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Impact of Breeding Hermaphroditic Melon on Early Production and Yield: Case of Snake Melon (*Cucumismelo* var. *flexuosus*) and Tibish (*C. melo* var. *tibish*)

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Abstract

Melon sex types are monoecious, andromonoecious, gynoecios or hermaphrodite. Monoecious is dominant (*AG*) and hermaphrodite is double recessive *(ag*). Hermaphrodite 'Paul' accession from India crossed with snake melon (monoecious) and tibish (andromonoecious) to transfer hermaphroditic character into both types of melon. F1 progenies of monoecious with hermaphrodite were monoecious, in F2 segregation ratio of 9 monoecious: 3 and romonoecious: 3 gynoecious: 1 hermaphrodite was obtained. But in cross of and romonoecious with hermaphrodite and romonoecy was dominant in F1 and ratio of 3 and romonoecious: 1hermaphrodite were obtained indicated that hermaphrodite is recessive to andromoney. Production of hermaphrodite melon is possible through successive selfing progenies of the crosses. Hermaphrodite lines obtained from these crosses exceeded their parents in earliness and number of fruits/plant.

Keywords

Hermaphrodite, Monoecious, Melon, Sex Expression, Melon Production

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1. Introduction

Most species in the genus *Cucumis* are monoecious although some are dioecious[1]. In melon (*Cucumismelo* L.), 60 to 70% cultivated melons are and romonoecious but wild melons are monoecious. Monoecism is found mainly in the *flexuosus*, *acidulus*, *chate* and *momordica* groups. And romonoecism is controlled by a single recessive gene [2], which was first named *monoecious* gene (symbol M) and now is and romonoecious gene (symbol *a*). Another phenotype, hermaphroditism, has been found in very few accessions. Poole and Grimball [3] studied the genetic control of sex expression in melons and they concluded that there is a recessive gene named *gynoecious* (symbol *g*), independent from gene *a* and the interaction between the two loci is as follows: *A G*monoecious, *Ag*gynoecious, *a G*andro monoecious and *ag* hermaphrodite. In tibish melon two linked genes (*A-2* and *A-3*) were involved in the loci of and romonoecy*a/A*[4]. Production hermaphroditic plants are necessary to use plants of sex types that enable self-pollination. However, many dicotyledonous plants, and in particular Cucurbitaceae, may be monoecious, and romonoecious, gynoecious or hermaphroditic. In cucumber, gynoecious plants were used for hybrid production and the fruits developed without fertilization in term of parth enocarpy, but this phenomenon not reported in melon. The

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implementation means for producing hermaphroditic is possible by conducting chemical treatments to plants, so plants get the ability for self-pollination. In melon, for example, spraying of ethylene inhibitors such as silver nitrate or silver thiosulfate enhances stamens in female flowers [5], [6]. In melons female or perfect flowers are appeared at the first and second nodes of the lateral branches in one-flowered sometimes two-flowered inflorescences in monoecious or and romonoecious plants, then male inflorescences appeared in the following nodes of the lateral branches and in the main stem in multi-flowered inflorescences, but in hermaphrodite plant flowers appeared in main stem and lateral branches in one-flowered. Breeding hermaphrodite cultivars, with perfect flowers at each node on the main stem and the lateral branches, belonging to cultivate groups of melon where fruits are harvested before maturity, as in *flexuosus* or *tibish* groups, could be a possibility to increase earliness and yield. Accordingly, the aims of this study are to study the possibility of transferring hermaphroditic character into snake melon and tibish and its effects in earliness and yield production.

2. Materials and Methods

2.1. Snake Melon

Four genotypes were used in this study; three monoecious cultivars belonging to the *flexuosus* group, namely, Alimin from Sudan, PI222187 from Afghanistan and Snakemelon from Saudi Arabia and the fourth was the hermaphroditic melon accession Paul from Far-East supplied by B. Kubicki. The F_1 and F_2 progenies between the three monoecious accessions and Paul were produced by hand pollination. The evaluation of 100 plants of each F_2 progeny was conducted on young plants in pots (9 cm in diameter). The hermaphroditic plants were selected, transplanted in the greenhouse and selfed and crossed to their *flexuosus* parents to produce F_3 and BC F_2 progenies. Twenty three F_3 lines of the cross Alimin× Paul, seven F_3 lines of the cross PI222187 × Paul and thirteen F_3 lines of the cross Snakemelon × Paul were grown under field conditions at the University of Gezira farm (Sudan) during the winter season of 2006/2007. The plants were evaluated for sex type; the longest ovary plants of F_3 were selfed to produce F_4.

