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Inheritance of Quantitative Characters in Tomato (*Lycopersicon esculentum* Mill)

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Abstract: Productivity of tomato, *Lycopersicon esculentum* Mill, can be reduced substantially by rampant flower abortion. Inheritance and heritability of high fruit set and yield were studied to develop efficient methods for breeding improved cultivars. High fruit setting (Cherry) and Low fruit setting (NR1, NR2, NR44 and NR46) tomato genotypes were chosen for studies of high fruit set, yield and good plant stature (determinate). Parental genotypes, F₁, F₂ and backcross progenies were evaluated under field conditions at the Horticultural Science Department of the Kwame Nkrumah University of Science and Technology, Kumasi during the 1998 and 1999 cropping seasons. Data on vegetative and yield components were recorded for the parents, F₁, F₂ and backcross populations. Cherry had higher mean values than the NR-Lines for all the characters except average fruit diameter, average fruit weight and total fruit weight per plant. Hybrid yields of 11.2-42.0 t ha⁻¹ was recorded compared with 16-22.0 t ha⁻¹ recorded for the parents. Narrow-sense heritabilities obtained from variance components of vegetative and yield traits were generally low to moderate indicating that all these traits were influenced by additive genes and environment will have much influence on such traits. In order to develop varieties with good agronomic characters, acceptable fruit yield and sizes, single seed descent with progeny row testing and selection must be used since backcrosses is not suitable for fixing such traits.

Key words: Tomato, *Lycopersicon esculentum*, quantitative characters, additive gene effect

INTRODUCTION

Tomato, *Lycopersicon esculentum* Mill., is an important vegetable crop widely cultivated for human consumption and it is second only to Irish potato (*Solanum tuberosum*) in terms of nutritive value. The fruits contain high levels and serve as an important dietary source of vitamins A, B, C, E and nicotinic acid (Davies and Hobson, 1981). Hundred gram tomato fruits can supply about 20 and 40% of the US recommended daily allowances of vitamins A and C, respectively for adults (Grierson and Kader, 1986). Although biotic factors are major causes of yield reductions in crops in the Sahelian and Sudanian zones of Africa, abiotic factors such as drought and high temperatures causing high flower abortion rates are also of considerable importance (Hall and Patel, 1987). For instance, the combination of high temperatures and minimum night temperatures higher than 20°C, which are not uncommon in major arable crop producing areas (Nelson and Hall, 1985; Patel and Hall, 1990), can result in considerably low fruit set and yield.

In subtropical zones, reduction in tomato productivity caused by high temperatures can be partially avoided by choosing a sowing date such that flowering does not coincide with the hot nights of the year; however, this

approach is not effective in tropical zones, such as those in West Africa, where the crop must be sown at the beginning of the rains and night temperatures are high during all the growing season. The most feasible alternative for tropical and subtropical zones is to develop cultivars with tolerance to high rate of flower abortion induced by high temperatures. Inheritance of heat tolerance during fruit set has been studied with tomato (*Lycopersicon esculentum* Mill). Shelby *et al.* (1978) reported that a few partially dominant genes conferred heat tolerance during fruit set, but narrow-sense heritability was very low (8%) due to large environmental effects. Where heritabilities are low, breeding to incorporate the trait can be difficult; therefore, it is necessary to design specific breeding methods for efficient transfer of the trait. Scanty or virtually no literature exists on the use of wild tomato (*Lycopersicon esculentum* ceraciforme Mill.) in developing heat tolerant tomato cultivars in Ghana. A preliminary study by Tetteh (1997) indicated that the wild tomato sets more fruits than the cultivated types under these conditions. This study seeks to examine the quantitative traits, their inheritance through interspecific crosses of cultivated and wild types and how they impact on high yielding tomato varieties which are tolerant to temperature stress and high flower abortion rate in Ghana.

MATERIALS AND METHODS

Two primary gene pools representing wild and cultivated types were selected as parents in interspecific crosses. The wild parent, *Lycopersicon esculentum* var *cerasiforme* (Cherry tomato) had previously been shown to set more fruits and to be highly tolerant to various biotic and abiotic stresses (Tetteh, 1997). This line has small fruit size and is indeterminate in growth habit. The cultivated parents were selected from germplasm collection (Natural Resource, NR lines 1, 2, 44 and 46) at Hazere, Israel (NR1 and NR2) and Wenchi, Ghana (NR44 and NR46). All the accessions constituting this group have shown to set few fruits and are less tolerant to various biotic and abiotic stress. These lines have bigger fruit size and are determinate in growth habit.

