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Genetics of cluster bearing habit and fruit surface morphology in ridge gourd (*Luffa acutangula* Roxb.)

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Abstract

Luffa acutangula or ridge gourd generally produces solitary and ribbed or ridged fruit, but Satputia a feral form of ridge gourd with hermaphrodite sex form produces non-ribbed fruits in cluster. The present study was conducted to determine the inheritance cluster bearing habit and non-ridge fruit in ridge gourd from the crosses of two hermaphrodite lines (Satputia Long and Satputia Small) which produced small numerous non-ribbed fruits in cluster and five monoecious lines (DRG-2, Pusa Nasdar, Utkal Tripti, Arka Summet and HARG-110), produced solitary long fruit with ten prominent ridges. It was observed that all the F1 plants were solitary bearer and produced ridged fruit. In F2 generation, the observed distribution of plant phenotypes for bearing habit and fruit surface morphology fitted well to the expected ratio of 3:1 (solitary vs cluster) and 15:1 (ridge vs non-ridge) for bearing habit and fruit surface morphology, respectively. The segregation pattern suggested monogenic recessive control of cluster bearing habit, while duplicate recessive genes control ridged fruit surface in *Luffa acutangula*.

Keywords: Ridge gourd, Satputia, Inheritance, Cluster fruiting and Non-ridged fruit.

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Introduction

Luffa is a member of the subfamily Cucurbitoideae, tribe Benincaseae, subtribe Luffinae (Jeffrey 1962, 1980). It is the only member of the subtribe and has species in both the Old and New Worlds. In some respects, it resembles members of the Cyclantherinae, an entirely New World subtribe of the Siceyeae. It thus may be the connecting link of these two tribes. All *Luffa* species are vines and bear solitary pistillate flowers and racemes of male flowers, but one of its feral form "Satputia" produces numerous fruits in cluster. Monoecious is most common sex form in *Luffa*; but hermaphrodite sex form also existed in "Satputia" which is primarily grown in Eastern parts of Uttar Pradesh, Bihar, Jharkhand and West Bengal (Chandra 1995). Factually, the meaning of Satputia is "Seven Children" which reflect in its fruit bearing habit (5-10 fruits/ cluster) and its fruits are regarded important component in a Hindu festival "Jiyutia" or "Jivitputrika Vrat" specifically celebrated by the mothers for long life of her children (Karmakar et al. 2013). Unlike monoecious ridge gourd, Satputia bears numerous small size fruits in cluster (Karmakar et al. 2014). Satputia are also known for their superior nutritional quality in term of antioxidant activity and minerals content (Karmakar et al. 2013). The ridge gourd generally produces solitary long fruits of 15-30 cm in length with prominent ribbed and rough fruit skin, but it has an ancestral form "Satputia" found in Bihar which is hermaphrodite in nature and was given a

separate taxonomic status *L. hermaphrodita* which produce small fruits in cluster. Species status of Satputia seems to be ambiguous because of its easy crossability and fully fertile hybrids with *Luffa acutangula*. Hermaphrodite sex form of Satputia, though considered primitive, is believed to be derived from monoecious species *Luffa graveolens*. Its fruits have faint line instead of prominent ridge. Fruit orientation and number of fruits per cluster are is important yield contributing trait which can be economically exploited through heterosis breeding in *Luffa*. Similar characters were studied in sponge gourd (Munshi et al. 2021), melon (Silpa et al. 2020) and pumpkin (Gopan et al. 2020).

In spite of the importance of cluster bearing habit and earliness in *Luffa*, information on inheritance pattern of cluster bearing habit and fruit surface morphology along with its utilization in heterosis breeding has not been reported so far. Though the knowledge of inheritance pattern of cluster bearing habit and ridging behavior will be helpful for speedy improvement of this crop, mainly for earliness, fruit quality and yield, but till now no information is available about the inheritance pattern of cluster bearing habit and fruit surface morphology in the cross combinations of monoecious and hermaphrodite ridge gourd. With this view the present experiment is designed to study the genetics of fruit bearing habit and fruit surface morphology utilizing common ridge gourd and its feral form 'Satputia'. This is probably the first conclusive report on the inheritance pattern of the above traits.

