INHERITANCE OF SHAPE, FIRMNESS, PERICARP THICKNESS AND LOCULE NUMBER OF FRUIT IN TOMATO

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وراثة الشكل والصلابة وسمك جدار وعدد المساكن فى ثمرة الطماطم

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ملخص البحث

درست وراثة أربعة صفات هى الشكل ، سمك الجدار ، الصلابة ، وعدد المساكن فى ثمرة الطماطم . أجريت الدراسة بمزرعة التجارب بكلية الزراعة بشبين الكوم فى أعوام ١٩٨٤ ، ١٩٨٥ ، ١٩٨٦م أستخدم فى الدراسة صنفين من الأصناف الأمريكية هى STD Cal-Ace كأم ، BL-6807 كأب حيث أجريت التهجينات اللازمة بينهما للحصول على بذور الجيل الأول والثانى والجيل الرجعى لكلا الأبوين .

زرعت التراكيب الوراثية الستة فى تجربة مصممة بطريقة القطاعات الكاملة العشوائية وأخذت القياسات اللازمة على ثمار النباتات الفردية – وبعد تحليل البيانات المتحصل عليها اتضح أن :– شكل الثمرة وسمك اللحم وعدد المساكن من الصفات بسيطة التوريث التى يحكمها زوج واحد من العوامل الوراثية – وظهرت سيادة كاملة لمعامل الشكل الكبير على الصغير وسيادة جزئية لعدد المساكن القليل ، وبجانب ذلك فان ظهور الثمار ذات معامل الشكل المرتفع والثمار القليلة المساكن يلزمه عدد من الجينات المحورة – وهنا هو السبب فى انحراف النسب المظهرية عن النسب المتوقعة (على أساس زوج واحد من الجينات) فى الأجيال الانعزالية بالنسبة لهاتين الصفتين ، ولوحظ أيضا أن صفة سمك جدار الثمرة بسيطة حيث يحكمها زوج واحد من الجينات ذات تأثير اضافى حيث ظهرت السيادة الغير تامة فى الجيل الأول وتأكدت فى الأجيال الانعزالية .

واتضح أن صلابة الثمرة يتحكم فيها ثلاثة أزواج من الجينات على الأقل ـ مع سيادة جزئية للعوامل المسئولة عن ارتفاع درجة الصلابة وكانت درجة التوريث عالية فى جميع الصفات مما يساعد على امكانية التحسين لها بالتربية والانتخاب ٠

ABSTRACT

Two tomato, Lycopersicon esculentum Mill., cultivars were used in studying the inheritance of shape index, pericarp thickness, firmness and locule number of fruit. Population studied were parents, F_1, F_2, BCP_1 and BCP_2. Data obtained indicated that Fruit shape, pericarp thickness and locule number per fruit are simply inherited with one major gene pair. Complete dominance for high shape index and partial dominance for few number of locules, while incomplete dominance for pericarp thickness were observed. Furthermore, many minor genes were required for the expression of high shape index and few locule number.

On the other hand, fruit firmness is quantitatively inherited with at least three major gene pairs. Partial dominance for the firm fruit was detected.

High broad sense heritability was obtained for all studied attributes, suggesting considerable improvement through breeding and selection.

INTRODUCTION

Tomato fruit firmness is an important quality attributer for maintaining satisfactory condition during postharvest handing, shipping, storing and marketing. Reynard (1960) reported that soft cultivars experienced more fruit cracking than firm cultivars. So the differences among cultivars in fruit firmness are considered important in choice of cultivars at cultivation. Al-Falluji et al. (1982) reported that this trait appears to be under genetic control.

Many fruit structural factors play roles in firmness of tomato fruit, among them are thickness of outer and inner wall (Hamson, 1952) and locule number per fruit (Al-Falluji et al., 1982).

Alvarez (1960) concluded that more than one genetic system operate in inheritance of tomato fruit firmness; while El-Sayed et al. (1966) stated complete dominance for soft fruit, which was controlled by a single major gene. According to Al-Falluji and Lambeth (1980), firmness was highly heritable, quantitatively inherited and the additive gene action was predominant. On the other hand, partial dominance for soft fruit was stated by Kanno and Kamimura (1981).