Hybridization: The Cherry (males) were crossed to the NR-lines (female) without reciprocals, to produce F_1 seed under natural day lengths at the Horticulture Department, KNUST, Kumasi. Some of the F_1 seeds were planted in the field and F_1 plants were backcrossed reciprocally with the parental lines or allowed to self-pollinate to produce F_2 seeds. Cherry was used as recurrent parent in backcross I (BC_1P_1) and NR-lines as recurrent parent in backcross II (BC_1P_2). Successful crosses and backcrosses obtained in the experiment are given in Table 1.

Field screening: The parental lines, F_1 , F_2 and BCs populations were planted in a randomized complete block design with four replications at the Horticulture Department of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in 1998 and 1999 cropping seasons. A plot measured 4.8×4.8 m with 1.0 m between plots and 1.0 m between blocks. No fertilizer was applied and weeds were controlled by hoeing. The number of plants within a plot varied according to the number of seed available for each cross and generation. Data on vegetative and yield components such as plant height, number of fruits per truss

and total fruit weight among others were recorded for parentals, F_1 , F_2 and backcross populations.

Data were analysed by ANOVA and means separated using Fisher protected LSD at 5% probability level when ANOVA indicated a significant difference. The equations suggested by Strickberger (1968) were used to estimate the additive, genetic and non-additive genetic variance. Broad-and Narrow-sense heritabilities (Allard, 1960) were then calculated based on individual plants. The genetic, additive and non-additive components of variance were estimated using the method of Allard (1999) as:

$V_p = V_G + V_E$ where V_p is the phenotypic variance, V_G is the genotypic variance and V_E is the environmental variance. Given the variance of $F_2 = V_p$, V_E was estimated as the average of the parents and F_1 as: $V_E = (V_{P1} + V_{P2} + V_{F1})/3$ where V_{P1} , V_{P2} and V_{F1} are variances of parent I (wild parent), parent II (cultivated parent) and F_1 generation, respectively. Fitting these values to Allard (1999) models: we solve the equations for D and H.

$$V_F = 1/2D + 1/4H + V_E \quad (1)$$

$$VBC_1P_1 + VBC_1P_2 = 1/2D + 1/2H + 2V_E \quad (2)$$

Where $1/4H$ is the dominance variance and $1/2D$ is the additive variance, VBC_1P_1 and VBC_1P_2 are the backcross I and backcross II variances, respectively. Solving them simultaneously give $1/2D = 2V_{F2} - (VBC_1P_1 + VBC_1P_2)$. The dominance component $1/4H$ was similarly estimated.

Heritability in the broad (H_b) and the narrow (h^2) senses were calculated as:

$$H_b = V_G/V_p \text{ and } h^2 = D/V_p$$

Response to selection (R) or Genetic gains (Gs) = $ih^2\sigma_G^2$ where i is the selection intensity (30% population retained), h^2 is the narrow sense heritability and σ_G^2 is the genotypic variance.

RESULTS

Cherry plants as well as all the F_1 and BC_1P_1 plants of all the crosses were observed to be indeterminate whereas all the recurrent parents and BC_1P_2 plants were seen to be determinate (Table 2). It was also observed that the F_2 progenies segregated into determinates and indeterminate types (ratios not shown). Significant differences ($p < 0.05$) were observed amongst all the genotypic means of all the crosses. The F_1 means of plant height of $C \times 2$ and $C \times 44$ crosses were similar to the mid-parental values and their F_2 except $C \times 46$. F_2 and BC_1P_2 of all the crosses were less

Table 1: Types of crosses made and the degree of successes achieved

Type of crosses	Total No. of crosses made	No. of successful crosses obtained	Percentage success
$C \times 1$	96	40	41.7
$C(C \times 1)$	90	47	52.2
$1(C \times 1)$	80	31	38.8
$C \times 2$	104	54	51.9
$C(C \times 2)$	98	52	53.1
$2(C \times 2)$	70	34	48.6
$C \times 44$	116	74	64.0
$C(C \times 44)$	112	83	68.0
$44(C \times 44)$	96	69	72.0
$C \times 46$	120	77	64.2
$C(C \times 46)$	108	70	65.0
$46(C \times 46)$	90	61	68.0

