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Assessment of Genetic Diversity and Determination of the Best Selection Indices for Genetic Improvement of Yield in Segregation Generations of Cucumber

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Abstract
In order to evaluate the amount of genetic diversity associated with total fruit yield and determining its affecting traits in two cucumber segregating populations (S_2 and S_3), 150 genotypes as 15 family, 10 plants of each family for every generation were sown in research greenhouse of Islamic Azad University, Isfahan Branch, as augment in randomized complete blocks design with three replications. Genotypes Sina, Nasim and Khasib were considered as control treatments. Toweny nine morphological, phonological and fruit weight and fruit number (on three growth stages) traits were recorded. The results of variance analysis on controls showed that blocks didn't affect on traits, significantly, and therefore didn't need to correct blocks effects. In S_2 population, the highest fruit number of each harvesting was observed in family No.2. On the other hand, average fruit number, total and average fruit weight, plant height in the middle of growth, stem diameter, total fruit number and weight in second growth period and average fruit weight in second and third growth period showed high amounts. In contrast, average fruit number of first growth period was low for this family. In S_3 population, the highest fruit number of each harvesting was belonging to family No.5 and average fruit number and fruit weight, fruit quality, average fruit weight in third growth period and fruiting period showed high amounts in this family, whereas fruit number in every node was low. Total fruit yield showed the highest correlation with total fruit number. Also, it had considerable positive correlation with average fruit number and fruit weight. In stepwise regression, when total fruit yield was considered as dependent variable and other trait were considered as independent variables, total fruit number, total and average fruit number in third growth period, average and total fruit number of second growth period explained %100 of variation in S_2 population. In S_3 population, total fruit number and node number could explain more than 98.54% of variation in dependent variable. These traits must be considered in explanation of total fruit yield variation. Pathway analysis showed that total fruit number had main direct positive effect on total fruit yield. On the other hand, fruit length and fruit diameter had indirect positive effects on total fruit yield .

Keywords: Cucumber, segregating population, correlation, stepwise regression, Pathway analysis.

1.INTRODUCTION

Cucumber is one of the old domesticated vegetables. Tatlioglu [22-24] reported that after tomato, cabbage and onion, cucumber is the fourth important vegetable. On the other hand, it's [12,13] announced that cucumber has high economical importance as a vegetable. This plant is adapted to warm season and is not resistant to cold situation. Cucumber starts its growth at temperatures above 20˚c. According to FAO reports [4], Iran is third cucumber producer country.

Success in crops breeding including cucumber depends on genetic diversity and this is one of the main bases of sustainable agriculture. On the other hand, management of diversity in segregating generations and native varieties is very important in breeding programs. The first step in plant breeding is recognition of its germplasm which depends on accurate sampling. Increasing of quality and production depends on saving and effective utilization of genetic resource [7]

Smith and lower [15] expressed that cucumber has low genetic diversity and cultivars have low diversity in traits like fruit yield. They reported that creation and development of a source population, by collecting germplasm of cultivars and breeding lines from various parts of world, will be useful. Also, using segregating populations is applicable as well as an important source of diversity. Selecting superior genotypes can be down for various breeding goals like fruit yield, fruit quality, strong vigor, good fruit shape, resistance against disease, and fruit taste in these populations. On the other hand, selection of desirable genotypes for breeding goals will be possible by studying genetic diversity. Because, starting of each breeding programs need to parents with maximum differences in traits which high genetic diversity of populations provides these goals. [16-23]

One of diversity resources is segregating populations like S_2 and S_3. Diversity can be differ in these populations; therefore the best genotypes could be selected for different desirable traits by comparing these populations. Correlation coefficients and multivariate statistical analysis including stepwise regression and pathway analysis can be used in assessment of genetic diversity and identify fruit yield affecting traits. [9-14] This study was carried out to determine the amount of correlation coefficient between total fruit yield, morphological traits and yield components. Also, determining traits with the highest

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effect on total fruit yield and calculating the amount of direct/indirect effects of other traits on total fruit yield are the other goal of this study.