Thick fruit pericarp aid in tolirating the fruit to the process of mechanical harvesting for processing and such fruit keeps better during shipping. Therefore, many studies had been conducted for genotypes evaluation regarding this trait (Padda et al., 1971 and Malash, 1979). Their results referred differences among the genotypes in pericarp thickness. Hatem (1986) mentioned that no, or may be, few studies have been conducted on the inheritance of pericarp thickness in tomato.

No hybrid vigour for locule number per fruit was found, but dominance in partial or complete was reported by many investigators among them were, Peter and Rai (1978); Khalil (1979) and Arora et al. (1982). No dominance for the trait was also observed by Bangaru et al. (1983).

The previous investigations on the inheritance of tomato fruit shape revealed that it was controlled by two genes (Yeager, 1937 and John and Honma, 1970), or by single gene (Dennett and Larson, 1953 and Khalil, 1979). While Salib (1970) and Silvetti et al. (1974) reported that fruit shape in tomato was quantitatively inherited. Khalil (1979) added that dominance for the lower shape index, furthermore, the additive gene action were important in the inheritance of fruit shape.

Hence, this investigation was conducted to obtain additional insight on the mode of inheritance of fruit firmness and shape, pericarp thickness and locule number per fruit in the segregating populations of tomato.

MATERIALS AND METHODS

The study involved six populations, i.e. P_1, P_2, F_1, F_2, BCP_1 and BCP_2, of the tomato hybrid "STD CAL-ACE x BL-6807". The parental cultivars were STD CAL ACE, which had higher values for firmness, thickness and locule number, and BL-6807, which showed higher shape index value. Essential crossing and selfing to produce the required seeds were made in the summer seasons of 1984 and 1985 at the experimental Farm of Faculty of Agriculture, Minufiya University.

In the summer season of 1986, the two parents, F_1, F_2 and the back cross to both parents were grown in field trail experiment. The experimental design was a completely randomized block with four replications. The total plant number included in the study was 640 distributed among the six populations as follows: 80 of each homogenous population (P_1, P_2 and F_1), 160 of the F_2 and 120 of each BC. . F_2, each of back cross and each of the non-segregating population were represented by 4,3 and 2 ridges, respectively. The ridge was 1.0 m. wide, 5.0 m long, and contained 10 plants. Usual fertilizer, irrigation and cultivation were practiced for the commerical production of tomato.

Fruits were harvested on an individual plant basis from all populations. Observations and measurements concerning fruit firmness, shape index, pericarp thickness and locule number were recorded on at least five fruits from each plant. Fruit firmness was determined by the pressure tester, fruit shape was estimated as the ratio of measured equatorial diameter to the polar diameter. The ratio was expressed as an index number for shape. Pericarp thickness was determined in mm.

Calculation of means, variances, coefficient of variability and standard error were obtained. The theoretical means of the F_1 and segreagating populations were estimated by the formula given by Powers (1955). Estimates of the genetic parameters taken from Warner et al. (1980). The minimum number of genes was determined by formula after Castle-Wright (1921) and Burton (1951).

Chi square test was used to compare the observed and theoretical ratios. Frequency distribution tables were also prepared and used in preparing histograms showing the percentage of plants in various levels of trait.

RESULTS AND DISCUSSION

Fruit shape:

Data of fruit shape for all populations studied are presented in Table (1) and illustrated in Figure (1). It is shown that the two parents different significantly in shape index with an average of 0.19. BL-6807 cultivar showed the highest index.

The mean of F_1 plants was exactly equal to that of the BL-6807 cv., suggesting complete dominance for the high index over the low shape index. Complete dominance was revealed from the estimated average degree of heterosis (ADH), potence ratio and the dominance variance, which were 0.0, 0.95 and 0.012, respectively.

The F_1 distribution clearly reveals the dominance of higher shape index, it distributed within the range of the BL-6807 cv. The F_2 plants segregated into two classes with ratio of 38 and 62%

Table 1. Statistics obtained on fruit shape for parents and hybrid populations of the tomato cross " STD Cal Ace x BL- 6807 "

Population	Obtained mean ± SE.	Theoretical mean	Variance	CV.
P_1	0.84 ± 0.007	—	0.0016	4.8
P_2	1.03 ± 0.000.5	—	0.0008	2.7
F_1	1.03 ± 0.000.4	0.94	0.0008	2.7
F_2	0.93 ± 0.009	0.98	0.0082	9.8
BCP_1	0.92 ± 0.016	0.94	0.013	12.4
BCP_2	0.97 ± 0.008	1.03	0.0053	7.5