Bc F2 plants of each cross evaluated for sex type, then hermaphrodite plants selfed four times under field condition of Sudan and greenhouse condition of INRA during seasons 2006/07 and 2007/08 successively.

F4 plants evaluated for sex type under greenhouse condition of INRA season 2007, hermaphroditic plants crossed to their parents to produce Bc F4 progenies.

Bc F4 plants of each cross evaluated for sex type, then hermaphrodite plants selfed twice under field and greenhouse conditions of Sudan and France during 2007/08 successively.

The following BC progenies were evaluated on the bases of agronomic characteristics:

- BC F_4(Alimin× Paul) ×Alimin

- BC F_4(Snakemelon× Paul) × Snakemelon

- BC Alimin× F_2(Alimin× Paul)

These genotypes were tested for agronomic traits, in comparison with their *flexuosus* parents (Snakemelon, PI 222187, Alimin) and the popular cultivar of snake melon ‘Silka’ in Sudan, in RCBD (Randomized Complete Block Design) with 3 replications.

The parameters collected were:

- Earliness (days from sowing to the first perfect flower in the plant)
- Yield (number of fruits/plant, fruit yield/plant).

2.2. Tibish

Three accessions of tibish were used, two and romonoecious accessions collected from Kordofan region during season 2005, namely tibish JabelKordofan 4,Tibishkhurtagat 15 and a monoecious *tibish* entry collected from Managil area, Gezira State, named as tibishManagil 36, were crossed with hermaphrodite accession ‘Paul’ (hermaphrodite x andromonoecious) in 2007 under greenhouse conditions at INRA, France to produce F1 progenies of each cross.

The F1 of each cross were evaluated in Sudan 2007/2008 under field conditions and selfed to produce F2.

Thirty plants of each F2 progeny were grown in pots under greenhouse conditions at INRA, France in 2008, then evaluated for sex types. The segregated hermaphroditic plants were selected, selfed and crossed with their parent to produce F3 and BC F_2 progenies. Then, F3 and BC F2 plants seeds of each progeny were grown under field conditions of Sudan and the plants were evaluated for sex type.

The following selected genotypes were evaluated for some agronomic characteristics: BcTibishkordofan 4 x F2 (Paul x Tibishkordofan 4), BcTibishkhurtagat 15 x F2 (Paul x Tibishkhurtagat 15) and BcTibishManagil 36 x F2 (Paul x TibishManagil 36).

The lines were planted in the experiment with their tibish cultivars parents in RCBD (Randomized Complete Block Design) with 3 replications.

Parameters measured were:

- Earliness (days from sowing to the first perfect flower in the plant)

- Yield (no. fruits/plant, fruit yield/plant).

2.3. Statistical Analysis

Segregation ratios in F_2 populations were tested for goodness of fit to theoretical ratio with Chi square test, analysis of variance for RCBD was used to analyse the data according to Steele and Torrie[17].

3. Results and Discussion

3.1. Snake Melon

F_1plants of crosses between monoecious lines and hermaphroditic Paul were clearly monoecious, indicating that monoecy was dominant in these accessions. In the F_2 generation, the segregation ratio of 9: 3: 3:1 for monoecious: and romonoecious: gynomonoecious: hermaphrodite was obtained, respectively, as presented in (Table 1). In the F_2 (Aliminx Paul), the segregations ratio was significant (χ^2= 5.928 P< 0.11) but not the same as in the F_2(PI 222187 × Paul) and the F_2 (Snakemelon× Paul). In both progenies, the segregating ratios were less than 5%.In some plants, male flowers with rudimentary ovary were observed (abnormal male) which produced fruit with irregular shape (Fig. 1 and 2). The appearance and sequential of the abnormal male was similar to male flowers in the main stem and lateral branches.

