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INHERITANCE OF GYNOECISM IN CUCUMBER (*Cucumis sativus* L.) USING GENOTYPE GBS-1 AS GYNOECIOUS PARENT

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The inheritance pattern of gynoecious sex expression in cucumber was studied by utilizing a gynoecious line (GBS-1) and two monoecious lines (Pusa Uday and Punjab Naveen). Crosses were made between gynoecious line (GBS-1) and monoecious lines (Pusa Uday and Punjab Naveen). The F_1 and F_2 population along with parental lines were evaluated to study the inheritance of this trait. All F_1 hybrids showed gynoecious sex in both crosses and in the F_2 generation, the observed distribution of plant phenotypes fitted the expected mendelian ratio of 3 (gynocious plant) : 1 (monoecious plant). The segregation of plant sex types suggested monogenic dominant control of gynoecious sex form in cucumber using genotype GBS-1 .

Key words: Cucumber, Gynoecious sex, Inheritance

INTRODUCTION

Cucumber (*Cucumis sativus* L.; $2n = 2x = 14$) is a very important vegetable crop of the world. The plant has three types of flowers: male, female, and bisexual. Cucumber and melon have long served as the primary model systems for sex determination studies due to their diverse floral sex types (TANURDZIC and BANKS, 2004). At the early stages of development, the flower buds of cucumber plant also contain primordia of both stamen and pistil, and sex determination occurs due to the selective arrest of development of either the staminate or pistillate primordia just after the bisexual stage (KATER *et al*., 2001). Sex determination occurs in flower buds situated at 10–12 nodes below the apical meristem irrespective of the age of the plant (SAITO *et al.,* 2007). The sex

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form (e.g., gynoecious or monoecious) and intensity of sex expression is important in commercial cucumber cultivars, since sex form and flowering have direct effect on date of harvesting and productivity of this crop. The potentiality in cucumber for development of tropical gynoecious hybrids was also demonstrated by MORE (2002). The predominant sex form in bitter melon (*Momordica charantia* L) is monoecious (BEHERA, 2004) however, gynoecious sex form has been reported from India (BEHERA *et al.*, 2006). Using gynoecious as one parent shows very high percentage of pistillate flowers and have high yield potential in bitter gourd (BEHERA *et al.*, 2006). Although cucumber plant is originally monoecious, the distribution of three flower types on the plant could result in seven sex types of cucumber plants (LIU *et al*., 2008): androecious (only male flowers), gynoecious (only female flowers), monoecious (male flowers at the base and female flowers at the top of the main stem), hermaphroditic (only bisexual flowers), andromonoecious (male and bisexual flowers), gynomonoecious (female and bisexual flowers), and trimonoecious (male, female, and bisexual flowers). There are three genes, *F*, *M*, and *A* are control the sex expression in cucumber plant. The *F/f* gene regulates the degree of female flower expression, whereas the *M/m* gene controls bisexual flower expression (YAMASAKI *et al.,* 2001; MIBUS and TATLIOGLU, 2004; LI *et al.,* 2008; LI *et al.,* 2009). The *F* locus influences the degree of femaleness (*FF*>*Ff*>*ff*), while the *M* locus determines whether flowers are unisexual (*M_*) or bisexual (*mm*). The *A* locus conditions increased male tendency if a plant is homozygous recessive *aa* and *ff*. Interactions between these loci yield the basic sex types found in cucumber (STAUB et *al*., 2008). Dominance of gynoecy over monoecy gave rise to a situation where F_1 plants were found to be highly productive. Sex expression in cucurbit species can be regulated by plant hormones and environmental factors (TANURDZIC and BANKS, 2004). The present investigation was carried out to study the inheritance of gynoecism in cucumber by utilising a gynoecious line GBS-1.