Table 2. Statistics obtained on pericarp thickness for parents and hybrid populations of the tomato cross " STD Cal Ace x BL- 6807 "

Population	Obtained mean ± SE.	Theoretical Mean	Variance	CV.
P_1	8.89 ± 0.16	—	0.81	10.1
P_2	3.22 ± 0.14	—	0.60	23.9
F_1	6.28 ± 0.12	6.06	0.45	10.7
F_2	5.44 ± 0.20	6.17	3.49	34.3
BCP_1	5.70 ± 0.18	7.59	1.60	22.2
BCP_2	4.44 ± 0.15	4.75	1.64	28.9

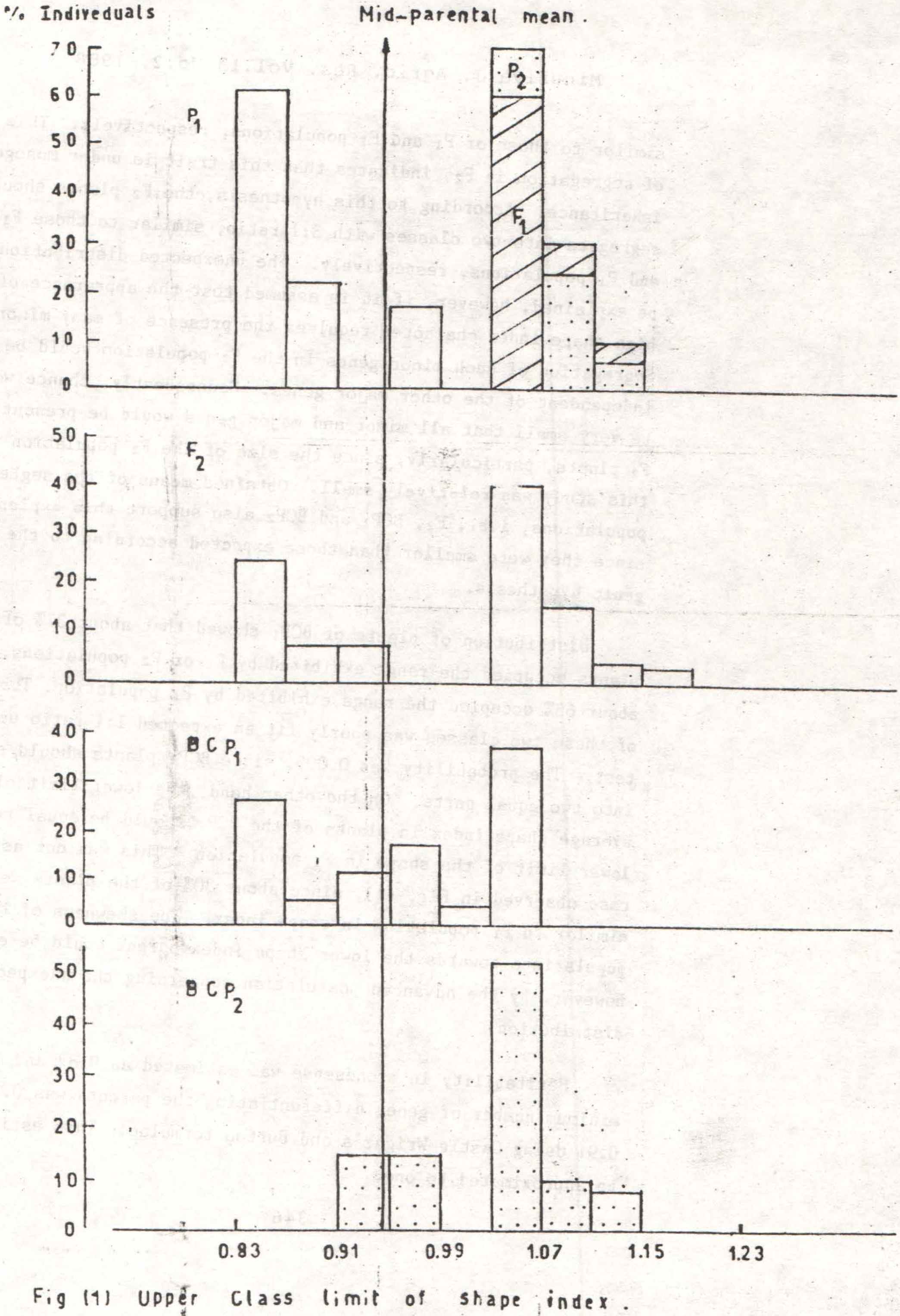

Fig (1) Upper Class limit of shape index.