Materials and Methods

The experiment was carried out at Indian Agricultural Research Institute. The experimental materials consisting of two hermaphrodite lines (Satputia Long and Satputia Small) which produce non-ridge and small size fruits (length: 8.5 to 10.5 cm and diameter:4 to 4.5 cm) in cluster; and five monoecious lines with solitary fruiting habit and produced fruit with prominent ridge (DRG-2, Pusa Nasdar, Utkal Tripti, Arka Sumeet and HARG-110). The seeds of 5 monoecious lines along with 2 hermaphrodite genotypes were sown during spring summer of the first year to produce ten F_1 hybrids involving hermaphrodite line as male parent. Evaluation of these 10 F_1 hybrids involving 'Satputia' as one of the parent for fruit bearing habit and fruit surface morphology was studied in replicated trial during rainy season of the first year. Each replication consisted of 20 plants. The F_1 hybrids were advanced to F_2, B_1 and B_2 by selfing and backcrossing with parent one and two, respectively. Evaluation of F_2s, B_1 and B_2 of 10 F_1 hybrids obtained from the previous generation was done for assessing segregation of fruit bearing habit and fruit surface morphology in three consecutive season of the the second and third year. Taking DRG-2 × Satputia Long, DRG-2 × Satputia Small and Pusa Nasdar × Satputia Long during spring summer season and Pusa Nasdar × Satputia Small, Utkal Tripti × Satputia Small and Utkal Tripti × Satputia Long during rainy season of the second year for evaluation purpose. While Arka Sumeet × Satputia Long, Arka Sumeet × Satputia Small, HARG -110 × Satputia Long, HARG-110 × Satputia Small were evaluated during spring summer season of the third year. Plant population maintained for F_1, F_2, B_1 and B_2 of each combination to study the sex behavior were 15, 130, 30 and 60, respectively. The data from the F_2, B_1 and B_2 populations were analyzed using the χ^2 for goodness-of-fit based on a monogenic recessive control of the above traits as suggested by Panse and Sukhatme (1985).

Results and Discussion

In the present experiment, an effort was made to place the genetics of cluster bearing habit and ridged or non-ridge fruit on classical dominant-recessive Mendelian model, keeping the plants only in two categories for cluster bearing habit and ridge or non ridge fruit. For this purpose, the F_2, B_1 (F_1 × parent with solitary bearing habit with ridged fruit) and B_2 (F_1 × parent with cluster bearing habit with non-ridged fruit) progenies were developed involving two cluster bearing parents (Satputia Long and Satputia Small) crossing with five solitary bearing parents (DRG-2, Pusa Nasdar, Utkal Tripti, Arka Sumeet and HARG-110). The frequency distribution of F_2, B_1 and B_2 progenies were classified based on fruiting habit and fruit surface morphology. Results pertaining to segregation for fruiting habit and fruit surface morphology in F_1, F_2, B_1 and B_2 generations were given in the Table 1 and 2. In the F_1 generations all the 15 plants under observation had solitary fruiting habit in all the 10 cross combinations. In the F_2 generation, out of 130 plants studied in all cross combination produced plant with two type of bearing habit viz., solitary and cluster fruiting habit. Out of the various Mendelian ratios tested, the chi-square values were significant for all ratios except 3 (Solitary): 1 (Cluster). Chi-square value for F_2 segregation in 10 crosses ranged from 0.01 to 0.09, while P value ranged from 0.70 to 1.0. In B_1 generation all 30 plants gave plant with solitary fruiting habit, while in B_2 generation two type of bearing habit were observed in all cross combinations. Out of the various Mendelian ratios tested, the chi-square values were fit well to 1:1 Mendelian ratio and chi-square value varied from 0.0001 to 3.27. With respect to fruit surface morphology, all the 15 F_1 plants under observation produced ridged fruit. In the F_2 generations, out of 130 plants studied in all cross combination gave two types of plants i.e., plant with ridged fruit and plant with non - ridged. Out of the various Mendelian ratios tested, the chi-square values were significant for all ratios except 15 (Ridged): 1 (Non-ridged). Chi-square value for F_2 segregation in 10 crosses ranged from 0.001to 0.59, while P value ranged from 0.04 to 1.0. In B_1 generation all 30 plants gave ridged fruit, while in B_2 generation two types of fruit surfaces were observed in all cross combinations. Out of the various Mendelian ratios tested, the chi-square values were fit well to 3:1 ratio and chi-square value varied from 0.001 to 2.220.