C = Cherry, 1 = NR 1, 2 = NR 44, 46 = NR 46

Table 2: Means (\pm SE) of plant height at harvest of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	147.0 \pm 3.2	147.8 \pm 3.7	147.8 \pm 3.9	147.8 \pm 3.3
P_2	95.3 \pm 2.1	86.9 \pm 2.2	83.8 \pm 2.2	69.3 \pm 1.6
F_1	-	114.9 \pm 2.9	119.3 \pm 3.2	120.4 \pm 2.7
F_2	116.2 \pm 2.5	106.3 \pm 2.7	116.6 \pm 3.1	114.0 \pm 2.6
BC_1P_1	134.2 \pm 2.9	129.5 \pm 3.3	114.9 \pm 3.1	139.7 \pm 3.2
BC_1P_2	96.8 \pm 2.1	97.4 \pm 2.4	95.3 \pm 2.5	107.6 \pm 2.4
CV (%)	13.6	15.8	16.8	14.2
LSD (0.05)	31.1	36.1	39.8	33.3

Table 3: Mean (\pm SE) days to visible bud stage of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	27 \pm 0.3	27.0 \pm 0.4	27.0 \pm 0.14	27.0 \pm 0.3
P_2	48 \pm 0.5	40.6 \pm 0.6	42.9 \pm 0.18	43.8 \pm 0.5
F_1	-	34.0 \pm 0.5	34.9 \pm 0.18	34.8 \pm 0.4
F_2	34 \pm 0.4	38.0 \pm 0.6	40.1 \pm 0.2	42.0 \pm 0.5
BC_1P_1	36 \pm 0.4	36.0 \pm 0.5	36.8 \pm 0.19	36.8 \pm 0.4
BC_1P_2	42 \pm 0.5	39.0 \pm 0.6	45.8 \pm 0.2	45.3 \pm 0.5
CV%	6.9	9.4	3.2	6.8
LSD (0.05)	5.2	6.8	2.5	5.4
Gs	13.0	2.9	21.4	10.4

than the mid-parental values. However, the BC_1P_1 means of all the crosses were greater than the mid-parental values.

The Cherry (wild) was significantly earlier (27 days) than all the recurrent parents which reached the stage in 40-48 days (Table 3). The differences between the wild and the cultivated recurrent parents and even the hybrid generations were significantly different ($p < 0.01$) indicating sufficient genetic variability and scope for improvement through hybridization and selection. However, $C \times 2$ (F_1) reached the stage at the same time as mid-parental value of 33.8, the mid-parental values of $C \times 44$ and $C \times 46$ crosses reached the visible bud stage the same time as the corresponding F_1 means. This is an indication of the absence of transgressive segregation of the alleles for the trait. This is in sharp contrast to the findings of Agble (1974) that hybridization using *Lycopersicon esculentum* var cerasiforme (Cherry tomato) conferred earliness. In all the crosses the F_2 means gave a later budding stage (segregating data not presented) than their corresponding F_1 , but the F_2 means were closer in magnitude to their corresponding recurrent parents (P_2).

Cherry significantly produced more flowers than all the NR-parents (at least 38% more) (Table 4). The average number of flowers per truss for NRI (5.1) was not significantly different from its back cross II ($BC_1P_2 = 5.95$). However mean numbers of flowers per truss of all the other crosses were significantly different ($p < 0.01$) from each other and from both parents. The F_2 means were not different from their mid-parental values whereas the BC_1P_1 values were closer but significantly lower than the mean of the wild for $C \times 2$ and $C \times 44$ crosses.

Cherry recorded the highest mean number of fruits per truss (6.4) whilst the cultivated parents recorded

significantly lower (2.3-3.6) mean number of fruits per truss (Table 5). In all the crosses, the parents were significantly different from their F_1 s. However, the F_2 s, BC_1P_1 s and BC_1P_2 were not significantly different from each other except for $C \times 44$ and $C \times 46$ crosses.