similar to those of P_1 and F_1 populations, respectively. This type of segregation in F_2, indicates that this trait is under monogenic inheritance. According to this hypothesis, the F_2 plants should segregate into two classes with 3:1 ratio, similar to those F_1or P_2 and P_1 populations, respectively. The unexpected distribution could be explained, however, if it is assumed that the appearance of the high shape index character requires the presence of many minor genes. Segregation of such minor genes in the F_2 population would be independent of the other major genes. Consequently, chance would be very small that all minor and major genes would be present in F_2 plants, particularly, since the size of the F_2 population in this study was relatively small. Obtained means of the segregating populations, i.e., F_2, BCP_1 and BCP_2 also support this explanation, since they were smaller than those expected according to the monogenic hypothesis.

Distribution of plants of BCP_1 showed that about 37% of the plants occupied the range exhibited by F_1 or P_2 populations, while about 63% occupied the range exhibited by P_1 population. The ratio of these two classes was poorly fit an expected 1:1 ratio using X^2 test. The probability was 0.005, since BCP_1 plants should segregate into two equal parts. On the other hand, the lower limit of the average shape index in plants of the BCP_2 should be equal to the lower limit of the shape in F_1 population. This was not as the case observed in Fig. (1), since about 30% of the plants were aimilar to P_1 population in shape index. The skewness of both BC populations towards the lower shape index parent could be explained, however, by the advanced postulation concerning the unexpected F_2 distribution.

Heritability in broadsense was estimated as 0.87 and the minimum number of genes differentiating the parents was 0.61 and 0.91 using Castle-Wright's and Burton formulae. This estimate may be approximated to one.

Accordingly, it could be concluded that one major gene with dominance for the high shape index affect the inheritance of shape index in these materials, in addition to many minor genes required for the expression of high index of shape.

This conclusion regarding fruit shape in tomato was in harmony with that reported by Dennet and Larson (1953).

Pericarp thickness:

Data of pericarp thickness are summerized in Table (2) and illustrated in Figure (2). Distribution of F_1 plants was mostly intermediate between parents, and its mean was close to the mid parental value. The estimated average degree of heterosis (ADH) in relation to mid-parental value, potence ratio and additive variance were 3.6%, -0.08 and 3.76, respectively. These figures strongly suggest that this attribute is controlled by additive action of genes.

The segregation of F_2 plants (Figure 2) also provides a clear evidence to the hypothesis presented regarding the inheritance of pericarp thickness. About 33, 41 and 26% of plants had an average pericarp thickness within the range of, respectively, P_2, F_1 and P_1. The 41% class includes plants covering pericarp thickness scale extending from the upper limit of the parent with thin pericarp to the lower limit of the parent with thick pericarp. This segregation fits a 1:2:1 ratio using a X^2 test, with probability of 0.1-0.5. This result strongly suggest that pericarp thickness is simply inherited.

The monogenic inheritance with the additive gene action was varified by the distributions of BCP_1 and BCP_2 plants. 52 and 44% of the BCP_1 and BCP_2, respectively, showed average pericarp thickness within the range of F_1 population, while the remaining plants

