Mysore J. Agric. Sci., 52 (2) : 293-299, 2018

Genetics of Fruiting Habit Traits in Chilli (*Capsicum annuum* L.)

C. ANILKUMAR AND A. MOHAN RAO
Department of Genetics and Plant Breeding, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
E-mail: anilcgpb@gmail.com

ABSTRACT

Fruiting habit traits- fruits number node^{-1} and their orientation in chilli could be solitary erect (SE), solitary pendant (SP), clustered erect (CE) and clustered pendant (CP). Farmer preferences for growth habit traits varies from region to region. An understanding of inheritance of fruiting habit traits help accelerate breeding chilli cultivars with a desired combination of farmer preferred fruiting habit traits. Genotypes contrasting for fruiting habit traits were crossed to develop four types of hybrids, *viz.*, CE × SE, CP × SP, SE × CP and CE × SP during 2015 rainy season, F_2, B_1 and B_2 were developed during summer 2016. F_1, F_2 and backcrosses of all the four types of crosses were evaluated and pattern of segregation for fruiting habit traits was recorded during 2016 and 2017 rainy seasons at the experimental plots of the Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences (UAS), Bengaluru. Results indicated bi-allelic monogenic inheritance of number of fruits node^{-1} (solitary *vs.* clustered) and orientation of fruits (erect *vs.* pendant) with solitary being dominant over clustered and pendant being dominant over erect orientation. Genes controlling number of fruits node^{-1} and orientation of fruits segregated independently. The results suggested the possibility of developing chilli varieties with desired combination of fruiting habit traits.

Keywords: Inheritance, fruit orientation, fruit number node^{-1}, goodness of fit

HOT pepper (*Capsicum annuum* L; 2n = 2x = 24), popularly known as chilli in India is an important economic and vegetable crop worldwide (Poulos, 1992), which is ranked second among solanaceous vegetable crops after tomato (Bosland *et al.*, 1996 and www.indianspices.com, 2016). The species Capsicum originated in Mexico with centre of diversity in South America (Gonzalez and Bosland, 1991). Presence of pepper-specific secondary metabolites, capsaicinoids, which confer pungency in fruits and have various medicinal effects made it an important part of diet (Kim *et al.*, 2014). Its fruits contain an appreciable quantity of nutrients including ascorbic acid, β-carotene and other carotenoid pigments such as lycopene and zeaxanthin possessing anticancer properties (Ghasemnezhad *et al.*, 2011). India being the foremost producer & exporter of chilli contributes one fourth to the world market. Even though chillies are grown in all parts of the country, Andhra Pradesh, Karnataka, Orissa, Maharashtra, Rajasthan and Tamil Nadu are the major chilli growing states in India accounting for 80 per cent in area and 84 per cent in total production (www.indianspices.com, 2016).

Fruiting habit traits-orientation and number of fruits node^{-1} are considered as important economic traits. Fruit orientation is either pendent (fruit tips are geotropic) or erect (fruit tips are phototropic) (Lee *et al.*, 2008). Number of fruits node^{-1} is either one (solitary) or more than one (clustered). Most chilli cultivars used in southern India bear solitary pendant fruits. Harvesting solitary pendant fruits is resource demanding and account for up to 20 per cent of cost of cultivation (Gopalakrishnan *et al.*, 1989). Reported literature indicated that development of cultivars with clustered fruiting habit is expected to result in concentrated fruit set, uniform maturity, and reduced cost of harvesting (Dhamayanthi and Reddy, 2001). A thorough knowledge on the inheritance of fruiting habit traits help accelerate breeding chilli cultivars with a combination of desired fruiting habits. Reported literature on genetics of fruiting habit in chilliis restricted to limited genetic backgrounds. In the milieu, the objective of the present study was to unravel the inheritance of fruiting habit traits in chilli under diverse genetic backgrounds.