Table 1. The segregating generations of F_2 plants (monoecious x hermaphrodite).

Genotype	No. of plant observed				Exp. ratio	χ^2		
	Mono	Andro	Gyno	Herm		value	df	P
F_2 (Aliminx Paul)	31	17	18	7	9:3:3:1	5.928	3	0.11
F_2 (PI 222187 × Paul)	22	5	2	5	9:3:3:1	7.621	3	0.05
F_2 (Snakemelon× Paul)	2	7	13	3	9:3:3:1	27.55	3	<0.001

Mono: monoecious, Andro: andromonoeciuos, Gyno: gynoecious, Herm: hermaphrodite

Figure 1. Female (left), hermaphrodite (middle) and abnormal male (right) flowers observed in F_2 progenies.

Figure 2. Shape of the fruit produced from abnormal male flowers.

For agronomic trials Table 2 showed the means of earliness, fruits number and fruits weight of the genotypes of BC in advanced stage of genetic purity for hermaphroditic character compared to their monoecious *flexuosus* parents. All the lines significantly exceeded the parents in earliness ($P < 0.01$), lines derived from the cross of (Alimin×Paul) produced flowers earlier (33-43 days) than those derived from the cross of Snakemelon × Paul (36-57 days). Among the 22 tested lines, only two lines, namely (BC Alimin× F_2(Alimin× Paul) *A1G3F1A* and (BC F_4 (Alimin× Paul) ×Alimin) *A1Y1A3B,* were earlier in flowering than the others (33 days). The latest line flowering was BC F_4 (Snakemelon × Paul) × Snakemelon *A1A1A1B* (57 days). The parent Snakemelon was the latest in flowering compared to other parents (66 days). The average of the parents was 53 days whereas the average of the lines was 39 days with reduction in earliness by about 26%.

Figure 3. Harvested fruits of hermaphrodite snake melon.

Fruit number exhibited significant differences among the lines and their parents ($P < 0.01$). The lines gave greater number of fruit (4-25) than the parents (2-6). The highest number of fruits was obtained from the line (BC Alimin× F_2(Alimin× Paul) *A1A1A1A,* which was 25 fruits. The lowest numbers of fruits were obtained from the parents Snakemelon, PI 222187 and Silka, which were 2 and 3, respectively. The percentage of increase in yield (fruit number) was about 275%.

There were highly significant differences in fruit weight (P <0.01) between the lines and their parents. The heaviest fruits were obtained from the parent Alimin, 1967 g (334 g/ fruit). The highest yield was obtained from the line BC Alimin× F_2 (Alimin× Paul) BC1I2 A1A1A1A which was 1817g (74 g/ fruit) and line BC Snakemelon × F_2 (Snakemelon × Paul) *A1H1A2B* gave 1700 g (107 g/fruit). The fruits produced varied in weight and in shape, which were elongated, oval and round (Fig. 3).

Table 2. The means of the days to flowering (days), number of fruits and fruit weight (fr.wt) of BC lines and their *flexuosus* parent.