2. MATERIAL AND METHOD

Segregating generations (S_2 and S_3) of two different parents [1] with different morphological properties and yield were evaluated in this study. After crossing parents, obtained seeds were sown and were self-pollinated for two consecutive generations to produce S_2 and S_3 generations. Because of parthenocarpy, gibberellin hormone (3000 ppm) was used to induce male flowers in male parent and also for self-pollination. The hormone was used in 2-4 leaves stage for three times with one week intervals. After that, obtained seeds from S_2 and S_3 generations were sown in one season. In each generation, 15 families and 10 plants in each family were evaluated. Therefore, total numbers of studied genotypes were as 150. Experiment was done in randomized complete blocks design with three replications. For measuring various traits, all plants of each generation were evaluated individually. Every experimental plot was prepared as two-row stack. In each plot, the space between and within double rows were 90 (cm) and 50 (cm), respectively, while the double rows were spaced at 180 (cm). Different fertilizers were used based on soil analysis that included: potassium nitrate, ammonium nitrate, magnesium nitrate, iron and other mineral elements such as sulphate dissolved in water. Irrigation was applied when needed. Dichlorvos, Trigard, Abamectin and organic neem oil were applied for insect control. During the growing period, the diurnal greenhouse air temperature was kept at 25-30 C° and the nocturnal one at 19-21 C° with a relative humidity of about 60%.Different traits including female flowering time , plant height (at mid- and late growth period), total fruit yield (total weight and fruit number), leaf length, leaf width, fruit length and diameter, internode length, leaf number, number of node, number of fruit in every nodes, stem diameter, fruit quality and average internode length were measured. Total fruit yield was measured regularly (three times a week when fruits had desirable sizes). Harvest time was divided in three parts, according to yield amount of plants. For each plant, some fruit were selected randomly in different days and length and diameter of fruits were measured using ruler and caliper. Three leaves of each plant were selected from 15 to 20 nodes and length and width of leaves were measured .

Statistical analysis was done for each generation, separately. Data analysis was done for calculating blocks effect using randomized blocks design on controls. Correlation coefficient of traits in S_2 and S_3 generations was calculated using SAS program. For stepwise regression, fruit weight was considered as dependent variable, whereas other traits were considered as independents variables. Pathway analysis was done using PATHS2 program and effects of yield components including total fruit number, fruit diameter and fruit length were studied on total fruit yield for each generation, separately.

3. RESULTS AND DISCUSSION

The results of variance analysis on controls showed that three genotypes were different in all traits, significantly ($p<0.01$), which Indicates that there is sufficient diversity among the studied genotypes. Meanwhile, block effect was not significant for none of traits, so there was no need to correct effect of blocks.

Correlation coefficient Simple correlation coefficient of different traits in S_2 population showed that total fruit weight had highly significant positive correlation ($p<0.01$) with some traits like leaf length (r=0/40), plant height in mid-growth (r=0/41), fruit length (r=0/54) and fruit diameter (r=0/54). Negative correlation was observed between fruit weight and leaf number, node number and fruit number in every node which were not significant.

In S3 population, total fruit weight had positive and significant correlation with total fruit number in first growth period (r=0/55),, and total fruit weight in first growth period (r=0/57) (table 1).

Naroui [11] reported the highest correlation between total fruit yield of pepper with fruit width and total fruit weight .

Naroeirad [3] showed that there was significant positive correlation between total fruit yield of melon and fruit weight, fruit length and fruit width .

Comparing correlation coefficients in two segregating populations showed that in both generations total fruit yield had positive and significant correlation ($p<0.01$) with average fruit weight. In S_2 generation, leaf length, fruit length, fruit diameter and plant height showed significant correlations with total fruit yield. However in S_3 generation, total fruit number in first growth period, average fruit number in first growth period, and total and average fruit weight in first growth period showed significant correlations with this trait. Therefore, we can use total fruit number, average fruit weight and average fruit number (traits which have shown correlations with fruit in various generations) as selecting criteria. However, morphological traits related to yield in early growth period are not suitable and may respond different in two generations.

Cramer and wehner [2] announced average fruit number as a yield component and reported that each traits of cucumber which had correlation with total fruit yield was considered as yield component. In a study by Gichimo et al. [19] on different cultivars of Kenya melon, significant positive correlation was observed between total fruit number and total fruit yield.