Material and Methods

Basic genetic material

Six genotypes [Utkal Awa (UA), CMS 6B, CMS 10B, PhuleJyothi (PJ), Pusa Sadabahar (PS) and Japani Long (JL)] with four distinct fruiting habit traits- solitary erect (SE), solitary pendant (SP), clustered erect (CE) and clustered pendant (CP) (Table I) were chosen for the study.

Table I

Fruiting habit traits of the genotypes used in the study

Genotype	Source	Fruiting habit
Utkal Awa	OUAT, Bhubaneshvar	Bear solitary and erect fruits
CMS 6B	AVRDC, TAIWAN	Bear solitary and pendant fruits
CMS 10B	AVRDC, TAIWAN	Bear solitary and pendant fruits
Phule Jyothi	MPKV, Rahuri	Bear clustered and pendant fruits
Pusa Sadabahar	Pusa, New Delhi	Bear clustered and erect fruits
Japani long	Pusa, New Delhi	Bear clustered and erect fruits

Development of experimental material (F_1, F_2 and back cross generations)

Six genotypes were used to generate four types of crosses (CE × SE, CP × SP, SE × CP and CE × SP) (Table II) in the polyhouse during 2015 rainy season. The plants of four types of crosses were grown and selfed to develop F_2 and back crossed to their respective parents to develop B_1 and B_2 populations, respectively during 2016 summer at the experimental plots of the Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences, Bengaluru, India. The six parental genotypes and F_1, F_2 and back cross generations derived from them constituted the experimental material.

Evaluation of experimental material

Forty day old seedlings of the six parental genotypes and their F_1, F_2, B_1 and B_2 generations of four crosses were planted during 2016 and 2017 rainy seasons by maintaining a spacing of 0.75m between rows and 0.4m between plants within row. The parental genotypes and F_1 of the four crosses were planted following two-replicated randomized block design (RBD). The F_2, B_1 and B_2 generations were un-replicated and planted in larger plots. Data were recorded on randomly chosen ten plants in parental genotypes and their F_1's, on 20 to 70 plants in B_1 and B_2 generations and on 40 to 84 plants in F_2 generations for fruiting habit traits. The plants in parental genotypes and their F_1's, F_2, B_1 and B_2 generations were classified as SE, SP, CP, and CE based on visual assessment.

Statistical analysis

Monogenic segregation : The goodness of fit of observed ratio of segregation of solitary *vs.* clustered fruiting habit with that of expected (3S:1C in F_2; 1S:0C in B_1; 1S:1C in B_2 generations) based on bi-allelic monogenic inheritance was examined using chi-square test in all the four types of crosses whose parents contrasted for number of fruits node^{-1}. In the F_2 and back crosses derived from crosses *viz.*, UA × PJ and PS × CMS 6B which differed for orientation of fruits, goodness of fit of observed segregation pattern with that expected (3P:1E in F_2; 1P:0E in B_1 and 1E:1E in

Table II

Types of crosses generated

Crosses			Type of Cross		
Japani Long (JL)	×	Utkal Awa (UA)	Clustered Erect (CE)	×	Solitary Erect (SE)
Phule Jyothi (PJ)	×	CMS 10B	Clustered Pendant (CP)	×	Solitary Pendant (SP)
Utkal Awa (UA)	×	Phule Jyothi (PJ)	Solitary Erect (SE)	×	Clustered Pendant (CP)
Pusa sadabahar (PS)	×	CMS 6B	Clustered Erect (CE)	×	Solitary Pendant (SP)

TABLE III

Segregation pattern of number of fruits node^{-1} in chilli based on 2016 and 2017 rainy season data

