*Indian J. Genet.*, 49(1): 9–17 (1989)

# ANALYSIS OF GENE EFFECTS FOR YIELD AND CERTAIN YIELD TRAITS IN CROSSES BETWEEN *CICER ARIETINUM* L. AND *C. RETICULATUM* LADZ.

H. K. JAISWAL AND B. D. SINGH

*Department of Genetics and Plant Breeding, Banaras Hindu University, Banaras 221005*

**(Received: January 27, 1986; accepted: February 26, 1988)**

## ABSTRACT

**Inheritance of eight agronomic traits, namely, leaf length, primary branches, days to flower, days to maturity, pods/plant, seeds/pod, yield/plant and 100-seed weight were studied in four interspecific crosses involving two chickpea varieties and *C. reticulatum* using the generation means analysis. For leaf length, primary branches, days to flower and days to maturity both additive and nonadditive gene effects were recorded. For yield/plant and 100-seed weight, $\hat{d}$, $\hat{j}$, and $\hat{i}$ interactions were more important than other gene effects. For pods/plant, dominance and $\hat{i}$ interaction effects were recorded. The preponderance of nonadditive gene effects indicates that a poor gain under selection may be expected in these crosses.**

**Key words:** *Cicer arietinum*, *Cicer reticulatum*, interspecific hybridization, gene effects.

The yielding ability of the present chickpea varieties is relatively low. Yield and yield traits are governed by both additive and nonadditive gene effects in the intervarietal crosses of chickpea [1-5].

The genus *Cicer* has 40 species, of which only one is cultivated. The cultivated chickpea readily hybridizes with *Cicer reticulatum*. Hybrids between the two species have normal meiosis [6] and pollen viability in $F_1$ is comparable to that of the parents involved in a cross [7]. Moreno and Cubero [8] suggested that *C. reticulatum* may be considered as a subspecies of *C. arietinum*. Several other crops, notably oats, have benefitted from yield genes contributed by their wild relatives [9, 10]. It is likely that chickpea would benefit from introgression of *C. reticulatum* genes [11]. The present study has been undertaken to estimate the gene effects controlling yield and certain yield traits in the crosses between *C. arietinum* and *C. reticulatum* using the generation means analysis [12, 13].

## MATERIALS AND METHODS

Crosses were made between chickpea varieties T 3 (desi), ICC 8923 (kabuli), and JM 2106 (*C. reticulatum*). Plots consisting of the parents, $F_1$, $F_2$ and backcrosses of the four crosses were grown according to the randomized block design with three replications. Each plot consisted of 3 rows for the parents, 1 row for $F_1$, 8 rows for $F_2$ and 2 rows each for the backcrosses. The row-to-row and plant-to-plant distances were 45 and 15 cm, respectively. Nonexperimental rows were grown on either sides of each plot in order to avoid border effects.

Observations were recorded on 10 plants in each plot of the parents and $F_1$, 20 plants from each backcross, and 100 plants from each $F_2$ plot selected randomly. Data were recorded for leaf length, primary branches, days to flower, days to maturity, pods/plant, seeds/pod, yield/plant, and 100-grain weight. The analysis of variance was carried out according to the randomized block design [14], crosswise. The A, B, C scaling tests [15, 16] and joint scaling test [17] were applied prior to the use of the six-parameter model [12, 13] for the estimation of various genetic components.

## RESULTS AND DISCUSSION

Seed set was obtained when the cultivated chickpea was used as male as well as female parent; the per cent of seed bearing pods ranged from 5.2 to 9.2 in different cross combinations. Pod formation was marginally higher when it was used as female (7.0 and 9.0%) than as male (5.2 and 5.3%). Pollen viability of the $F_1$ hybrids was comparable to that of the three parents (Table 1). This indicated that there was little evidence for selective elimination of gametes in the $F_1$ hybrids. This was supported by seed set in all the pods of $F_1$ hybrids, and the pattern of segregation for various characters in the $F_2$ populations (Fig. 1). The $F_2$ population showed