(Table 1) – Correlation coefficients populations' segregation S_2 and S_3 cucumber (above numbers the diagonal of S_3 and low numbers of diameter S_2)

X20	X19	X18	X17	X16	X15	X14	X13	X12	X11	X10	X9	X8	X7	X6	X5	X4	X3	X2	X1	
0/55*	0/55*	0/63*	0/63*	0/11	0/46	0/08	-0/05	-0/01	-0/02	0/32	0/23	0/15	0/21	0/08	0/08	0/82**	0/85**	0/99**	1	x_1
0/55*	0/55*	0/64*	0/64*	0/13	0/45	0/1	-0/05	0/03	0/02	0/34	0/27	0/16	0/24	0/05	0/05	0/83**	0/85**	1	0/94**	x_2
0/57*	0/57*	0/55*	0/55*	0/11	0/37	0/18	-0/06	0/11	0/11	0/27	0/31	0/26	0/26	0/11	0/11	0/99**	1	0/93**	0/99**	x_3
0/55*	0/55*	0/53*	0/54	0/13	-0/34	0/21	-0/06	0/15	0/14	0/27	0/33	0/27	0/29	0/09	0/08	1	0/93**	0/99**	0/93**	x_4
0/04	0/05	-0/01	0/004	-0/09	0/004	-0/11	0/002	0/03	0/03	-0/03	-0/11	-0/05	-0/04	0/91**	1	0/38	0/41	0/36	0/38	x_5
0/06	0/06	0/02	0/02	-0/09	-0/05	0/03	0/06	-0/01	-0/01	-0/04	-0/11	-0/05	-0/11	1	0/91**	0/36	0/38	0/34	0/36	x_6
0/05	0/05	-0/05	0/003	0/11	0/14	0/24	-0/22	0/53	0/53	0/16	0/27	0/61*	1	0/56*	0/59*	0/41	0/41	0/39	0/39	x_7
0/16	0/16	0/095	0/095	0/14	0/14	0/34	-0/32	0/47	0/47	0/03	0/14	1	0/61*	0/46	0/55*	0/35	0/34	0/33	0/33	x_8
0/27	0/27	0/28	0/28	0/01	0/21	0/06	-0/03	0/20	0/21	0/58*	1	0/37	0/41	0/3	0/31	0/58*	0/54	0/58	0/54	x_9
0/10	0/11	0/17	0/18	0/03	0/17	0/04	-0/02	0/14	0/14	1	0/69*	0/36	0/34	0/31	0/33	0/45	0/54	0/45	0/54	x_{10}
-0/04	-0/04	-0/14	-0/13	0/03	0/04	0/25	-0/17	0/99**	1	-0/03	-0/03	0/22	0/25	0/13	0/13	0/05	-0/003	0/05	0/007	x_{11}
-0/04	-0/03	-0/13	-0/12	0/03	0/04	0/24	-0/17	1	0/98**	-0/04	-0/06	0/20	0/22	0/13	0/12	0/01	-0/03	0/02	-0/01	x_{12}
-0/14	-0/13	-0/1	-0/1	-0/02	-0/1	-0/1	1	-0/17	-0/17	0/19	-0/2	-0/003	0/05	0/19	0/17	-0/19	-0/07	-0/16	-0/06	x_{13}
0/12	0/12	0/11	0/11	-0/03	-0/04	1	-0/16	0/18	0/23	0/25	0/42	0/17	0/25	0/3	0/28	0/42	0/33	0/42	0/33	x_{14}
0/29	0/3	0/31	0/31	0/15	1	0/32	-0/22	0/22	0/23	0/15	0/30	0/16	0/26	0/22	0/18	0/32	0/35	0/32	0/35	x_{15}
0/16	0/15	0/19	0/18	1	0/33	0/32	0/039	0/093	0/10	0/22	0/29	0/33	0/51	0/63	0/69	0/36	0/38	0/34	0/35	x_{16}
0/87**	0/87**	0/99**	1	0/21	0/06	0/08	-0/18	-0/19	-0/21	0/19	0/38	0/24	0/40	0/22	0/31	0/33	0/36	0/31	0/34	x_{17}
0/87**	0/87**	1	0/99**	0/21	0/06	0/07	-0/18	-0/2	-0/22	0/19	0/37	0/25	0/40	0/23	0/31	0/33	0/36	0/31	0/33	x_{18}
0/99**	1	0/96**	0/96**	0/2	0/09	0/13	-0/19	-0/18	-0/19	0/25	0/42	0/25	0/39	0/25	0/33	0/37	0/36	0/35	0/33	x_{19}
1	1	0/96**	0/96**	0/2	0/09	0/13	-0/19	-0/18	-0/19	0/25	0/42	0/25	0/39	0/25	0/33	0/37	0/36	0/35	0/33	X_{20}