MATERIALS AND METHODS

Crossing of one gynoecious line (GBS-1, Figure-1) with two monoecious lines (Pusa Uday and Punjab Naveen) was carried out at vegetable research farm of Indian Agricultural Research Institute, New Delhi. The gynoecious line is being maintained using silver thiosulfate @ 200 ppm. The F_1 (GBS-1 × Pusa Uday and GBS-1 × Punjab Naveen) progeny was selfed to obtain the F_2 generation. All pollinations were made by hand. Seeds of the parental lines, F_1 and F_2 were sown during and March-June, 2011. The number of plants tested for each generation was 20 in each of parents and F_1 and 80 plants of F_2. Seeds were sown on the side of the channel in a well prepared hill, with a spacing of 1.5 m between channels and 60 cm between hills. All the recommended agronomic package of practices along with plant protection measures was followed to raise a successful crop of cucumber. Plants from each generation were evaluated for sex expression at full flowering stage. Based on flowering habit, individual F_2 plants were classified as gynoecious or/monoecious. Chi-square analysis was made to assess the null hypothesis. This test takes into account the observed deviation in each component of an expected ratio as well as the sample size and reduces them to a single numerical value. The value of χ^2 is March-June, 2010 then used to estimate how frequently the observed deviation can be expected to occur strictly as a result of chance. The total number of F_2 plants both in monoecious and gynoecious categories were counted and subjected to chi-square analysis for goodness of fit to various classical Mendelian ratios as suggested by PANSE and SUKHATME (1985).

Figure1. Gynoecious line GBS-1

RESULTS AND DISCUSSION

Floral induction and differentiation is perhaps the most important developmental transition in the life cycle of higher plants, and it is also a step that directly affects the agricultural yield by determining the time of flowering, the number of flowers and fruits, as well as the diversion of resources from vegetative growth (TEREFE and TATLIOGLU, 2005). In young floral buds of cucumber, both stamen primordia and carpel primordia are initiated, and sex determination occurs just after the bisexual stage; subsequently, male or female flowers are formed and enlarged owing to the selective arrestment of carpel or stamen development, respectively (BAI *et al*., 2004). Cucumber is a very important vegetable worldwide.

In this experiment, all the F_1 plants of the cross were gynoecious, showing that gynoecy is dominant over monoecy. Further, the F_1 plants of (GBS-1 × Pusa Uday) were selfed to generate F_2 to determine the inheritance of gynoecy in GBS-1. Out of 80 F_2 plants screened, 66 plants showed gynoecy and 14 plants showed monoecy. χ^2 analysis revealed a perfect fit to 3:1 (gynoecious *vs.* monoecious) Mendelian segregation ratio (2.40), P = 0.12 (Table 1). This experiment suggested that gynoecism was under the control of single dominant gene when GBS-1 used as gynoecious line. In another case (GBS-1 × Punjab Naveen) all F_1 plants showed gynoecy, and out of 80 F_2 plants, 64 showed gynoecy and 16 showed monoecy. This result also perfectly fit to 3:1 (gynoecious *vs.* monoecious) Mendelian segregation ratio (1.07), P = 0.30 (Table 2). Thus, this finding also showed gynoecy in GBS-1 is monogenic dominant in nature. Similar type of result was found in chilling resistance in cucumber seedlings (KOZIK *et al.,* 2008).

Table 1. Chi square (χ^2) analysis of F_2 population for studying inheritance pattern of gynoecism in GBS-1 × Pusa Uday

Generation	Total number of plants	Observed ratio		Expected ratio	χ^2-value	P- value
		GP	MP			
GBS-1	20	20	-	-	-	-
Pusa Uday	20	-	20	-	-	-
GBS-1 × Pusa Uday (F_1)	20	20	-	-	-	-
GBS-1 × Pusa Uday (F_2)	80	66	14	3:1	2.4	0.12

GP: Gynoecious plants, MP: Monoecious plant

Table 2. Chi square (χ^2) analysis of F_2 population for studying inheritance pattern of gynoecism in GBS-1 × Punjab Naveen

Generation	Total number of plants	Observed ratio		Expected ratio	χ^2-value	P- value
		GP	MP			
GBS-1	20	20	-	-	-	-
Punjab Naveen	20	-	20	-	-	-
GBS-1 × Punjab Naveen (F_1)	20	20	-	-	-	-
GBS-1 × Punjab Naveen (F_2)	80	64	16	3:1	1.07	0.30