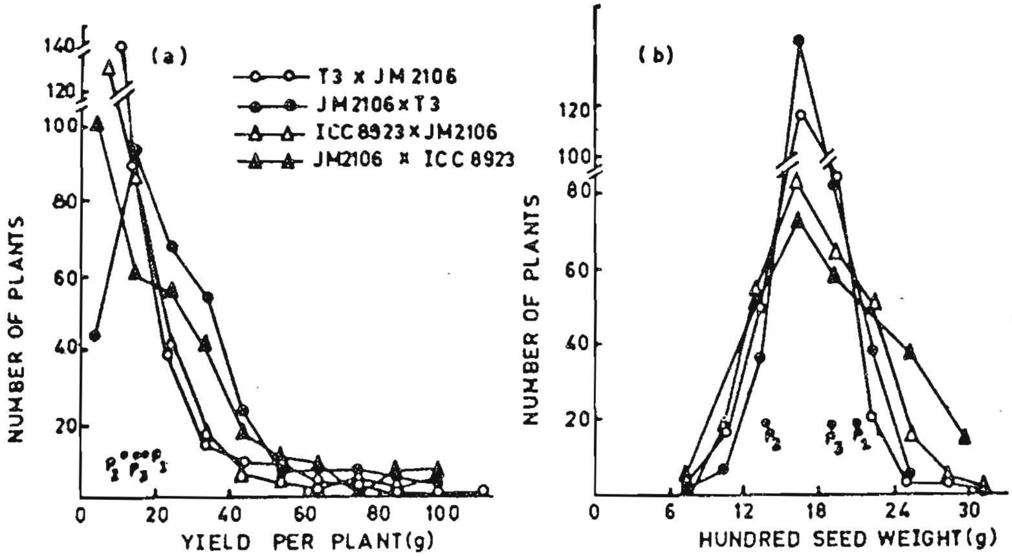

Fig. 1. Frequency distribution for yield/plant (a), and 100-seed weight (b) in $F_2$ generation of crosses between *C. arietlnum* (desi) T 3, (kabuli) ICC 8923 and *C. reticulatum* JM 2106. The mean of the parents T 3 ($P_1$), JM 2106 ($P_2$) and ICC 8923 ($P_3$) are presented as single points.

wide transgressive segregation towards both higher and lower values for all the characters, unimodal distribution and recovery of both parental values [7]. Thus, there was little evidence of zygotic elimination and as such the crosses between *C. reticulatum* and *C. arietinum* may be treated as intervarietal crosses for genetic analysis. The mean values of six generations in various crosses are presented in Table 2.

The analysis of variance revealed that the six generations differed significantly for all the characters in all crosses, except for days to maturity (ICC 8923 × JM 2106), 100-seed weight (JM 2106 × T 3), yield/plant (T 3 × JM 2106 and JM 2106 ICC 8923), pods/plant (ICC 8923 × JM 2106 and its reciprocal), and seeds/pod (JM 2106 × ICC 8923) (Table 3). This seems to be due to lack of significant genetic differences among the progenies (Table 2) and/or due to a larger error variance as a result of sampling error and environmental effects on these traits.

The A, B, C scaling tests and the joint scaling test agreed closely with each other (Table 4), except in the case of leaf length in cross JM 2106 × T 3, where the joint scaling test indicated epistasis, while the A, B, C scales did not. Estimation of gene effects using the six-parameter model revealed the interaction component $\hat{i}$ to be significant. Interestingly, for days to maturity in cross T 3 × JM 2106, the A, B, C and the joint scaling tests indicated epistasis but the estimates of $\hat{i}$, $\hat{j}$ and $\hat{l}$ were nonsignificant. It is difficult to explain this discrepancy. Ketata et al. [18, 19] and Singh and Singh [20] concluded that the joint scaling test was more accurate for identification of interacting crosses. The findings of the present study agree with these conclusions.