Line	Pedigree	Days to flowering	No. of fruits	Fr. Wt(g)
BC Alimin x F_2 (Alimin x Paul)	A1A1A1A	38	25	1817
BC Alimin x F_2 (Alimin x Paul)	A1D1A1B	41	18	1117
BC Alimin x F_2 (Alimin x Paul)	A1D1A3A	38	11	700
BC Alimin x F_2 (Alimin x Paul)	A1D1A3B	37	7	400
BC Alimin x F_2 (Alimin x Paul)	A1D1C1B	34	4	467
BC Alimin x F_2 (Alimin x Paul)	A1G3B1A	38	9	672
BC Alimin x F_2 (Alimin x Paul)	A1G3B2A	43	6	534
BC Alimin x F_2 (Alimin x Paul)	A1G3B2B	35	16	717
BC Alimin x F_2 (Alimin x Paul)	A1G3F1A	33	7	734
BC Alimin x F_2 (Alimin x Paul)	A1G3F1B	36	13	1500
BC Alimin x F_2 (Alimin x Paul)	A1G3G1A	34	17	859
BC Alimin x F_2 (Alimin x Paul)	A1G3G1B	43	8	384
BC Alimin x F_2 (Alimin x Paul)	A1G3L2A	41	15	859
BC Alimin x F_2 (Alimin x Paul)	A1G3L2B	35	6	317
BC Alimin x F_2 (Alimin x Paul)	A1G3L3A	36	4	417
BC F_4 (Alimin x Paul) x Alimin	A1U1A3B	33	5	475
BC F_4 (Alimin x Paul) x Alimin	A1Y1A3B	33	8	783
BC F_4 (Alimin x Paul) x Alimin	A1Y1A3C	37	13	1192
BC F_4 (Snakemelon x Paul) x Snake melon	A1A1A1B	57	8	700
BC F_4 (Snakemelon x Paul) x Snakemelon	A1H1A1A	43	8	592
BC F_4 (Snakemelon x Paul) x Snakemelon	A1H1A1B	36	22.	1059
BC F_4 (Snakemelon x Paul) x Snakemelon	A1H1A2B	38	16.	1700
Alimin		55	6	1967
PI 222187		53	3	434
Snakemelon		66	2	317
Silka		58	3	384
$LSD_{0.05}$		11	4	325
C.V. %		17	20	25

3.2. Tibish

In all crosses between accessions of and romonoecious Tibish, namely (Tibish Jebel Kordofan 4 and TibishKhurtagat 15), with hermaphrodite Paul, F1 plants were entirely and romonoecious indicating that and romonoecy is dominant to hermaphrodite (Table 3).

F2 plants segregated in and romonoecious to hermaphrodite ratio of 3: 1 (X^2 =0.04 P < 0.91), indicating that and romonoecious was dominant to hermaphrodite (Table 3). All plants in F3 were hermaphrodite.

For the BC of F2 plants with their parents BC Tibish Khurtagat 15 x F2 (Paul x T. Khurtagat 15) compared to BC Tibish Kordofan 4 x F2 (Paul x T. Kordofan 4), the plants obtained were segregated in the ratio of 3 and romonoecious: 1 hermaphrodite (X^2 = 4.6 P< 0.006and X^2 =7.68 P< 0.03, respectively). High numbers of hermaphrodite plants were observed.

Table 3. Segregating generation of sex expression of F2 (hermaphrodite x andromonoecious) and their BC.

Genotype	No. Plants observed			X^2		
	andro	Herm	Exp. ratio	value	df	P
F2 (Paul x T. Kordofan 4)	23	7	3:1	0.04	1	0.91
F2 (Paul x T. Khurtagat 15)	22	8	3:1	0.04	1	0.91
BC T. Kordofan 4 x F2(Paul x T. Kordofan 4)	87	13	3:1	7.68	1	0.006
BC T. Khurtagat 15 x F2(Paul x T. Khurtagat 15)	94	46	3:1	4.6	1	0.03

For agronomic trials the Table 4 showed the means of earliness, number of fruits and fruit weight of the hermaphroditic lines derived from the crosses among hermaphrodite Paul and and romonoecious Tibish varieties. They showed no significant differences with respect to earliness. They started flowering during 34 to 57 days after sowing while the parents started flowering 40- 42 days after sowing.

Number of fruits/ plant exhibited high significant differences among the lines and their parents (P < 0.01). Line BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15 (BC1I2 A1J1A) produced a high number of fruits (19.00), similar to its parent T. Khurtagat 15 whereas line BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15 (BC1I2 A1H2C) gave a few number of fruits (2.00).

Table 4. The means of days to flowering (days), number of fruit and fruit weight (fr.wt) of the BC lines and their *tibish* parents.