Cherry matured significantly earlier (77.95 days) than any other genotype where as the cultivated parents (125.4-129.1) were the latest to mature (Table 6). For $C \times$ NR1 cross, Cherry (77.95 days) was significantly earlier ($p < 0.01$) than the cultivated parents (129.1) and both parents means were significantly different from F_2 (104.6), BC_1P_1 (91.7) and BC_1P_2 (110.7) generation means (Table 5). For $C \times 2$ cross, Cherry, the cultivated parent (129.1), F_2 (99.6) and F_1 (112.0) generations means were significantly different from each other but F_2 mean was not significantly different from B_2 (101.3) generation mean. The cultivated parent (NR2), F_2 and BC_1P_2 (121.0) generation means were not significantly different from each other. For $C \times 44$ cross, Cherry, the cultivated parent (125.4) and F_1 (100.8) were significantly different ($p < 0.01$) from each other. F_1 , F_2 and BC_1P_1 generation means were not significantly different from each other. F_2 (109.9), BC_1P_1 (99.15) and BC_1P_2 (120.1) generation means were not significantly different from each other. However, apart from the NR 46 (128.7) which was not significantly different from its BC_1P_2 (122.3) generation mean, Cherry, F_1 (101.2), F_2 (103.2) and BC_1P_1 (92.5) generation means were significantly different from each other. The F_1 of all the crosses were significantly ($p < 0.05$) earlier than their corresponding mid-parental values indicating greater earliness. This confirms the observation made by Agble (1979) that earliness was one of the principal manifestation of heterosis in tomato breeding involving the wild.

Table 4: Mean (\pm SE) number of flower per truss of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	8.2 \pm 0.12	8.2 \pm 0.01	8.2 \pm 0.1	8.2 \pm 0.2
P_2	5.1 \pm 0.1	5.0 \pm 0.02	4.0 \pm 0.03	4.6 \pm 0.1
F_1	-	6.9 \pm 0.03	6.7 \pm 0.1	6.7 \pm 0.14
F_2	7.0 \pm 0.1	6.1 \pm 0.03	6.1 \pm 0.1	6.3 \pm 0.1
BC_1P_1	7.0 \pm 0.1	6.4 \pm 0.03	6.9 \pm 0.1	6.8 \pm 0.14
BC_1P_2	6.0 \pm 0.1	4.5 \pm 0.02	5.4 \pm 0.04	6.1 \pm 0.1
CV%	9.0	3.0	4.8	12.5
LSD (0.05)	1.2	0.4	0.6	1.6
Gs	3.3	2.4	2.2	2.4

Table 5: Mean (\pm SE) number of fruits per truss of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	6.4 \pm 0.19	6.4 \pm 0.1	6.4 \pm 0.06	6.4 \pm 0.05
P_2	2.7 \pm 0.1	3.6 \pm 0.05	2.3 \pm 0.02	2.7 \pm 0.02
F_1	-	4.4 \pm 0.06	4.4 \pm 0.04	4.3 \pm 0.03
F_2	4.4 \pm 0.13	5.0 \pm 0.07	4.5 \pm 0.04	4.7 \pm 0.03
BC_1P_1	5.1 \pm 0.15	4.6 \pm 0.07	5.1 \pm 0.04	4.5 \pm 0.03
BC_1P_2	3.0 \pm 0.1	3.9 \pm 0.06	3.4 \pm 0.03	2.9 \pm 0.02
CV%	18.6	8.9	5.4	4.5
LSD (0.05)	1.6	0.7	0.5	0.4
Gs	1.9	3.2	2.5	3.1

Table 6: Mean (\pm SE) number of days to maturity of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	78.0 \pm 1.4	78.0 \pm 0.6	78.0 \pm 0.8	78.0 \pm 0.40
P_2	129.1 \pm 2.3	129.1 \pm 1.0	125.4 \pm 1.4	128.7 \pm 0.72
F_1	-	99.6 \pm 0.7	100.8 \pm 1.1	101.2 \pm 0.60
F_2	104.6 \pm 1.8	112.0 \pm 0.8	109.9 \pm 1.2	103.2 \pm 0.60
BC_1P_1	92.5 \pm 0.5	91.7 \pm 1.6	101.3 \pm 0.7	99.2 \pm 1.10
BC_1P_2	110.7 \pm 2.0	121.0 \pm 0.9	120.1 \pm 1.3	122.3 \pm 0.70
CV (%)	11.0	4.5	6.80	3.5
LSD (0.05)	22.7	10	14.6	7.4