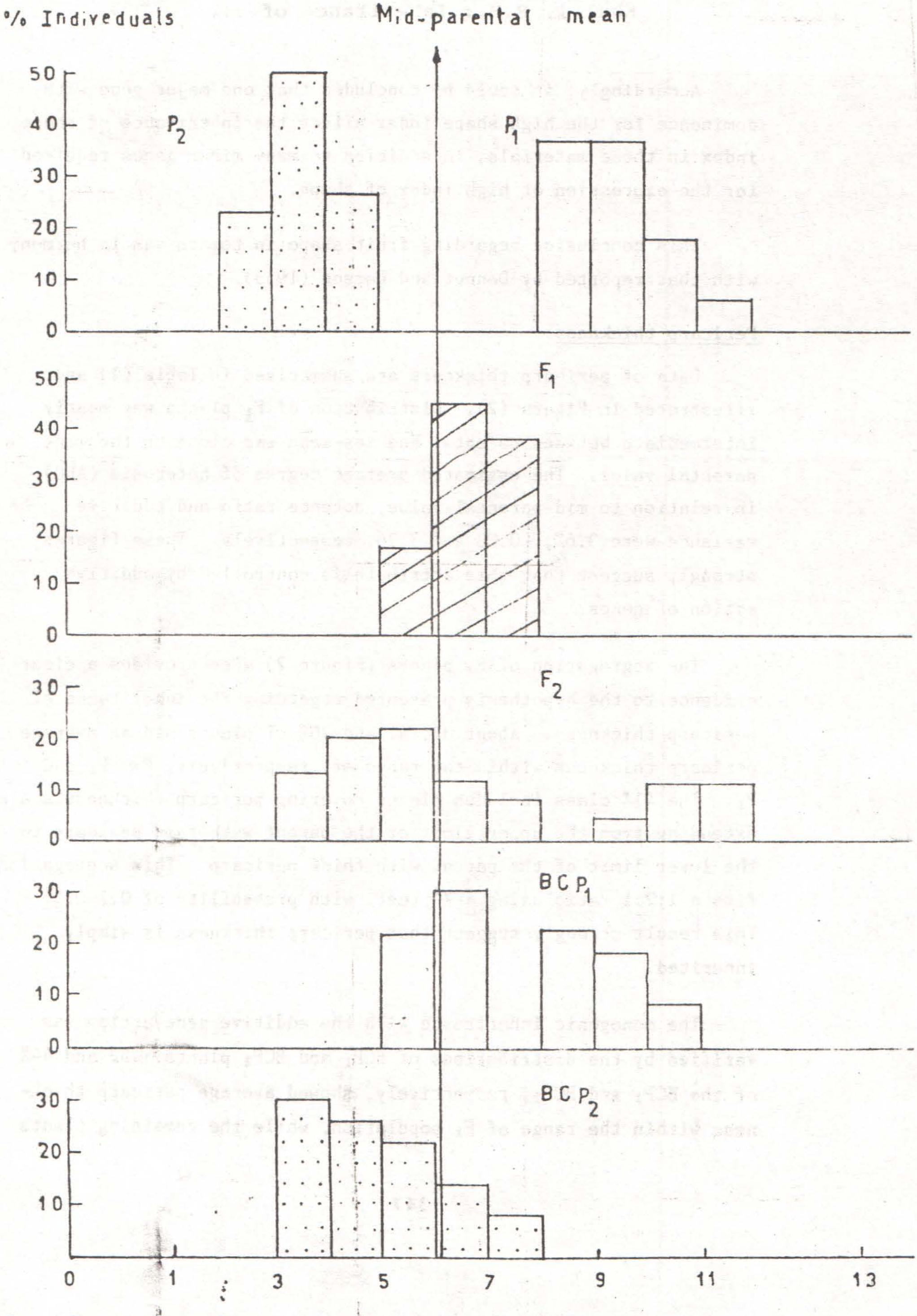

Fig (2). Upper Class limit of pericarp thickness.

showed an average similar to that of the recurrent parent. The ratios of the two classes of plants in the two populations fit a 1:1 ratio using a X^2 test. The probability of segregation according to these ratios were 0.50-0.90 and 0.10-0.50 for BCP_1 and BCP_2, respectively.

The obtained and theoretical means of F_1 and BCP_1 were very close, supporting the additive gene action involved in the inheritance of pericarp thickness. Estimated BSH (0.82), minimum number of genes (1.32) controlling the trait, potence ratio (0.08) and the additive variance (3.76) also suggested that pericarp thickness is controlled by one gene pair with additive gene action.

This result was in harmony with that reported by Hatem (1986), who mentioned that some of tomato intervarietal hybrids were intermediate between their respective parents in wall thickness. Also this conclusion confirmed the previous studies conducted by Khalil (1987), on gene action for this trait on the same cross, since the additive effects were the most important effects in the inheritance of pericarp thickness.

Fruit firmness:

Data concerning fruit firmness of the six populations appear in Table (3) and frequency distributions are shown in Figure (3). The two parents differed significantly in their fruit firmness. B1-6807 (P_2) had the lowest mean, while STD Cal-Ace (P_1) had the highest.