Parental identity and type of cross	Generation	Total no. plants		Observed segregation pattern				Expected ratio	Expected segregation pattern				χ^2 Statistic	
				Solitary fruiting		Clustered fruiting			Solitary fruiting		Clustered fruiting			
		2016	2017	2016	2017	2016	2017		2016	2017	2016	2017	2016	2017
	P_1	10	10	-	-	10	10	-	-	-	10	10	-	-
Japani long	P_2	10	10	10	10	-	-	-	10	10	-	-	-	-
x	F_1	10	10	10	10	-	-	-	10	10	-	-	-	-
Utkal awa	F_2	84	80	60	58	24	22	3:01	63	60	21	20	0.57	0.27
(clustered x soliatry)	B_1	70	20	38	11	32	9	1:01	35	10	35	10	0.51	0.2
	B_2	52	28	52	28	-	-	1:00	52	28	-	-	-	-
	P_1	10	10	-	-	10	10	-	-	-	10	10	-	-
Phule Jyothi	P_2	10	10	10	10	-	-	-	10	10	-	-	-	-
x	F_1	10	10	10	10	-	-	-	10	10	-	-	-	-
CMS 10B	F_2	50	77	41	56	9	21	3:01	37.5	57.75	12.5	19.25	1.31	0.21
(clustered x soliatry)	B_1	20	50	12	28	8	22	1:01	10	25	10	25	0.80	0.72
	B_2	58	41	58	41	-	-	1:00	58	41	-	-	-	-
	P_1	10	10	10	10	-	-	-	10	10	-	-	-	-
Utkal awa	P_2	10	10	-	-	10	10	-	-	-	10	10	-	-
x	F_1	10	10	10	10	-		-	10	10	-		-	-
Phule Jyothi	F_2	56	54	39	39	17	15	3:01	42	40.5	14	13.5	0.86	0.29
(soliatry x clustered)	B_1	60	36	60	36	-	-	1:00	60	36	-	-	-	-
	B_2	40	21	26	14	14	7	1:01	20	10.5	20	10.5	3.6	2.33
	P_1	10	10	-	-	-	10	-	-	-	-	10	-	-
Pusa sadabahar	P_2	10	10	10	-	-	-	-	10	-	-	-	-	-
x	F_1	10	10	10	-	-	-	-	10		-	-	-	-
CMS 6B	F_2	40	80	32	59	8	21	3:01	30	60	10	20	0.53	0.07
(clustered x soliatry)	B_1	48	80	29	45	19	35	1:01	24	40	24	40	2.08	1.25
	B_2	48	50	48	50	-	-	1:00	48	50	-	-	-	-
Heterogenity χ^2 for fruits node^{-1} @ 3df													3.26	0.70

TABLE IV

Segregation pattern of fruit orientation in chilli based on 2016 and 2017 rainy season data

Parental identity and type of cross	Generation	Total no. plants		Observed segregation pattern				Expected ratio	Expected segregation pattern				χ^2 Statistic	
				Pendant fruiting		Erect fruiting			Pendant fruiting		Erect fruiting			
		2016	2017	2016	2017	2016	2017		2016	2017	2016	2017	2016	2017
	P_1	10	10	10	10	-	-	-	10	10	-	-	-	-
Utkal Awa	P_2	10	10	-	-	10	10	-	-	-	10	10	-	-
x	F_1	10	10	10	10	-		-	10	10	-		-	-
Phule Jyothi	F_2	56	56	42	40	14	14	3:01	42	40.5	14	13.5	1×10^{-5}	0.03
(erect x pendant)	B_1	60	36	35	23	25	13	1:00	30	18	30	18	1.66	2.17
	B_2	40	21	40	21	-	-	1:01	40	21	-	-	-	-
	P_1	10	10	-	-	-	10	-	-	-	-	10	-	-
Pusa sadabahar	P_2	10	10	10	-	-	-	-	10	-	-	-	-	-
x	F_1	10	10	10	-	-	-	-	10		-	-	-	-
CMS 6B	F_2	40	80	30	61	10	19	3:01	30	60	10	20	1×10^{-5}	0.07
(erect x pendant)	B_1	48	80	19	45	29	35	1:01	24	40	24	40	2.08	1.25
	B_2	48	50	48	50	-	-	1:00	48	50	-	-	-	-
Heterogenity χ^2 for fruits node $^{-1}$ @ 1df													0.78	1.60

TABLE V

Joint segregation pattern for number of fruits node^{-1} and fruit orientation in chilli based on 2016 and 2017 rainy season data