Table 7: Mean (\pm SE) fruit diameter (cm) of wild Cherry tomato (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	2.3 \pm 0.01	2.3 \pm 0.03	2.3 \pm 0.02	2.3 \pm 0.01
P_2	4.6 \pm 0.01	5.5 \pm 0.07	4.9 \pm 0.03	5.1 \pm 0.03
F_1	-	3.5 \pm 0.04	3.7 \pm 0.02	3.4 \pm 0.02
F_2	3.1 \pm 0.01	3.5 \pm 0.04	3.4 \pm 0.02	3.2 \pm 0.02
BC_1P_1	3.0 \pm 0.01	3.2 \pm 0.04	2.6 \pm 0.02	2.9 \pm 0.01
BC_1P_2	3.8 \pm 0.01	4.1 \pm 0.05	4.0 \pm 0.03	4.0 \pm 0.02
CV%	1.8	7.9	4.1	3.6
LSD (0.05)	0.1	0.6	0.3	0.3
Gs	0.1	0.7	0.4	0.34

Table 8: Mean (\pm SE) total fruit weight (g) per plant of wild Cherry (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	921.7 \pm 44.3	921.70 \pm 31.00	921.70 \pm 160	921.7 \pm 34.4
P_2	1011.5 \pm 48.7	745.74 \pm 25.0	773.40 \pm 13.3	1007.5 \pm 38.0
F_1	-	1187.74 \pm 39.8	852.10 \pm 14.6	1354.5 \pm 50.5
F_2	1073.6 \pm 51.6	1556.12 \pm 52.1	1203.50 \pm 20.6	1029.0 \pm 38.4
BC_1P_1	693.5 \pm 33.4	2213.70 \pm 74.10	1049.60 \pm 18.0	1310.2 \pm 49.0
BC_1P_2	835.9 \pm 40.2	1025.70 \pm 34.40	912.53 \pm 16.0	943.8 \pm 35.0
CV (%)	30.3	21.10	10.80	23.50
LSD (0.05)	550.4	544.1	206.8	514.8

The cultivated parents produced the largest fruit diameter (4.6-5.5 cm) whilst Cherry had significantly smaller fruit size (2.3 cm) for all the genotypes (Table 7). The fruit size of the Cherry was significantly smaller than recurrent parents BC_1P_1 s (3.1-3.5 cm), F_1 s (3.4-3.7 cm) and B_2 (3.8-4.1 cm) generation means of all the crosses except BC_1P_1 (2.6 cm) of $C \times 44$ crosses. All the recurrent parental

means were significantly larger ($p < 0.01$) than F_1 s, F_2 s, BC_1P_1 s and BC_1P_2 s generation means of all crosses. F_2 (3.1 cm) and BC_1P_1 (3.0 cm) generation means were not significantly different from each other but both means were significantly larger than BC_1P_2 (3.7 cm) mean for $C \times 1$ cross. F_1 (3.5 cm) mean was not significantly different from F_2 (3.5 cm), BC_1P_1 (3.2 cm) and BC_1P_2 (4.1 cm) generation

Table 9: Mean (\pm SE) yield (t/ha) of wild Cherry tomato (P_1) and tomato varieties (P_2) and their hybrid generations

Generation	C (P_1) \times NR1 (P_2)	C (P_1) \times NR2 (P_2)	C (P_1) \times NR44 (P_2)	C (P_1) \times NR46 (P_2)
P_1	19.1 \pm 0.5	19.1 \pm 1.0	19.1 \pm 0.71	19.1 \pm 0.6
P_2	22.2 \pm 0.5	16.1 \pm 0.8	21.7 \pm 0.81	21.7 \pm 0.7
F_1	-	27.1 \pm 1.3	29.2 \pm 0.3	29.2 \pm 0.91
F_2	22.1 \pm 0.6	30.2 \pm 1.4	22.2 \pm 0.83	24.2 \pm 0.8
BC_1P_1	23.8 \pm 0.6	42.0 \pm 2.0	28.2 \pm 1.05	27.2 \pm 0.85
BC_1P_2	11.2 \pm 0.3	21.8 \pm 1.0	20.2 \pm 0.8	20.3 \pm 0.63
CV (%)	15.6	29.6	23.5	19.6
LSD (0.05)	6.2	15.6	11.1	9.3

means of $C \times 2$ cross. Significant differences were established between F_1 (3.0 cm), F_2 (3.4 cm) and BC_1P_2 (4.0 cm) generation means of $C \times 44$ cross. F_1 (3.4 cm) and F_2 (3.2 cm) means of $C \times 46$ crosses were not significantly different from each other but both were significantly different from BC_1P_1 (2.9 cm) and BC_1P_2 (4.0 cm) generation means.