The F_1 mean was significantly higher than mid-parental mean and lower than that of STD Cal-Ace, it was closer to STD Cal-Ace, suggesting partial dominance for the firm fruit with slight additive gene effects. Partial dominance was varified by estimated average degree of heterosis (ADH) which was 20.5 and -5.2%, in

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Table 3. Statistics obtained on fruit firmness for parents and hybrid populations of the tomato cross " STD Cal Ace x BL- 6807 "

Population	Obtained mean ± SE	Theoretical mean	Variance	CV.
P_1	234.2 ± 1.8	--	100.7	4.7
P_2	134.2 ± 1.8	--	100.7	7.5
F_1	221.9 ± 1.6	184.2	79.8	4.1
F_2	182.0 ± 3.3	203.1	600.3	13.5
BCP_1	200.0 ± 4.3	228.1	530.0	12.1
BCP_2	185.7 ± 2.5	178.1	443. 0	11.3

Table 4. Statistics obtained on locule number per fruit for parents and hybrid populations of the tomato cross " STD Cal Ace x BL- 6807 ".

Population	Obtained mean ± SE.	Theoretical mean	Variance	CV.
P_1	8.4 ± 0.21	--	1.31	13.7
P_2	2.2 ± 0.09	--	0.30	24.7
F_1	2.7 ± 0.08	5.31	0.21	16.9
F_2	4.7 ± 0.24	4.0	5.05	47.4
BCP_1	4.7 ± 0.27	5.55	3.63	46.8
BCP_2	4.4 ± 0.17	2.45	1.17	24.4