The six-parameter model was applied in all cases for estimation of the various gene effects in view of epistasis indicated by A, B, C and the joint scaling tests (Table 5). In case of leaf length, both additive and nonadditive gene effects were important. For primary branches, dominance and interaction effects $\hat{i}$, $\hat{j}$, and $\hat{l}$ seemed to be more important than additive gene effects. Zafar and Abdullah [1] reported additive gene action with some dominance for primary branches. In case of days to flower, both additive and nonadditive gene effects were important [3]. Days to maturity was governed primarily by additive gene effects, except for cross JM 2106

**Table 1. Pollen fertility of the $F_1$ hybrids between *C. arietinum* and *C. reticulatum***

| Parent/$F_1$ hybrid | Pollen fertility, % |
|---|---|
| *C. arietinum*<br>(cv. T 3) | 97.2 |
| *C. reticulatum*<br>(JM 2106) | 96.5 |
| *C. arietinum*<br>(ICC 8923) | 94.7 |
| T 3 × JM 2106 | 93.6 |
| ICC 8923 × JM 2106 | 94.0 |

**Table 2. Generation means for different characters in four crosses between *C. arietinum* and *C. reticulatum***

| Cross | $P_1$ | $P_2$ | $F_1$ | $F_2$ | $BC_1$ | $BC_2$ |
|---|---|---|---|---|---|---|
| **Leaf length (cm):** | | | | | | |
| T 3 × JM 2106 | 6.9 | 5.3 | 6.7 | 5.9 | 6.7 | 5.6 |
| JM 2106 × T 3 | 5.2 | 6.6 | 6.8 | 6.0 | 6.1 | 6.5 |
| ICC 8923 × JM 2106 | 6.7 | 5.2 | 6.8 | 5.8 | 5.6 | 5.1 |
| JM 2106 × ICC 8923 | 5.5 | 6.7 | 6.6 | 6.3 | 6.2 | 6.1 |
| **Primary branches:** | | | | | | |
| T 3 × JM 2106 | 3.4 | 4.7 | 3.7 | 3.2 | 3.4 | 4.2 |
| JM 2106 × T 3 | 5.0 | 3.2 | 4.9 | 3.9 | 3.7 | 3.4 |
| ICC 8923 × JM 2106 | 2.4 | 4.2 | 3.2 | 3.0 | 4.3 | 4.5 |
| JM 2106 × ICC 8923 | 4.2 | 2.4 | 3.4 | 3.8 | 4.1 | 2.7 |
| **Days to flower:** | | | | | | |
| T 3 × JM 2106 | 80.0 | 93.0 | 90.6 | 82.6 | 76.6 | 93.6 |
| JM 2106 × T 3 | 92.0 | 79.0 | 85.6 | 89.0 | 92.0 | 75.0 |
| ICC 8923 × JM 2106 | 75.3 | 94.6 | 94.3 | 89.0 | 74.0 | 89.0 |
| JM 2106 × ICC 8923 | 101.3 | 75.6 | 91.0 | 90.3 | 84.0 | 69.6 |
| **Days to maturity:** | | | | | | |
| T 3 × JM 2106 | 153.6 | 170.0 | 162.6 | 167.0 | 160.6 | 174.0 |
| JM 2106 × T 3 | 175.6 | 150.3 | 175.3 | 167.6 | 171.3 | 160.0 |
| ICC 8923 × JM 2106 | 158.0 | 171.0 | 166.3 | 159.6 | 170.3 | 173.0 |
| JM 2106 × ICC 8923 | 166.0 | 156.3 | 172.6 | 151.0 | 171.6 | 163.0 |
| **Pods/plant:** | | | | | | |
| T 3 × JM 2106 | 95.1 | 93.8 | 173.8 | 78.7 | 129.5 | 99.9 |
| JM 2106 × T 3 | 116.8 | 77.8 | 144.5 | 107.5 | 76.6 | 95.1 |
| ICC 8923 × JM 2106 | 79.0 | 96.6 | 132.2 | 88.9 | 94.8 | 95.8 |
| JM 2106 × ICC 8923 | 90.5 | 72.1 | 104.2 | 93.6 | 70.4 | 83.9 |
| **Seeds/pod:** | | | | | | |
| T 3 × JM 2106 | 1.1 | 0.9 | 1.0 | 1.1 | 1.1 | 1.0 |
| JM 2106 × T 3 | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 |
| ICC 8923 × JM 2106 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 |
| JM 2106 × ICC 8923 | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 |
| **Yield/plant(g):** | | | | | | |
| T 3 × JM 2106 | 20.2 | 13.1 | 28.8 | 15.4 | 12.3 | 23.0 |
| JM 2106 × T 3 | 14.2 | 18.3 | 27.3 | 19.5 | 15.8 | 23.7 |
| ICC 8923 × JM 2106 | 18.4 | 15.6 | 39.3 | 15.6 | 15.4 | 15.9 |
| JM 2106 × ICC 8923 | 12.0 | 15.3 | 22.2 | 18.3 | 11.5 | 15.0 |
| **100-seed weight (g):** | | | | | | |
| T 3 × JM 2106 | 21.7 | 13.9 | 19.6 | 17.4 | 18.9 | 17.2 |
| JM 2106 × T 3 | 15.0 | 20.3 | 17.9 | 17.9 | 18.1 | 19.1 |
| ICC 8923 × JM 2106 | 20.0 | 14.6 | 20.5 | 17.6 | 15.6 | 15.7 |
| JM 2106 × ICC 8923 | 13.8 | 14.1 | 13.6 | 13.0 | 17.7 | 16.5 |