Line	Pedigree	Days to flowering	No. fruits	Fr. Wt(g)
BC T. Kordofan 4 x F2 (Paul x T. Kordofan 4)	BC1I2 A1A1B	43	6	692
BC T. Kordofan 4 x F2 (Paul x T. Kordofan 4)	BC1I2 A1B1A	44	4	500
BC T. Kordofan 4 x F2 (Paul x T. Kordofan 4)	BC1I2 A1B1B	46	11	867
BC T. Kordofan 4 x F2 (Paul x T. Kordofan 4)	BC1I2 A1B2A	57	6	592
BC T. Kordofan 4 x F2 (Paul x T. Kordofan 4)	BC1I2 A1G1B	40	12	1100
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1E1A	42	7	617
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1E1B	43	7	800
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1E3B	47	6	967
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H1A	43	11	1150
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H1B	40	14	1392
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H2A	38	14	1234
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H2B	42	6	450
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H2C	49	2	283
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H3A	34	9	750
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1H3B	35	10	959
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1J1A	55	19	1617
BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15)	BC1I2 A1J1B	43	14	1875
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1C1A	43	6	359
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1C2A	40	5	325
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1C2C	48	6	450
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1C2D	47	3	309
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1F1A	56	7	684
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1G1C	51	10	967
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1G1E	47	10	850
BC T. Managil 36 x F2 (PAUL x T. Managil 36)	BC1I2 A1G1F	50	15	825
TibishKordofan 4		40	11	1967
TibishKhurtagat 15		42	19	2334
TibishManagil 36		41	7	750
LSD $_{0.05}$		Ns	5	376

Fruit weight showed significant differences between lines and their parents (P < 0.01). Heavier fruits were obtained from the parent T. khurtagat 15 (2334.00 gm), with average fruit weight of 125 gm/fruit. Among the tested lines, line BC T. Khurtagat 15 x F2 (Paul x T. Khurtagat 15 (BC1I2 A1J1B) gave the heaviest fruit weight (1875 gm), with average fruit weight of 133 gm/fruit.The sex types in Cucurbitaceae are monoecious, and romonoecious, gynomonoecious or hermaphrodite. Work on inheritance of flowering types in melon (*Cucumismelo* L.) done by many researchers [2], [3], [9], [10], [16], [18], [19]. [20], [21][22] indicated that monoecy is dominant to and romonoecy. Dominance is controlled by a single pair of alleles giving monoecious, and romonoecious, gynomonoecious and hermaphrodite in ratios of 9:3:3:1 in F_2 of the cross between monoecious and hermaphrodite plants as we revealed in this study. In tibish, and romonoecious was dominant in F1 indicating that and romonoecy was dominant to monoecy. The ratio of 3 and romonoecious: 1 hermaphrodite was obtained in F2 generation indicating that hermaphroditic was recessive to and romonoecy by a single gene [7], [11]. Recent study indicated that dominance of and romonoecy in tibish may controlled by other two linked genes involved in loci of and romonoecy[4].Cultivar Paul was the hermaphrodite accession used as a source to transfer the hermaphroditic character to *flexuosus* and *tibish*. Production of hermaphroditic lines is possible through many selfing generations. Moreover, no difference effectsin source of pollen whether from male or hermaphrodite flowers [12]. Hermaphrodite flowers appeared earlier compared to female flowers in monoeciousor hermaphrodite in and romonoecious plants. Therefore, early production and high number of fruits could be obtained, because hermaphrodite flowers always bear in the main stem and lateral branches instead of the first two nodes of lateral branches as in monoecious or and romonoecious plants. Appearance of male flowers with rudimentary ovary (abnormal male) in F_2 and F_3 generations indicated that these generations probably influenced by environmental conditions or it has modifier genes. These abnormal male flowers produced fruits with irregular shapes [10],[11]. Tendency: Flowers on the main stem of hermaphrodite plants have often a longer peduncle than flowers on the lateral branches (Figure 1). Moreover, abnormal fruits observed on the main stem compared with branches?

Tibish was domesticated recently as a melon type [13], which was different from another intra-specific melon groups[14] and considered as a source of resistance to some major diseases of melon [15]. On the other side, the inheritance of sex expression in tibish was complicated because there are two linked genes were involved in the loci of and romonoecy*a/A*[4]. Moreover, no pleiotropic effects of and romonoeciousgene '*a*'were expected on fruit shape because it will be in dominant form. More studies concerning stability of hermaphrodite and fruit quality are required.

4. Conclusions

Based on the results of this study, the production of hermaphrodite melon will be possible through successive selfing progenies of the crosses. The Hermaphrodite lines from these crosses exceeded their parents in characters of earliness and number of fruits per plant. Thus further research is needed to production of hermaphrodite melon.

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