Parental identity and type of cross	Generation		Total no. plants	Observed segregation pattern				Expected ratio	Expected segregation pattern				χ^2 Statistics
				SP	CP	SE	CE		SP	CP	SE	CE	
		P_1	10	-	-	10	-	-	-	-	10	-	-
		P_2	10	-	10	-	-	-	-	10	-	-	-
	2016	F_1	10	10	-	-		-	10	-	-		-
Utkal Awa		F_2	56	29	13	10	4	9:3:3:1	31.5	10.5	10.5	3.5	0.89
x		B_1	60	35	-	25	-	1:0:1:0	30	-	30	-	1.67
Phule Jyothi		B_2	40	26	14	-	-	1:1:0:0	20	20	-	-	3.6
(solitary x clustered)		P_1	10	-	-	10	-	-	-	-	10	-	-
		P_2	10	-	10	-	-	-	-	10	-	-	-
	2017	F_1	10	10	-	-		-	10	-	-		-
		F_2	54	29	11	10	4	9:3:3:1	30.37	10.12	10.12	3.37	0.89
		B_1	36	23	-	13	-	1:0:1:0	18	-	18	-	2.78
		B_2	21	14	7	-	-	1:1:0:0	10.5	10.5	-	-	2.33
		P_1	10	-	-	-	10	-	-	-	-	10	-
		P_2	10	10	-	-	-	-	10	-	-	-	-
		F_1	10	10	-	-	-	-	10		-	-	-
	2016	F_2	40	24	6	8	2	9:3:3:1	22.5	7.5	7.5	2.5	4.95
Pusa sadabahar		B_1	48	13	6	16	13	1:1:1:1	12	12	12	12	4.5
x		B_2	48	48	-	-	-	1:0:0:0	48	-	-	-	-
CMS 6 B		P_1	10	-	-	-	10	-	-	-	-	10	-
(Clustered x Soliatry)		P_2	10	10	-	-	-	-	10	-	-	-	-
		F_1	10	10	-	-	-	-	10		-	-	-
	2017	F_2	80	43	18	16	3	9:3:3:1	45	15	15	5	1.56
		B_1	80	25	21	20	14	1:1:1:1	20	20	20	20	3.1
		B_2	50	50	-	-	-	1:0:0:0	50	-	-	-	-
Heterogenity χ^2 for fruits node $^{-1}$ @ 1df											1.34 (2016)		0.30 (2017)
Hetrogenity χ^2 for fruit orientation @ 1 df											1x10^{-1}(2016)		0.08 (2017)

B_2) based on bi-allelic monogenic inheritance was examined using χ^2 test.

Joint segregation : Linkage / independent segregation of genes controlling fruit orientation and number fruits node^{-1} was examined by testing the goodness of fit of observed segregation for combination of fruiting habit traits - SE, SP, CE and CP with that expected (9SP:3SE:3CP:1CE) based on their independent inheritance, in the two crosses (UA × PJ and PS × CMS 10B) which differed for both the fruiting habit traits. The heterogeneity χ^2 test was performed to confirm the goodness of fit between observed and expected fruiting pattern of segregation of the two fruiting habit traits based on pooled data.

Results and discussion

Inheritance of number of fruits node^{-1}

The F_1 plants of the four types of crosses which are contrasting for number of fruits node^{-1} produced solitary fruits suggesting dominance of solitary over cluster fruiting habit (Table III). Good agreement between observed and expected segregation of F_2 (3S:1C), B_1 (1S:0C) and B_2 (1S:1C) generations of all the four types of crosses confirmed the dominance of solitary over clustered fruiting habit, besides indicating bi-allelic monogenic inheritance of number fruits node^{-1}. These results are in agreement with those of Gopalakrishnan *et al.* (1989).

Inheritance of orientation of fruits

The F_1's of UA × PJ and PS × CMS 6B derived from parents contrasting for orientation of fruits produced pendant fruits, suggesting dominance of pendant over erect fruiting habit. The good fit of observed segregation with that of the expected (3P:1E in F_2, 1P:0E in B_1 and 1P:1E in B_2 generations) confirmed the dominance of pendant over erect fruiting habit besides, suggesting bi-allelic monogenic inheritance of fruit orientation (Table IV). Dhamayanthi and Reddy (2001) also reported bi-allelic monogenic control of fruit orientation in chilli.