$P_1$—female parent, $P_2$—male parent; $BC_1$—first back-cross generation $F_1 \times P_1$, $BC_2$—first back-cross generation $F_1 \times P_2$.

**Table 3. Analysis of variance for eight agronomic traits in different interspecific crosses between *C. arietinum* and *C. reticulatum***

| Source | d.f. | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | primary branches | days to flower | leaf length | days to maturity | pods per plant | seeds per plant | yield per plant | 100-seed weight |
| | | | | | **T3 × JM 2106** | | | | |
| Replications | 2 | 0.1 | 4.4 | 0.1 | 6.5 | 0.3 | 0.004 | 31.4 | 0.9 |
| Progenies | 5 | 1.0** | 158.2** | 1.3** | 157.2** | 3600.5** | 0.01** | 167.4 | 21.1** |
| Error | 10 | 0.1 | 8.8 | 0.2 | 9.9 | 614.9 | 0.001 | 57.3 | 1.2 |
| | | | | | **JM 2106 × T3** | | | | |
| Replications | 2 | 0.3 | 4.1 | 0.0 | 66.9 | 123.0 | 0.001 | 1.5 | 5.0 |
| Progenies | 5 | 1.7* | 149.5** | 1.0* | 294.0** | 1996.4** | 0.01** | 73.0** | 9.2 |
| Error | 10 | 0.3 | 10.2 | 0.2 | 32.1 | 212.7 | 0.001 | 7.9 | 7.7 |
| | | | | | **ICC 8923 × JM 2106** | | | | |
| Replications | 2 | 0.1 | 9.0 | 0.0 | 57.6 | 63.6 | 0.002 | 56.2 | 0.1 |
| Progenies | 5 | 2.2** | 247.4** | 1.6** | 117.7 | 1020.8 | 0.009* | 269.6** | 180.9** |
| Error | 10 | 0.2 | 35.4 | 0.1 | 48.3 | 327.6 | 0.002 | 44.6 | 0.5 |
| | | | | | **JM 2106 × ICC 8923** | | | | |
| Replications | 2 | 0.1 | 23.2 | 0.2 | 9.7 | 388.6 | 0.001 | 19.3 | 0.6 |
| Progenies | 5 | 1.7** | 392.2** | 0.6* | 218.9** | 509.9 | 0.009 | 48.1 | 19.8** |
| Error | 10 | 0.1 | 15.8 | 0.1 | 33.2 | 437.2 | 0.003 | 20.3 | 2.0 |

*, **P<0.05 and 0.01, respectively.