The mean total fruit weight per plant of Cherry (921.7 g), recurrent parents (745.7 g), F_1 (1187.7 g), BC_1P_2 (1925.0 g) and F_2 (1556.1 g) were not significantly different from each other in the $C \times 2$ cross but the BC_1P_1 (2213.7 g) was significantly higher than all the other genotypes (Table 8). For $C \times 46$ crosses, all the genotypic means, except F_2 mean (1029.01 g) were not significantly different from each other.

Data on yield ($t\ ha^{-1}$) are presented in Table 9. For $C \times 1$ cross, all the genotypic means were significantly higher ($p < 0.01$) than BC_1P_2 (11.2) but were not significantly different from each other. All the genotypic means of $C \times 2$ except BC_1P_1 (42.0) were not significantly different from each other. No significant difference ($p > 0.05$) was observed between the genotypic means of $C \times 44$ and $C \times 46$ crosses. Results presented in Table 6 for $C \times 1$ and $C \times 2$ genotypic means show that although BC_1P_1 had smaller mean fruit size (3-3.2 cm), it gave the highest fruit yield ($t\ ha^{-1}$) which is an indication that it is the number of fruits rather than the size/weight that determines the overall yield. This confirms the findings of Caraballo *et al.* (1989). Indeterminate character was observed to be associated with higher yields and determinate with lower yields (Table 2 and 9).

GENETIC ANALYSIS

Heritability (in narrow sense) estimates (Table 10) for plant number of flowers/truss were moderate ($h^2 = 0.44-0.67$) showing the importance of additive gene in this trait with F_1 mean range of 6.7-6.9.

Heritability estimates (h^2) for plant height at harvest (Table 10) were ($h^2 = 0.52-0.74$) showing the importance of additive gene effect on the trait. These agree with the findings of Kumari and Subramanian (1994). Selection for this trait on the basis of the individual's own phenotype (individual or mass selection) would be

effective. Heritability values (h^2) across all the crosses for days to visible bud stage were moderate ($h^2 = 0.35-0.43$) as in Table 10 showing additive gene actions and F_1 means from 34.0 to 34.99.

Heritability estimates (h^2) for number of fruits/truss (Table 10) were moderate ($h^2 = 0.38-0.53$) showing the importance of additive gene actions with F_1 mean range from 4.3 to 4.4. With an expected genetic gain of 1.94- 3.2 (Table 5), the expected number of fruits per truss will be 6.3- 8.2.

With the expected genetic gain (Gs) of 2.2-3.3 (Table 4), the expected number of flowers per truss will be 8.3-10.2. The high rate of flower abortion observed amongst the cultivated parents could be attributable to the negative impact of high temperatures and humidity couple with the susceptibility of the NR-lines.

Heritability estimates (h^2 , Table 10) were high ($h^2 = 0.35- 0.66$) for number of days to maturity indicating the importance of additive gene action. Inheritance was partially dominant ($F_1 = 99.6-101.2$, Table 6). Additive gene effect was the most important gene action on fruit diameter. Heritability estimates (h^2 , Table 10) ranged from ($h^2 = 0.28$) to ($h^2 = 0.58$) showing incomplete dominance ($F_1 = 3.42-3.67$). This confirms the results obtained by Kumari and Subramanian (1994). However, traits having low heritability (between 0.26 and 0.35) such as this are an indication of the importance of both additive and non-additive gene effects.

Heritability estimates (h^2 , Table 10) of total fruit weight (g) for all the four crosses were moderate ($h^2 = 0.48-0.64$) indicating the importance of additive gene effect on this trait and the reliability of selection based on the phenotype. Heritability estimates (h^2 , Table 10) were very moderate to high ($h^2 = 0.39-0.74$) indicating the important role additive gene plays in the yield of tomatoes. This confirms the findings of Kumari and Subramanian (1994).