GP: Gynoecious plants, MP: Monoecious plants

CHEN *et al.,* (2011) observed that gynoecicm was controlled by one pair of recessive gene and one pair of incompletely dominant gene by using two subgynoecious (only female flower at later stage) inbred lines (97-17 and S-2-98), which were designated presently as *mod-F2* and *Mod-F1*, respectively. Furthermore, the *mod-F2* and *Mod-F1* loci, which enhance the intensity of femaleness, also inherited independently with *F* and *M* genes. They indicated that the *Mod-F1* and *mod-F2* are two novel subgynoecious genes for enhancing the intensity of femaleness, and it would be very interesting to further study the sex-determining genes, enrich the genetic map of cucumber plant and breed the subgynoecious varieties with utilization of heterosis.

The gynoecious line GBS-1 showed lowest node number of first female flower and the hybrids GBS-1× Pusa Uday and GBS-1 × Punjab Naveen had female flower at lower node (Table 3). DIJKHUIZEN and STAUB (2002) reported that gynoecious cucumber hybrids are typically early flowering and possess a concentrated fruit set. A positive correlation (r = 0.24–0.40) was observed with the number of females nodes on lateral branches and total fruit per plant (FAZIO 2001; FAN *et al.,* 2006). The gynoecious line, GBS-1 took only 40.09 days for first female flower anthesis and 48.77 days for first fruit harvest and was considered as the best parent. The combinations GBS-1 × Punjab Naveen and GBS-1 × Pusa Uday produced early fruits (around 48 days) compared to other hybrids (Table 3). More fruits per plant were produced by parents GBS-1 followed by Pusa Uday and Punjab Naveen. The hybrids GBS-1 × Pusa Uday and GBS-1× Punjab Naveen produced more fruits per plant (Table 3). HAYES and JONES (1916), reported the first generation crosses in cucumber frequently exhibit high parent heterosis due to increased fruit size and fruit number per plant. Fruit length and diameter are also important attributes to determine yield besides purpose of use and means of handling. Longest fruit was found in parent, Pusa Uday followed by Punjab Naveen whereas, among hybrids, GBS-1 × Pusa Uday had longest fruit, followed by GBS-1 × Punjab Naveen. Individual fruit weight was highest in Pusa Uday, followed by Punjab Naveen and DC-1-1 and among the hybrids, GBS-1 × Pusa Uday produced heavier fruit (161.74g; Table 3), followed by GBS-1 × Punjab Naveen. All the combinations with gynoecious line as female were proved to be excellent in this respect. The top performing hybrids for productivity were GBS-1 × Pusa Uday and GBS-1 × Punjab Naveen.

Table 3. Performance of parental lines and F_1 hybrids with gynoecious parent (GBS-1) in cucumber