× ICC 8923, where dominance and interaction effects were also important. For days to maturity, Asawa and Tiwari [3] reported preponderance of additive component, but Katiyar and Singh [4] found that nonadditive gene action played a major role.

For pods/plant, dominance gene effects and $\hat{i}$ and $\hat{l}$ interactions were more important. Previous workers have reported the importance of both additive [1] and nonadditive [1, 2, 5] gene effects for pods/plant, which is in agreement with the findings of the present study. Both additive and dominance gene effects were involved in the control of seeds/pod (Table 5). For seeds/pod, the nonadditive component plays major role [2, 3]. Yield/plant was under the control of additive gene effects and $\hat{j}$ and $\hat{l}$ interactions, as reported earlier [3]. In case of 100-seed weight, the interaction effects were more important than either additive or dominance effects. Katiyar and Singh [4] reported predominance of additive gene effects for 100-seed weight which, however, is not confirmed by our study.

The three-parameter model was applied to all the cases where scaling tests indicated absence of epistasis as well as in cross T 3 × JM 2106 for days to maturity. Leaf length and days to maturity were governed by additive gene effects in cross T 3 × JM 2106 (Table 6). In cross JM 2106 × T 3, days to maturity was controlled by both additive and dominance gene effects.

**Table 4. A, B, C and joint scaling tests for yield and yield traits in the crosses between *C. arietinum* and *C. reticulatum***

| Character | Cross | Test | | | |
|---|---|---|---|---|---|
| | | A | B | C | joint scaling test |
| Leaf length | T 3 × JM 2106 | ns | ns | ns | ns |
| | JM 2106 × T 3 | ns | ns | ns | ** |
| | ICC 8923 × JM 2106 | ** | ** | ** | ** |
| | JM 2106 × ICC 8923 | ns | * | ns | ** |
| Primary branches | T 3 × JM 2106 | ns | ns | ** | ** |
| | JM 2106 × T 3 | ** | ns | ns | ** |
| | ICC 8923 × JM 2106 | ** | * | ns | ** |
| | JM 2106 × ICC 8923 | * | ns | * | ** |
| Days to flower | T 3 × JM 2106 | ** | ns | ** | ** |
| | JM 2106 × T 3 | ns | * | * | ** |
| | ICC 8923 × JM 2106 | * | ns | ns | ** |
| | JM 2106 × ICC 8923 | ** | ** | ns | ** |
| Days to maturity | T 3 × JM 2106 | ns | * | * | ** |
| | JM 2106 × T 3 | ns | ns | ns | ns |
| | JM 2106 × ICC 8923 | ns | ns | ** | ** |
| Pods/plant | T 3 × JM 2106 | ns | ns | ** | ** |
| | JM 2106 × T 3 | ** | ns | ns | ** |
| Seeds/pod | T 3 × JM 2106 | ns | * | ** | ** |
| | JM 2106 × T 3 | * | ** | ** | ** |
| | ICC 8923 × JM 2106 | ns | * | ns | * |
| Yield/plant | JM 2106 × T 3 | ** | ns | ns | ** |
| | ICC 8923 × JM 2106 | * | * | * | * |
| 100-seed weight | T 3 × JM 2106 | * | ns | ns | * |
| | ICC 8923 × JM 2106 | ** | ** | ** | * |
| | JM 2106 × ICC 8923 | ns | ** | ns | ** |

*, **$P<0.05$ and 0.01, respectively. ns—nonsignificant.

The previous workers studied these gene effects in intervarietal crosses of chickpea, while the present study is based on interspecific crosses. This may limit the validity of comparison of the results from this study with those of earlier workers. However, there was a general similarity between the present findings and those from the earlier studies.