DISCUSSION

Cherry normally produced a high number of fruits perplant, which is explained by the fact that it has a larger number of branches, which form floral branches. This

Table 10: Heritability estimates for some agronomic characters of wild Cherry tomato (P_1) and NR-Lines (P_2) and their hybrid generations

Trait		C (P_1) × NR1 (P_2)	C (P_1) × NR2 (P_2)	C (P_1) × NR44 (P_2)	C (P_1) × NR46 (P_2)
Plant height	h^2	0.74	0.56	0.52	0.55
at harvest	H	0.93	0.87	0.84	0.73
Days to visible	h^2	0.42	0.41	0.35	0.43
bud stage	H	0.78	0.68	0.58	0.51
No. of flowers	h^2	0.67	0.64	0.67	0.44
per truss	H	0.72	0.74	0.83	0.83
No. of fruit	h^2	0.53	0.38	0.40	0.50
per truss	H	0.64	0.68	0.65	0.74
Days to	h^2	0.66	0.64	0.35	0.42
maturity	H	0.77	0.77	0.62	0.65
Average fruit	h^2	0.28	0.53	0.58	0.46
diameter	H	0.59	0.78	0.74	0.62
Total fruit weight	h^2	0.49	0.64	0.58	0.48
(g)	H	0.78	0.94	0.75	0.85
Total fruit	h^2	0.34	0.74	0.48	0.53
yield ($t\ ha^{-1}$)	H	0.62	0.93	0.67	0.66

h^2 - Heritability in narrow sense, H - Heritability in broad sense

coupled with the genetic ability to set more fruits led to the production of high number of fruits per plant. All the F_1 hybrids exhibited vigorous growth in plant height but not significantly different from their mid-parental values (Table 2) and number of branches per plant (Data not shown) thus showing the influence of additive genes on this trait. This is an advantage for using cherry in tomato improvement as was observed by Agble (1974).

Results obtained (Table 3) gave enough evidence that *L. esculentum* var. cerasiforme is an early flowering species compared with the cultivated parents. However, mean values of hybrid generations with Cherry as a parent were not significantly earlier than their commercial parents (Table 3) and not confirming the observation made by Burdick (1954) and Fabig (1966) that earliness was one of the principal manifestations of heterosis in tomato breeding. The gene responsible for earliness was observed in the study to be additive (Table 3 and 10) implying the environment has much influence and selection for the trait will be effective in the F_4 to F_7 generations. Fruit yield of the hybrids although not statistically significant, were generally numerically higher than that of the cultivated parents. In all the crosses, the F_1 and F_2 means exceeded the mid-parental values. The improvement in yield can be attributed to alleles contributed by the wild Cherry, which had better fruit set and higher number of fruit as observed by Talpalaru (1972) and Ognyanova (1975). The fruit yield of $42\ t\ ha^{-1}$ obtained from the backcross to Cherry (BC_1P_1) (Table 9) of $C \times 2$ cross was higher than the $32\ t\ ha^{-1}$ reported by Agble (1991) in similar interspecific crosses although no fertilizer was applied in this experiment.

Fruit sizes of F_1 and BC_1P_1 were intermediate between Cherry and cultivated types. This disadvantage would appear to be a limiting factor in using Cherry for tomato improvement as indicated by Daskalov (1943). However,

larger fruit sizes or types were recovered in the F_2 and more especially when recurrent parents were used in backcrossing to give BC_1P_2 generation.

Since fruit size (Table 7 and 10) was observed to be governed by additive genes, selecting for such trait in a later generations will be effective.

Heritability (h^2) estimates for vegetative traits and yield and its components (Table 10) were low to moderate indicating the important role additive genes play in the genetic control of vegetative traits and yield of tomatoes and the reliability of selection based on the phenotype. This is ample evidence that much progress can be made since according to Perera *et al.* (1998) rice cultivars possessing sufficient additive genetical variation permit further response to selection for increased yield. F_1 values or means were mostly intermediate values between the two parental means and not significantly different from the mid-parental values.

Lower to moderate heritability imply relatively low to moderate genetic gains (Gs) in all generations as observed (Table 3 to 7). However, it must be stressed that some of the possible ways of increasing heritability estimates are by optimizing growth conditions and minimizing abiotic and biotic stresses which were not considered in this study.

In order to develop stable varieties with high fruit set and yield and acceptable fruit sizes, it is suggested that single seed descent and progeny row selection based on the phenotype at later generation may be followed.

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