Table 1: Inheritance of cluster bearing habit in ridge gourd

Cross combination	*Generation*	*Phenotypes*		*Ratio tested*	*X^2-value*	*P-value*
		Solitary Fruited	*Clustered fruited*			
DRG-2× SPL	F_1	15	0	-	-	-
	F_2	99	31	3:1	0.09	0.70-0.80
	B_1	30	0	-	-	-
	B_2	37	23	1:1	3.27	0.05-0.10
DRG-2 × SPS	F_1	15	0	-	-	-
	F_2	98	32	3:1	0.01	0.90-1.0
	B_1	30	0	-	-	-
	B_2	31	29	1:1	0.06	0.80-0.90
PN × SPL	F_1	15	0	-	-	-
	F_2	98	32	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	31	29	1:1	0.06	0.80-0.90
PN × SPS	F_1	15	0	-	-	-
	F_2	98	32	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	32	28	1:1	0.26	0.60-0.70
UT × SPL	F_1	15	0	-	-	-
	F_2	98	32	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	32	28	1:1	0.26	0.60-0.70
UT × SPS	F_1	15	0	-	-	-
	F_2	99	31	3:1	0.09	0.70-0.80
	B_1	30	0	-	-	-
	B_2	31	29	1:1	0.06	0.80-0.90
AS × SPL	F_1	15	0	-	-	-
	F_2	97	33	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	30	30	1:1	0.0001	0.9-1.0
AS × SPS	F_1	15	0	-	-	-
	F_2	96	34	3:1	0.09	0.70-0.80
	B_1	30	0	-	-	-
	B_2	32	28	1:1	0.26	0.60-0.70
HARG-110 × SPL	F_1	15	0	-	-	-
	F_2	98	32	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	33	27	1:1	0.60	0.40-0.50
HARG-110 × SPS	F_1	15	0	-	-	-
	F_2	97	33	3:1	0.01	0.80-0.90
	B_1	30	0	-	-	-
	B_2	32	28	1:1	0.26	0.60-0.70

SPL: Satputia Long, SPS: Satputia Small, PN: Pusa Nasdar, UT: Utkal Tripti, AS: Arka Sumeet

For inheritance of cluster bearing habit it was found that in all 10 cross combinations out of 130 plants studied in F_2 generation, the range of solitary and cluster bearing plant varied from 96-99 and 31-34, respectively. In B_2 generation, the range for number of plants with different bearing habit varied from 30-37 and 23-29, respectively for solitary and cluster bearing habit. Chi-square analysis of F_2 segregation data also revealed a perfect fit to 3:1 (solitary vs. cluster).

Table 2: Inheritance of fruit surface morphology in ridge gourd

Cross combinations	*Generation*	*Phenotypes*		*Ratio tested*	*X^2-value*	*P-value*
		Ribbed fruited	*Non-ribbed fruited*			
DRG-2 x SPL	F_1	15	0	-	-	-
	F_2	124	6	15:1	0.59	0.40-0.50
	B_1	30	0	-	-	-
	B_2	50	10	3:1	2.22	0.05-0.10
DRG-2 x SPS	F_1	15	0	-	-	-
	F_2	121	9	15:1	0.10	0.70-0.80
	B_1	30	0	-	-	-
	B_2	46	14	3:1	0.08	0.80-0.90
PN x SPL	F_1	15	0	-	-	-
	F_2	120	10	15:1	0.46	0.50-0.60
	B_1	30	0	-	-	-
	B_2	44	16	3:1	0.08	0.80-0.90
PN x SPS	F_1	15	0	-	-	-
	F_2	122	8	15:1	0.002	0.90-1.0
	B_1	30	0	-	-	-
	B_2	47	13	3:1	0.35	0.50-0.60
UT x SPL	F_1	15	0	-	-	-
	F_2	121	9	15:1	0.10	0.70-0.80
	B_1	30	0	-	-	-
	B_2	46	14	3:1	0.08	0.80-0.90
UT × SPS	F_1	15	0	-	-	-
	F_2	123	7	15:1	0.16	0.60-0.70
	B_1	30	0	-	-	-
	B_2	44	16	3:1	0.08	0.80-0.90
AS × SPL	F_1	15	0	-	-	-
	F_2	120	10	15:1	0.46	0.50-0.60
	B_1	30	0	-	-	-
	B_2	45	15	3:1	0.001	0.90-1.0
AS × SPS	F_1	15	0	-	-	-
	F_2	121	9	15:1	0.10	0.70-0.80
	B_1	30	0	-	-	-
	B_2	48	12	3:1	0.80	0.40-0.50
HARG-110 × SPL	F_1	15	0	-	-	-
	F_2	122	8	15:1	0.002	0.90-1.0
	B_1	30	0	-	-	-
	B_2	45	15	3:1	0.001	0.90-1.0
HARG-110 × SPS	F_1	15	0	-	-	-
	F_2	120	10	15:1	0.46	0.50-0.60
	B_1	30	0	-	-	-
	B_2	46	14	3:1	0.08	0.80-0.90