It appears that the interaction gene effects were more important than additive and dominance effects in the control of most yield and yield traits in the crosses

**Table 5. Estimates of gene effects (six-parameter model) for yield and yield traits in crosses between *C. arietinum* and *C. reticulatum***

| Cross | $m$ | $\hat{d}$ | $\hat{h}$ | $\hat{i}$ | $\hat{j}$ | $\hat{l}$ |
|---|---|---|---|---|---|---|
| **Leaf length** | | | | | | |
| T 3 × JM 2106 | 5.9±0.2** | 1.1±0.3* | 1.7±1.1 | 1.1±1.1 | 0.2±0.4 | −0.3±1.8 |
| JM 2106 × T 3 | 6.1±0.1** | −0.3±0.1* | 2.0±0.6* | 1.1±0.4* | 0.4±0.2 | −1.0±1.1 |
| ICC 8923 × JM 2106 | 5.8±0.1** | 0.5±0.1* | −0.8±0.6 | −1.7±0.6* | −0.3±0.2 | 5.9±0.9** |
| JM 2106 × ICC 8923 | 6.3±0.04** | 0.1±0.1 | −0.1±0.5 | −0.6±0.3 | 0.7±0.2** | 1.5±1.1 |
| **Primary branches** | | | | | | |
| T 3 × JM 2106 | 3.3±0.1** | −0.8±0.2* | 2.1±0.7* | 2.4±0.7** | 0.1±0.3 | −2.3±1.2 |
| JM 2106 × T 3 | 3.9±0.3** | 0.3±0.1 | −0.4±1.4 | −1.3±1.2 | 0.6±0.2* | 5.0±1.9 |
| ICC 8923 × JM 2106 | 3.1±0.1** | −0.3±0.2 | 5.5±0.8** | 5.6±0.7** | 0.7±0.3 | −10.2±1.2** |
| JM 2106 × ICC 8923 | 3.9±0.1** | 1.4±0.1** | −1.5±0.7 | −1.6±0.8* | 0.5±0.2* | 1.4±0.9 |
| **Days to flower** | | | | | | |
| T 3 × JM 2106 | 82.7±1.4** | −17.0±2.9** | 14.2±8.4 | 10.0±8.2 | −10.5±3.1** | 3.7±13.3 |
| JM 2106 × T 3 | 89.0±0.5** | 17.0±2.8** | −21.8±6.7** | −22.0±6.2** | −10.5±3.6** | 30.3±12.8* |
| ICC 8923 × JM 2106 | 89.0±1.5** | −14.7±3.5** | −20.0±10.1 | −29.3±9.3* | −5.0±4.8 | 61.3±17.1** |
| JM 2106 × ICC 8923 | 90.3±3.2** | 14.3±2.8** | −51.5±13.9** | −54.0±13.9** | 1.5±3.3 | 105.7±17.6** |
| **Days to maturity** | | | | | | |
| T 3 × JM 2106 | 167.0±1.7** | −13.7±2.5** | 2.2±6.7 | 1.3±8.5 | −5.2±2.9 | −21.7±12.5 |
| JM 2106 × T 3 | 167.7±2.4** | 11.3±4.6* | 4.3±14.0 | −8.0±13.3 | −1.3±5.5 | 22.0±22.6 |
| JM 2106 × ICC 8923 | 151.0±4.6** | 8.7±3.5* | 76.8±19.8** | 65.3±19.6** | 3.8±42.8 | −66.9±23.8* |
| **Pods per plant** | | | | | | |
| T 3 × JM 2106 | 78.7±4.3** | 29.6±21.6 | 223.3±48.8** | 144.0±47.0* | 29.0±25.1 | −66.1±92.9 |
| JM 2106 × T 3 | 107.5±9.3** | −18.5±5.7** | −39.4±40.5 | −86.6±38.8* | −38.0±8.3** | 226.6±51.0** |
| **Seeds per plant** | | | | | | |
| T 3 × JM 2106 | 1.2±0.01** | 0.1±0.03 | −0.1±0.1 | −0.1±0.1 | −0.1±0.3 | −0.2±0.1 |
| JM 2106 × T 3 | 1.2±0.01** | −0.1±0.01** | −0.2±0.05** | −0.1±0.05* | 0.004±0.01 | −0.1±0.1 |
| ICC 8923 × JM 2106 | 1.1±0.02** | 0.1±0.04 | −0.1±0.1 | −0.1±0.1 | 0.004±0.04 | 0.5±0.2 |
| **Yield per plant** | | | | | | |
| JM 2106 × T 3 | 19.5±1.6** | −7.9±1.5** | 12.1±7.6 | 1.1±7.2 | −5.9±1.8** | 6.9±10.2 |
| ICC 8923 × JM 2106 | 15.7±1.3** | −0.5±0.3 | 22.1±10.7 | −0.1±5.1 | −1.9±1.2 | 50.2±19.4* |
| **100-seed weight** | | | | | | |
| T 3 × JM 2106 | 17.4±0.4** | 1.8±0.8 | 4.5±2.6 | 2.6±2.3 | −2.1±0.8* | 0.2±4.3 |
| ICC 8923 × JM 2106 | 17.7±0.2** | 0.1±0.2 | −4.7±1.2** | −7.9±1.1** | −2.6±0.4** | 21.0±1.8** |
| JM 2106 × ICC 8923 | 18.3±0.6** | 1.2±0.4* | −0.6±3.0 | −4.9±2.7 | 4.2±0.8* | 12.4±3.9** |