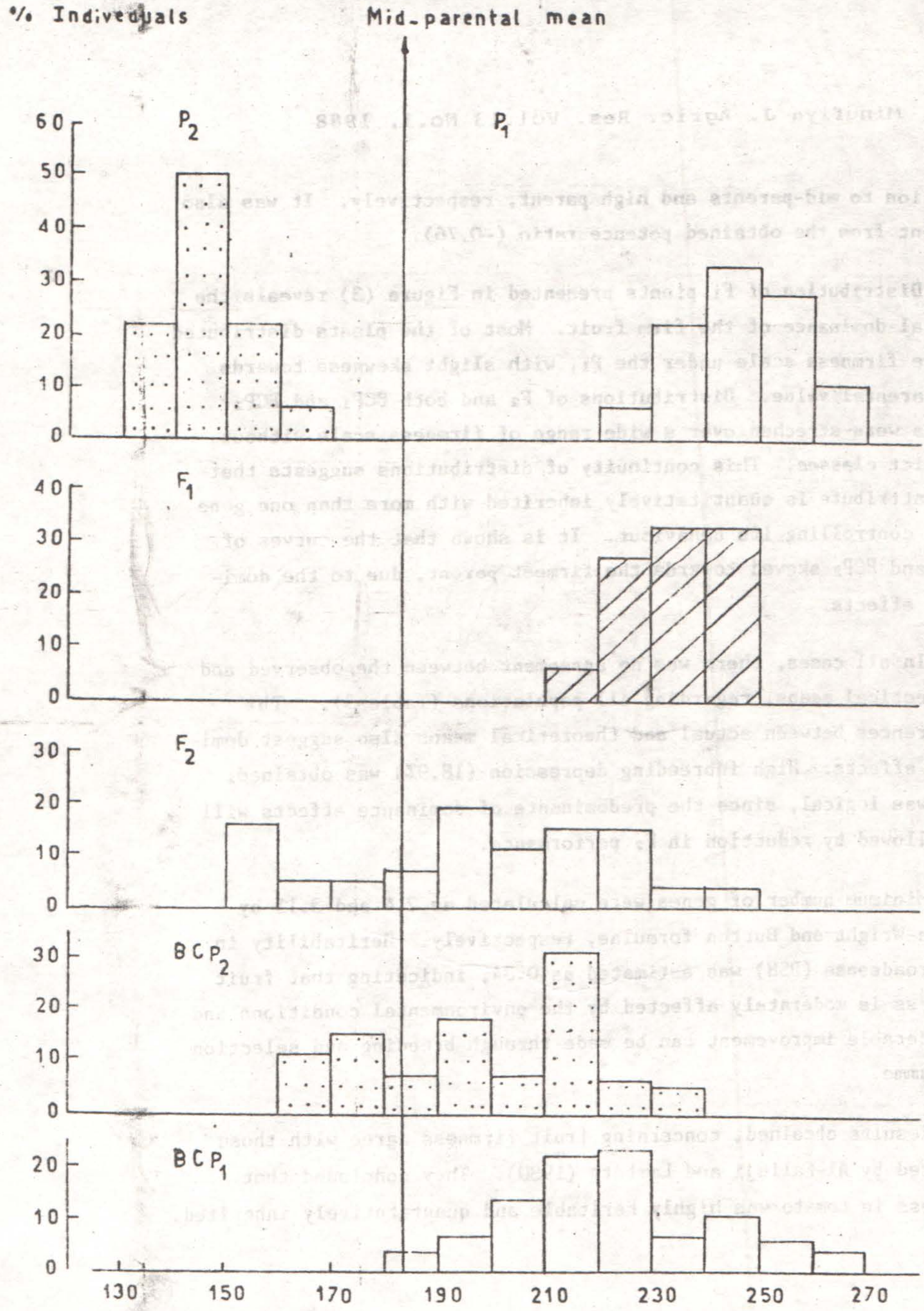

Fig (3). Upper Class limit of Fruit firmness .

relation to mid-parents and high parent, respectively. It was also evident from the obtained potence ratio (-0.76).

Distribution of F_1 plants presented in Figure (3) reveals the partial dominance of the firm fruit. Most of the plants distributed on the firmness scale under the P_1, with slight skewness towards mid-parental value. Distributions of F_2 and both BCP_1 and BCP_2 plants were streched over a wide range of firmness scale without distnict classes. This continuity of distributions suggests that this attribute is quantitatively inherited with more than one gene pairs controlling its behaviour. It is shown that the curves of BCP_1 and BCP_2 skewed towards the firmest parent, due to the dominance effects.

In all cases, there was no agreement between the observed and theorectical means, regarding all populations (Table 3). The differences between actual and theoretical means also suggest dominance effects. High inbreeding depression (18.9%) was obtained, this was logical, since the predominante of dominance effects will be followed by reduction in F_2 performance.

Minimum number of genes were calculated as 2.4 and 3.15 by Castle-Wright and Burton formulae, respectively. Heritability in the broadsense (BSH) was estimated as 0.84, indicating that fruit firmness is moderately affected by the environmental conditions and considerable improvement can be made through breeding and selection programme.

Results obtained, concerning fruit firmness agree with those reported by Al-Falluji and Lambeth (1980). They concluded that firmness in tomato was highly heritable and quantitatively inherited.

Locule number:

Data obtained concerning number of locules in tomato are presented in Table (4) and Figure (4). They lead to the conclusion that this trait is controlled by one pair of genes with partial dominance of the few number. Furthermore, many minor genes were required for the expression of the few number of locules. This conclusion is derived from the means, distribution of populations studied, potence ratio, ADH value and minimum number of genes.

The partial dominance of few number of locules is evident in the distribution of F_2 and BC populations. About 27% of F_2 plants had an average locule number within the range occupied by the recessive parent (P_1). This value is very close to the expected 25% value on the basis of segregation of one pair of genes. From the remaining portion of plants, which represent the heterozygous and homozygous dominant genotypes, 61% showed an average locule number within the range occupied by the dominant parent (P_2) and (F_1) plants, while 12% lied between the two parents on locule number scale. The appearance of this plants could be explained as previously mentioned in fruit shape, since the appearance of few locule number requires the presence of many minor genes. A X^2 test made on these two classes fit a 1:3 ratio with a probability of 0.01-0.05.

The same case was observed in the distribution of BCP_1 plants, since about 46% of plants was with an average similar to that of P_1, as expected when the trait controlled by one gene pair. On the other hand, the remaining plants, which should show an average similar to that of F_1 and P_2, showed slight skewness towards P_1 population, supporting the partial dominance hypothesis and the importance of minor genes for appearance of the small number of locules.