Joint segregation of fruiting habit traits

A good agreement between observed joint segregation of number of fruits node^{-1} and orientation fruits in F_2, B_1 and B_2 generations derived from the crosses UA × PJ and PS × CMS 6B involving parents which differed for both number of fruits node^{-1} and their orientation with that expected (9SP:3SE:3CP:1CE in F_2, 1SP:0SE:0CP:0CE in B_1 and 1SP:1SE:1CP:1CE in B_2) suggested independent segregation of genes controlling the two fruiting habit traits. These results are expected to have strategic importance in chilli breeding research. Non-linkage of genes controlling number of fruits node^{-1} and orientation of fruits clearely suggest possibility of developing chilli cultivars with any desired combination of fruiting habit traits (Table V).

Further, both, number of fruits node^{-1} and orientation of fruits being simply inherited and easily assayable using visual assessment could be used as diagnostic descriptor traits for identifying and eliminating duplicates and maintaining the identity of germplasm accessions, identification of true hybrids, and establishing distinctness, uniformity and stability of cultivars, a prerequisite for protecting intellectual property rights associated with the development of cultivars.

Solitary fruits node^{-1} and pendant fruit orienation are dominant over clustered fruiting and erect fruit orientation, respectively. Fruiting habit traits, number of fruits at a node (solitary *vs*. clustered) and orientation of fruits (pendant *vs*. erect) are each controlled by single bi-allelic un-linked genes.

References

Bosland, P. W., Bailey, A. L. and Iglesias-olivas, 1996, *Capsicum pepper varieties and classification*. New Mexico Cooperative Extension Service Circle, Las Cruces New Mexico, pp. 530.

Dhamayanthi, K. P. M. and Reddy, V. R. K., 2001, Transfer of clustered and upright fruit characters into two popular chilli cultivars of Tamil Nadu. *J. Spices Aromatic Crops,* **10** (1) : 41 - 43.

Ghasemnezhad, M, Sherafati, M. and Payvas, G. A., 2011, Variation in phenolic compounds, ascorbic acid and antioxidant activity of five coloured bell pepper (*Capsicum annuum*) fruits at two different harvest times. *J. Functional Foods,* **3** : 44 - 49.

GONZALEZ, M. AND BOSLAND, P., 1991, Strategies for stemming genetic erosion of Capsicum germplasm in the Americas. *Diversity*, **7** : 52 - 53.

GOPALAKRISHNAN, T. R., GOPALAKRISHNAN, P. K. AND PETER, K. V., 1989, Inheritance of Clusterness and Fruit Orientation in Chilli (*Capsicum annuum* L.). *Indian J. Genet.*, **49** (2) : 219 - 222.

KIM, S., PARK, M., YEOM, S. I., KIM, Y. M., LEE, J. M., LEE, H. A., SEO, E., CHOI, J., CHEONG, K., KIM, K. T. AND JUNG, K., 2014, Genome sequence of the hot pepper provides insights into the evolution of pungency in Capsicum species. *Nature Genet.*, **46** (3) : 270.

LEE, J. M., NAHM, S. H., KIM, Y. M. AND KIM, B. D., 2004, Characterization and molecular genetic mapping of microsatellite loci in pepper. *Theor. Appl. Genet.*, **108** : 619 - 627.

POULOS, J. M., 1992, Problems and progress of chilli pepper production in the tropics. *In* : Hock C. B., Hong, L.W., Rejab, M., Syed, A. R., editors. *Proc. Conference on Chilli Pepper Production in the Tropics*. Malaysia: Kuala Lumpur, pp. 98 - 129.

www.indiaspices.com/sites/default/files/major%20spice%20vise%20area%20and%20production%202017%20web.pdf.

(*Received :* May, 2018 *Accepted :* June, 2018**)**