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Short Communication

Inheritance of parthenocarpy in gynoecious cucumber (*Cucumis sativus* L.) cultivar PPC-2

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ABSTRACT

The gynoecious and parthenocarpic inbred line, Pant Parthenocarpic Cucumber-2 (PPC-2) was crossed with Indian monoecious and non-parthenocarpic cultivar Pusa Uday to develop F_1, F_2, B_1 and B_2 to determine the inheritance of parthenocarpy.The crop was grown under insect proof net house of 40 mesh. The pistillate buds were covered using butter paper bags before anthesis to prevent out-crossing.The observations were recorded separately for the development of early parthenocarpic fruits (*i.e.*1-7th nodes), late parthenocarpy (8th and above nodes) and non-parthenocarpic fruits. In F_1 generation, out of 40 plants screened, 2 plants produced parthenocarpic fruits at lower nodes (1-7th nodes), 37 plants produced parthenocarpic fruits at upper nodes (8th and above), whereas,only 1 plant that did not produced any fruit was considered as non-parthenocarpic. The segregation of F_2 population and test crosses for parthenocarpic fruit development suggested that parthenocarpy in gynoecious and parthenocarpic cucumber line PPC-2 is under the control of incomplete dominant gene.

Keywords: Inheritance, parthenocarpy, gynoecious, cucumber

INTRODUCTION

Cucumber (*Cucumis sativus* L., 2n = 2x = 14) is an important valuable vegetable of Cucurbitaceae family. It is originated in India (Sebastian *et al*, 2010) from its wild progenitor *Cucumis sativus* var. *hardwickii* R., which is still found in southern foothills of Himalayas. It is primarily cultivated for tender fruits, which are used as salad, pickles and *rayata* preparation. In India, cucumber is cultivated from higher altitude to plains under open field as well as under protected conditions. The cultivated cucumber has narrow genetic base with 3-8% polymorphism within the cultivated genotypes, and 10-25% between botanical varieties (Behera *et al*, 2011). India being considered the home of cucumber possesses a vast range of genetic diversity and variability for both growth and fruit characters, but this diversity has not been fully utilised for its genetic improvement. The development of gynoecious varieties with parthenocarpic traits has become major challenge to the cucumber breeders for use as a parent in F_1 hybrid development for achieving higher yield, earliness, uniformity and suitability for protected cultivation (Jat *et al*, 2015, 2016, 2017). Therefore, there is an important need to develop gynoecious hybrids with parthenocarpic traits, which may be utilized on commercial scale, especially in the north Indian plains because most of Indian cucumber cultivars are monoecious with non-parthenocarpic trait. Therefore, these varieties are not suitable for growing under protected conditions as these require pollination for fruit set. Gynoecy coupled with parthenocarpic cucumber is a yield and quality-related parameter and a high value vegetable crop immensely suited for off season cultivation under protected condition because parthenocarpic varieties do not require pollination for fruit setting. Moreover, the fruits are mild in flavour, seedless and have thin skin that does not require peeling. Plant growth regulators also regulate the parthenocarpic trait and its stability is significantly influenced by environmental factors. It is a complex physiological process that can be influenced by environmental, physiological and genetic factors. Some studies indicated that low temperature, light and

exogenous hormone could induce parthenocarpy. However, the genetic mechanism of parthenocarpy in cucumber is still unclear. The information about genetics of parthenocarpy is utmost important for efficient breeding procedure to be used for the development of stable parthenocarpic lines. Keeping in view all above facts and realizing the importance of cucumber as an important vegetable crop for protected cultivation, it was felt crucial to conduct an experiment for inheritance of parthenocarpy in cross of gynoecious parthenocarpic line with Indian monoecious non-parthenocarpic line.