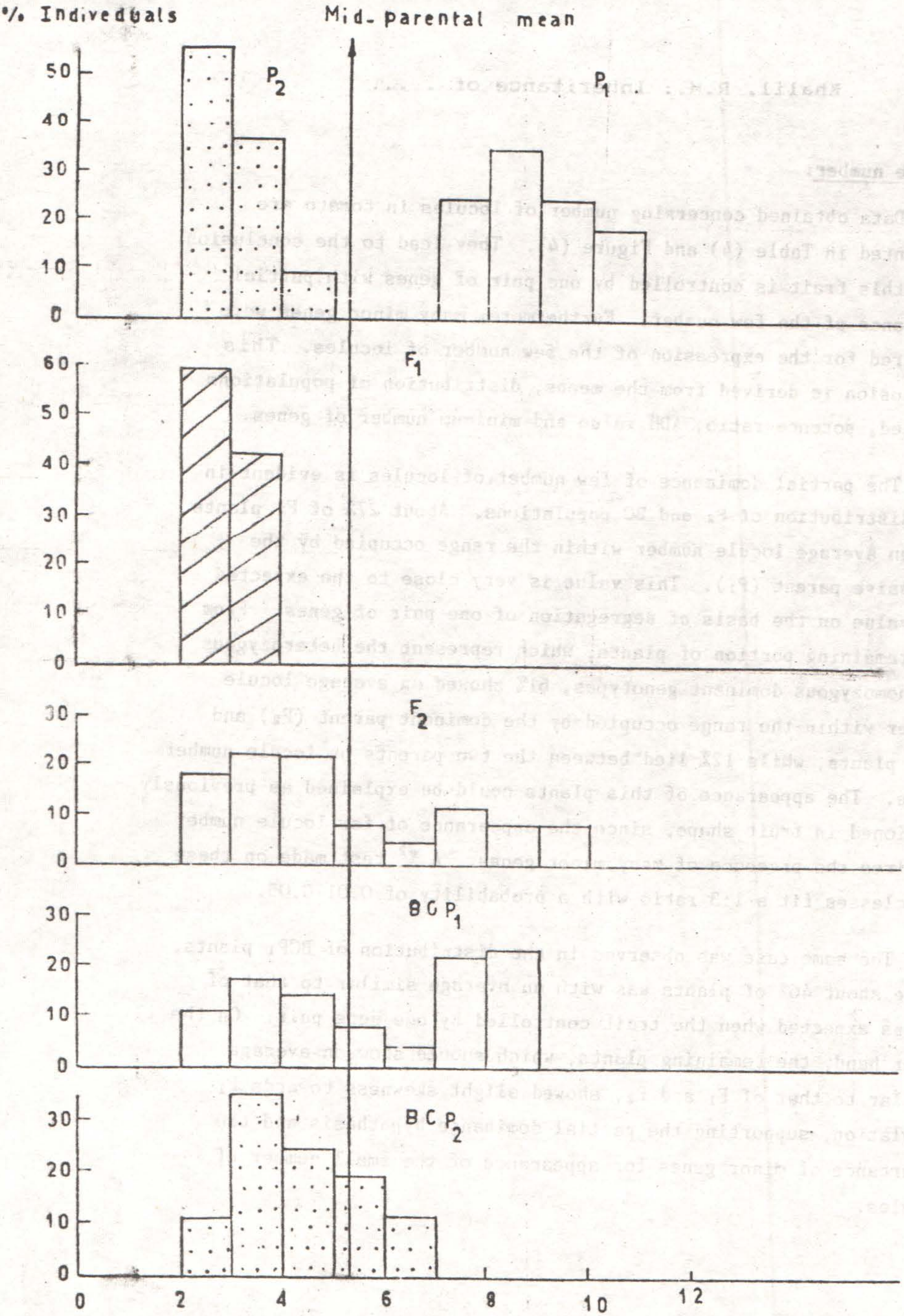

Fig (4). Upper Class limit of locule number / Fruit.

Regarding BCP_2, most plants had an average number of locules similar to that of F_1 and P_2. Only 29% had an average slightly higher than those of F_1 and P_2 populations, due to the absence of the minor genes required for appearance of few number of locules.

Obtained negative ADH values in relation to both mid-parents and high parent, which were -48.8 and -67.6%, respectively, in addition to the relatively high estimated potence value (0.84) were in accordance with the partial dominance of the few locules. The monogenic inheritance of the trait was also evident from the high obtained BSH (0.88%) and calculated minimum number of genes (0.98 and 1.34) by Castle-Wright and Burton formulae, respectively.

Similar results on the inheritance of locule number in tomato were reported by Peter and Rai (1978) and Arora et al. (1982).

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