SPL: Satputia Long, SPS: Satputia Small, PN: Pusa Nasdar, UT: Utkal Tripti, AS: Arka Sumeet

This result suggested that cluster bearing habit in Satputia Long and Satputia Small was controlled by a single recessive gene. This was also confirmed by the test cross segregation of 1:1for solitary and cluster bearing habit and appearance

of 100% solitary fruited plant in F_1 generation. Though no report on inheritance of bearing habit (Solitary vs Cluster) was available in ridge gourd, the present finding is strongly supported by the repot of Dhamayanthi and Reddy (2001) in chilli, that clustered fruit trait was monogenic recessive.

For inheritance of fruit surface morphology it was found that in all 10 cross combinations out of 130 plants studied in F_2 generation the range of plants with ridged fruit and non-ridge fruit varied from 120-124 and 6-10, respectively. In B_2 generation, the range for number of plants with different bearing habit varied from 44-50 and 10-16, respectively for ridge fruit and non-ridge fruit, respectively. Chi-square analysis of F_2 segregation data also revealed a perfect fit to 15:1 (ridge vs. non-ridge). This result suggested that ridged fruit was controlled by duplicate dominant gene. This character governed by duplicate gene is determined by two completely dominant genes. These dominant gene produce the same phenotypes whether they are alone or together. Therefore, non-ridge fruit character of hermaphrodite line is recessive to ridge fruit trait of monoecious line. This was also confirmed by the test cross segregation of 3:1for ridge and non-ridge fruit surface and the appearance of 100% ridge fruited plant in F_1 generation. This is the contrary to the report Thakur and Choudhury (1966) as they took small population of only 10 plants in F_2 generation and found single recessive gene for inheritance of the smooth fruit in sponge gourd. In our investigation use of preferably high F_2 population (130 plants) might help in proper expression of the gene responsible for fruit surface morphology.

Conclusion

In studying the inheritance pattern of fruit bearing habit and fruit surface morphology, it was found that F_2 population segregated in the ratio 3:1 (solitary *vs* cluster) and 15:1 (ridge *vs* non-ridge), respectively for bearing habit and fruit surface morphology. These F_2 segregation patterns were strongly supported by test cross segregation for cluster bearing habit and fruit surface morphology segregated in the way of 1:1 (solitary *vs* cluster) and 3:1 (ridge *vs* non-ridge) respectively. Therefore, it is quite clear that cluster bearing habit inherited through a single recessive, while ridged fruit surface governed by duplicate dominant genes.

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सारांश

नसदार तोरई में सामान्यतः एकल एवं उठी हुई/नसयुक्त फल का विकास होता है लेकिन सतपुतिया जो नसदार तोरई की एक अनुवन्य में उभयलिंगी के साथ गुच्छे में बिना नस के फल विकसित होते हैं। वर्तमान अध्ययन में दो उभयलिंगी लाइन (लम्बा सतपुतिया एवं छोटा सतपुतिया) के संकरण से अनेकों छोटे व बिना नसदार वाले गुच्छे में फल विकसित हुए तथा पाँच एकलिंगी लाइन्स (डी.आर.जी.-2, पूसा नसदार, उत्कल तृप्ति, अर्का सुमिति व एच.ए.आर.जी.-110) ने लम्बे तथा एकल फल विकसित किये जिनके फलों में प्रबल नसें पायी गयी। ऐसा पाया गया कि सभी संकरों में एकल व नसदार फल बने। एफ-2 पीढ़ी में पौधों के बाह्यस्वरूप फल बनने व फल विकास की प्रवृत्ति का अनुमानित अनुपात 3:1 (एकल विपरीत गुच्छेदार) एवं 15:1 (नसदार विपरीत बिना नसदार) फल विकास प्रवृत्ति व फल सतह आकृति क्रमशः पाया गया। पृथक्करण प्रवृत्ति से स्पष्ट हुआ कि मोनोजेनिक अप्रभावी नियंत्रण फल बनने की प्रवृत्ति में पाया गया जबकि डुप्लीकेट अप्रभावी नियंत्रण बिना नसदार फल सतह के लिए क्रमशः लम्बे सतपुतिया व छोटे सतपुतिया में पाया गया।