Numbers greater than 0/16 at the 5% level (*) and Numbers greater than 0/23 are significant at the 1% level (**).

X1: fruit number, X2: average fruit number, X3: fruit weight, X4: average fruit weight, X5: leaf length, X6: leaf width, X7: early height growth, X8: mid-height growth, X9: fruit length, X10: fruit diameter, X11: leaf number, X12: number of node, X13: fruit of the nodes, X14: stem diameter, X15: fruit quality, X16: average internode, X17: total fruit number in first period, X18: average fruit number in first period, X19: : total fruit weight in first period, X20: average fruit weight in first period.

Stepwise regression

The results of stepwise regression of S_2 and S_3 generations by yield as dependent and other traits as independents variables is presented in table 3. Based on this result, in S_2 generation, the first trait which was entered in model was fruit number that explained more than %98.5 of yield variations (table 2). In next stage, average fruit number in third growth period was added to model which explained about %99.05 variation. Average fruit number was entered to model in third stage. These three traits explained more than % 99.71 of variations. Over all, results showed that all traits which entered to model were related to fruit number which indicates high importance of fruit number in improving total fruit yield. On the other hand, evaluating three harvesting periods showed that yield and fruit number of first growth period did not affect total fruit yield highly, and third growth period was the most effective period. Also, results showed that studied genotypes could keep production until late growth period .

($Y= -0/003 + 0/25 X_1 +0/99 X_2 + 14/9 X_3 +0/99 X_4 – 0/04 X_5$)

(Table 2) – The results of stepwise regression of S_2 population fruit yield.

(Fruit yield as the dependent variable and other traits as the independent variable).

The regression coefficient for all traits								
Mean square	Cumulative explained factor	5	4	3	2	1	intercept	traits
3/23	98/5					32/39	-2/48	X_1
2/06	99/05				0/20	28/91	-1/19	X_2
0/64	99/71			-5/24	0/67	29/77	-0/27	X_3
0/56	99/75		-5/13	0/71	1/71	27/40	-0/23	X_4
0/001	1	-0/048	0/99	14/87	0/99	0/24	-0/003	X5

X_1: fruit number, X_2: average fruit number in third growth period, X_3: average fruit number, X_4: average fruit number in second growth period, X_5: total fruit number in first growth period.

In S_3 population (table 3), average fruit number was the first trait which entered to model and explained more than 98.45% of variations. After that, node number was added to model and explained more than 98.56% of variations with previous trait .

($Y = -0/64 + 31/13 X_1 - 0/002 X_2$)

(Table 3) – The results of stepwise regression of S_2 population fruit yield.

(Fruit yield as the dependent variable and other traits as the independent variable).

The regression coefficient for all traits					
Mean square	Cumulative explained factor	2	1	intercept	traits
3/45	98/45		31/11	-1/39	X_1
3/16	98/56	-0/001	31/13	0/64	X_2

Results of stepwise regression was in agreement with simple correlation, so that in S_2 population, average fruit number which was the first trait of model, had highly significant correlation (r=0/85) with total fruit yield. Also, other traits had significant correlations including (r=0/55), (r=0/88), (r=0/88) and (r=0/55) for total fruit number of first and second growth period, average fruit number of second growth period and Total fruit number of third growth period, respectively. Average fruit number in third growth period did not have significant correlation, however was entered to two models, which shows affecting yield by this trait via other traits.