Parents/ Crosses	NNOFFF	DFFFA	DFFH	NFPP	FL (cm)	FD (cm)	AFW (g)	Yield (g)
GBS-1	3.44^{e*}	40.09^{fg}	48.77^{e}	8.94^{cde}	11.81^{f}	3.80^{e}	120.50^{g}	1078.02^{efgh}
DC-319-B	4.94^{c}	45.47^{bcd}	55.06^{abcd}	5.55^{f}	16.33^{bc}	4.63^{abcd}	175.19^{bcd}	975.79^{fgh}
GS-4	5.03^{bc}	46.69^{abc}	55.22^{abcd}	5.25^{f}	16.25^{bcd}	4.87^{abc}	170.83^{cde}	900.00^{gh}
DC-1-1	5.24^{abc}	47.42^{abc}	56.73^{abc}	5.93^{f}	16.69^{abc}	5.04^{ab}	183.50^{abc}	1086.71^{defgh}
Pusa Uday	5.41^{a}	50.72^{a}	58.45^{ab}	6.72^{def}	18.53^{a}	5.28^{a}	201.33^{a}	1368.44^{cdefg}
Punjab Naveen	5.36^{a}	49.86^{ab}	59.98^{a}	6.38^{ef}	17.74^{ab}	5.13^{ab}	193.78^{ab}	1229.65^{cdefgh}
LOM-404	5.21^{abc}	44.04^{cdef}	54.44^{bcd}	5.25^{f}	15.15^{cde}	5.00^{ab}	182.86^{abc}	853.83^{h}
7206-B-76	5.28^{ab}	44.98^{cde}	56.96^{abc}	6.41^{ef}	15.18^{cde}	4.03^{de}	159.41^{def}	966.60^{fgh}
GBS-1 × DC-319-B	3.88^{d}	41.63^{defg}	50.67^{de}	10.31^{c}	14.16^{e}	4.29^{cde}	153.26^{ef}	1580.40^{c}
GBS-1 ×GS-4	3.97^{d}	41.66^{defg}	51.36^{de}	10.37^{c}	14.34^{de}	4.49^{bcde}	150.79^{ef}	1561.12^{cd}
GBS-1 × DC-1-1	3.77^{d}	42.73^{cdefg}	52.14^{cde}	10.98^{bc}	14.36^{de}	4.45^{bcde}	153.07^{ef}	1680.11^{bc}
GBS-1 ×Pusa Uday	3.35^{e}	38.71^{g}	48.75^{e}	14.08^{a}	15.34^{cde}	4.80^{abc}	161.74^{def}	2277.11^{a}
GBS-1 × Punjab Naveen	3.38^{e}	39.41^{fg}	48.07^{e}	13.41^{ab}	14.99^{cde}	4.71^{abcd}	157.56^{def}	2113.37^{ab}
GBS-1× LOM-404	3.87^{d}	40.70^{efg}	51.96^{cde}	9.19^{cd}	13.94^{e}	4.57^{bcd}	152.47^{ef}	1401.05^{cdef}
GBS-1 ×7206-B-76	4.05^{d}	40.85^{defg}	52.51^{cde}	10.50^{c}	13.98^{e}	4.03^{de}	143.45^{f}	1506.74^{cde}
Tukey's HSD (p=0.05)	0.29	4.73	5.01	2.74	1.96	0.69	20.20	482.52

*Letter groupings on the superscript in each cell are based on Tukey's HSD (Honestly Significant Difference)

NNOFFF: Node number of first female flower, DFFFA: Days to first female flower anthesis, DFFH: Days to first fruit harvest, NFPP: Number of fruits per plant, FT: Fruit length, FD: Fruit diameter, AFW: Average fruit weigh, The potential use of gynoecy in increasing cucumber yield was studied by several workers. Moderate to highly significant positive correlations (r) between per cent pistillate nodes and yield were also identified in cucumber suggesting sex expression has potential for increasing yield through indirect selection (CRAMER and WEHNER, 2000). In bitter gourd BEHERA *et al.,* (2009) recorded a substantial increase in female flowers, number of fruits per plant, and yield per plant in (gynoecious × monoecious) hybrids. Gynoecious hybrids of bitter gourd have high potential for commercial cultivation with respect to yield and earliness (DEY *et al.,* 2010). The gynoecious line GBS-1 holds on immense potential in future breeding programmes for improving yield and earliness in cucumber. GBS-1 × Pusa Uday and GBS-1 × Punjab Naveen can also be exploited for increasing the yield in cucumber.

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ISPITIVANJE NASLEĐIVANJA GINECIUMA KOD KRASTAVCA (*Cucumis sativus* L.) KORIŠĆENJEM GENOTIPA GBS-1 KAO ŽENSKOG RODITELJA

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Izvod

Nasleđivanje ekspresije ženskog pola (tučka) kod krastvca je ispitivano korišćenjem ginecijum linije (GBS-1) i dve linije koje na istoj biljci imaju i muške i ženske cvetove (Pusa Uday i Punjab Naveen). Vršeno je ukrštanje GBS-1 linije sa navedene dve linije sa cvetovima oba pola. Vršena su istovremena ispitivanja F_1 i F_2 populacija i roditeljskih linija. Svi F_1 hibridi su bili ženskog pola u oba ukrštanja a u F_2 generaciji distribucija fenotipa biljaka odgovaraju mendelovom odnosu segregacije 3:1 (3 ženske biljke i jedna sa dvoplonim cvetovima). Segregacija tipa pola biljaka ukazuje na monogensku dominantnu kontrolu pola kod krastavca u GBS 1 liniji.

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