were governed by single dominant gene. Simple inheritance of these fruit traits will enable the bitter gourd breeder to incorporate these traits in hybrids. The black seed coat colour will act as a morphological marker for hybrid seed purity test as well.

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