The gynoecious line PPC-2 (used as a female parent for source of parthenocarpic gene) was crossed with monoecious and non-parthenocarpic line Pusa Uday (used as male parent) to develop F_1 hybrid during August-November, 2012. The resulting F_1 generation of the cross PPC-2× Pusa Uday was selfed to obtain F_2 seeds and pollinated simultaneously with P_1 (PPC-2) and P_2 (Pusa Uday) to generate backcross generations, B_1 and B_2, respectively, during August-November, 2013. The seed material of all segregating and backcross generations (F_2, $B_1$and B_2) including parental lines and F_1were sown in plug trays using soil less media *i.e.* coco-peat, vermiculite and perlite in 3:1:1 ratio. The seedlings at three leaf stage were transplanted in insect proof net-house of 40 mesh size during March-June, 2014 at the Research Farm, Centre for Protected Cultivation Technology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India. All plants of segregating generations (F_2, B_1 and B_2) along with parents and F_1 hybrids were tagged and numbered after transplanting for their individual identity for parthenocarpic fruit development. The F_2 population comprising 213 plants were used for genetics of parthenocarpy in background of gynoecious and parthenocarpic inbred line PPC-2.

The female flowers were covered with butter paper bag one day prior to anthesis to maintain isolation. The fruit set and development were examined after at 7 to 8 days after flower opening. The number of parthenocarpic fruits developed and total number of female flowers labelled per plant were counted. Observations were recorded for development of parthenocarpic fruits up to 25th nodes. Plants that produced parthenocarpic fruits up to 25th node were considered as parthenocarpic plants. Observations were recorded separately for early parthenocarpy (1-7th node), late parthenocarpy (8th and above node) and non-parthenocarpy.

The goodness of fit of the observed segregation ratio for the segregation of parthenocarpic and non-parthenocarpic plants was tested using the classical Chi-square (χ-^{2}) test as suggested by Panse and Sukhatme (1985). The χ-^{2} value was calculated using the formula given below.

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

The test of significance is judged when the computed χ^2 statistic exceeds the critical value in the table for a 0.05 probability level, then we can reject the null hypothesis of equal distributions and then it is revealed that the observed values are the same as the theoretical distribution.

Parthenocapy is an important yield related trait in cucumber, especially in protected cultivation. In the present study, an attempt was made to consign the inheritance of parthenocarpy on classical dominant-recessive Mendelian model by keeping the cucumber fruits only in three categories of their fruit development *i.e.* early parthenocarpic, late parthenocarpic and non-parthenocarpic fruit development.

The development of parthenocarpic fruit in 'Pant Parthenocarpic Cucumber-2 (PPC-2)' is taking place from the beginning at the lower nodes from the base of the plant (early parthenocarpy). Therefore, 'PPC-2' was considered as a homozygous genotype for parthenocarpic fruits development. The variety Pusa Uday was monoecious and produced non-parthenocarpic fruits and it was considered to be homozygous for non-parthenocarpic fruit development. The F_1 hybrid derived from the cross of PPC-2 × Pusa Uday with heterozygous condition produced some parthenocarpic fruits on the lower nodes *i.e.*5-7th node and above 8th node, were considered as late parthenocarpic fruits. In F_1 generation, most of the plants produced parthenocarpic fruits but some plants that did not set any fruit were considered as non-parthenocarpic fruit. In segregating F_2population, early, late and non-parthenocarpic plants were recorded. Out of 213 plants, 170 produced as early and late parthenocarpic fruits where as 43 as non-parthenocarpic fruits. The χ^2 value indicated a good fit for segregation of parthenocarpy (early, late and non-