In S_3 population, total fruit number as the first trait that was entered to model, had the highest and significant correlation with total fruit yield (r=0/94). Node number didn't show significant correlation with yield however entered to model. This explains that this trait affects total yield via other traits. Comparing stepwise regression in S_2 and S_3 generations revealed that in both generations average fruit number explained the highest fruit weight variation and can be introduce as selection criteria.

On the other hand, measuring of fruit number is easier than fruit weight in breeding programs.

It's [5] reported that when pepper's fruit weight was considered as dependent variable and other quantitative traits were independent, fruit width, fruit wall thickness, leaf length, leaf width and fruit length explained 73.8% of dependent variable variations. in [6] announced that fruit length and fruit weight explained 66% and 73% of melon's fruit weight, respectively.

4-Pathway analysis

Pathway analysis was carried out to determine direct and indirect effects of traits on total fruit yield (table 4). Yield components including total fruit number, and length and diameter of fruit had direct and indirect effects on fruit yield. Result of this analysis for S_2 population showed that average fruit number had negative direct effect on fruit weight (-0/94). Indirect effect of this trait via fruit length was high and positive (0/99), whereas its indirect effect via fruit diameter was low (0/40), which caused correlation of this trait (r=0/45) with total fruit yield (table 4). Fruit length had direct effect (0.99) on fruit weigh, but its indirect effect via total fruit number was equal to negative indirect effect on fruit number (-0/88) and via fruit diameter was equal to (0/36). Correlation coefficient between this trait and total yield was (0/54).

Fruit diameter had direct effect (0.66) on total fruit yield, however its indirect effect via total fruit number and fruit length was equal to (-0/55) and (0/58), respectively. The amount of correlation between this trait and total yield was (0/69).

Pathway analysis for S_3 population showed that total fruit number had small negative direct effect (-0.2) on total fruit yield. Indirect effect on yield was via fruit length and fruit diameter (0.31 and 0.16, respectively) which caused correlation of this trait (r=0.27) with total fruit yield (table 5). Fruit length had direct effect (0.36) on total fruit yield and low indirect effect by fruit number (-0.17) and fruit diameter (0.12) which caused correlation coefficient as r=0.31. Fruit diameter had direct effect (0.55) on total fruit yield, however indirect effect of this trait was obtained by total fruit number (-0.62) and fruit length (0.84). This trait had positive correlation (r=0.57) with total fruit yield.

(Table 4) – The results of Pathway analysis for S2 population

Total effect (correlation)	fruit diameter	fruit length	fruit Number	total fruit yield
0/27	0/16	0/31	-0/20	fruit Number
0/54	0/12	0/36	-0/17	fruit length
0/69	0/55	0/84	-0/62	fruit diameter
			0/78	Residual effect

(Table 5) – The results of Pathway analysis for S3 population.

Total effect (correlation)	fruit diameter	fruit length	fruit Number	total fruit yield
0/45	0/40	0/99	-094	fruit Number
0/54	0/36	0/99	-0/88	fruit length
0/69	0/66	0/58	-0/55	fruit diameter
			0/66	Residual effect

Comparing pathway analysis results in mentioned generations showed that although fruit length and fruit yield had positive correlation, however fruit number had indirect negative effect on fruit yield via fruit number. It means that increasing fruit number reduced fruit length. Fruit diameter had also positive direct effect on yield; however it also had negative effect on yield via fruit number. Therefore, by increasing fruit number, fruit diameter reduced. However, over all, higher length and diameter of fruit have increased fruit yield. Consequently, it is determined that although direct effect of fruit number on fruit weight was negative, but because of indirect effect of fruit length and fruit diameter, the correlation of fruit number and fruit weight was positive. This was observed in both S_2 and S_3 generations. However, the amounts of correlations were higher in S_2 generation.

In zhang et al. [25] Study about relationships between different traits and fruit yield in cucumber, data of 14 recorded traits in primary growth stages were compared. Obtained results revealed the highest direct effects for average fruit weight, fruit number and average fruit length on fruit yield. Therefore these traits played positive roles on fruit yield.

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