parthenocarpy) in the F_2 population and backcrossed populations confirmed with the expected ratio of 1:2:1 and 1:1, respectively **(Table1).** Therefore, the genotypes for inbred line PPC-2 representing parthenocarpy, non-parthenocarpy and late parthenocarpy phenotypes were considered as *PP, pp* and *Pp,* respectively. These data support that parthenocarpic trait in cucumber is controlled by single incompletely dominant gene, as suggested by Pike and Peterson (1969). They had used a parthenocarpic monoecious variety and a non-parthenocarpic gynoecious line as parents, whereas in our study, gynoecious parthenocarpic and monoecious non-parthenocarpic inbred lines were used as parents. Average first fruiting node in segregating generation was observed at the 5thnode. Rudish *et al* (1977) also suggested that the degree or intensity of parthenocarpy could be measured by both the earliness of fruiting and the total number of parthenocarpic fruits. The segregation for parthenocarpic fruits observed in F_2 population of PPC-2 × Pusa Uday is shown in **Fig.1.** These data support that parthenocarpic trait in cucumber is controlled by single incompletely dominant gene, as suggested by Pike and Peterson (1969). Exploring the parthenocarpic trait for development of high yielding cultivars and F_1 hybrids suitable for protected cultivation is one of the current priority areas of cucumber breeding.The breeding procedure for development of parthenocarpic varieties in cucumber is not well understood because of the complexity in nature of inheritance and involvement of physiological factors for parthenocarpic fruit development(Wu *et al*, 2016). In cucumber, parthenocarpic mutants have been largely used to breed cultivars suitable for greenhouse cultivation. It was also clear that parthenocarpy trait is genetically controlled, but there is some argument regarding the number of genes and type of gene action involved in development of parthenocarpic fruits. Parthenocarpy in cucumber is controlled by an incomplete dominant gene *P* (Pike and Peterson, 1969; Kim *et al*, 1992). In the homozygous condition *PP* develops early parthenocarpic fruits generally at fifth node. In the heterozygous condition *Pp* produce parthenocarpic fruits later than homozygous plants and small in numbers. In homozygous condition recessive *pp* develops non-parthenocarpic fruits. Single recessive gene might be responsible for the expression of parthenocarpy in cucumber (Juldasheva, 1973) or many incompletely recessive genes control parthenocarpy (Kvasnikov *et al*, 1970). The study of F_3 population showed that more than five genes are involved in parthenocarpy, whereas growing environmental conditions and epistatic interactions significantly influence the expression of this trait (Sun *et al*, 2006 a and b) and two additive-dominant epistatic major genes and additive-dominant polygenes (Li *et al*, 2012). Thus, the parthenocarpic line PPC-2 could be utilized for development of light green parthenocarpic cucumber lines using pedigree method of breeding (hybridization followed by selection of pure homozygous parthenocarpic lines).

It was revealed from the present study that parthenocarpy in cucumber particularly in gynoecious and parthenocarpic lines PPC-2 is governed by incomplete dominant gene. This study has to be

Table 1. Segregation for parthenocarpy in cucumber

Generations	Number of plants	Early parthenocarpic (1-7th nodes)		Late parthenocarpic (8th and above nodes)		Non-parthenocarpy		Expected ratio	Chi-square	P-value
		Observed	Expected	Observed	Expected	Observed	Expected			
PPC-2 (P_1)	40	40	40	-	-	-	-	-	-	-
Pusa Uday (P_2)	40	-	-	-	-	40	40	-	-	-
PPC-2 × Pusa Uday (F_1)	40	2	-	37	40	1	-	-	-	-
PPC-2 × Pusa Uday (F_2)	213	49	56	121	105	43	52	3:1	0.94	0.23
(PPC-2 × Pusa Uday) × PPC-2 (B_1)	40	23	20	17	20	-	-	1:1	-	-
(PPC-2 × Pusa Uday) × Pusa Uday (B_2)	40	-	-	24	22	16	18	-	-	-

Fig. 1. Phenotypic evaluation of parthenocarpic and non-parthenocarpic parental genotypes, F_1 and F_2 population (PPC-2 × PusaUday) of cultivated *Cucumis sativus* for parthenocarpy, (a) parthenocarpic fruit of PPC-2, (b) non-parthenocarpic fruit of Pusa Uday, (c) parthenocarpic fruits of F_1 of PPC-2 × Pusa Uday, (d-f) showing segregation for parthenocarpy in F_2 population, (d) early parthenocarpic fruit development, (e) late parthenocarpic fruit development, (f) seeded fruit (after pollination).

continued further by employing more number of populations in different cross-combinations and plants in segregating population in different environment and locations and confirmation of genetics for this trait would be required in other potential parthenocarpic lines. This information would facilitate the adoption of appropriate breeding strategies for the development of Indian stable parthenocarpic cucumber lines and will improve the efficiency of selection procedures.Therefore, the information generated on inheritance of parthenocarpy from this study would be of immense importance in the context of developing parthenocarpic cultivars/hybrids in Indian cucumber suitable for protected cultivation.

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