*, **p< 0.05 and 0.01, respectively.

**Table 6. Estimates of $\hat{m}$, $\hat{d}$ and $\hat{h}$ by the three-parameter model for the noninteracting crosses between *C. arietinum* and *C. reticulatum***

| Cross | Character | Parameter | | |
|---|---|---|---|---|
| | | $\hat{m}$ | $d$ | $h$ |
| T 3 × JM 2106 | Leaf length | 6.10 ± 0.14** | 0.80 ± 0.13** | 0.31 ± 0.31 |
| T 3 × JM 2106 | Days to maturity | 164.56 ± 1.09** | 7.83 ± 1.09** | 0.86 ± 1.57 |
| JM 2106 × T 3 | –do– | 161.38 ± 2.58** | 11.20 ± 2.40** | 11.18 ± 4.34* |

*, ** P<0.05 and 0.01, respectively.

between *C. arietinum* and *C. reticulatum*. It may be expected that progress under selection in these crosses will be hampered by the preponderance of nonadditive gene effects. This, in fact, has been the case in the experiments on selection for yield and yield traits in these crosses [7].

## REFERENCES

1. A. M. Zafar and M. Abdullah. 1971. Diallel analysis of some economic characters in gram. J. Agric. Res. Pak., **9:** 14–24.
2. V. P. Gupta and S. Ramanujam. 1974. Genetic architecture of yield and its components in Bengal gram. Indian J. Genet., **34A:** 793–799.
3. B. M. Asawa and A. S. Tiwari. 1976. Analysis of genetic architecture in segregating populations of gram (*C. arietinum* L.). Z. Pflanzenzuchtg., **77:** 251–256.
4. R. P. Katiyar and D. Singh. 1979. Genetic architecture of yield and its components in chickpea. Indian J. Genet., **39:** 146–149.
5. Ramakrishna, R. P. Katiyar and Ziauddin Ahmad. 1979. Fractional diallel analysis for combining ability in Bengal gram. Indian J. Genet., **39:**: 171–177.
6. G. Ladizinsky and A. Adler. 1976. The origin of chickpea, *Cicer arietinum* L. Euphytica, **25:** 211–217.
7. H. K. Jaiswal. 1984. Genetic Studies on Interspecific Hybrids in *Cicer*. Ph. D. Thesis, Banaras Hindu University, Varanasi.
8. M. T. Moreno and J. I. Cubero. 1978. Variation in *Cicer arietinum* L. Euphytica, **27:** 465–485.
9. P. K. Lawrence and K. J. Frey. 1975. Backcross variability for grain yield in oat species crosses (*Avena sativa* × *A. sterilis* L.). Euphytica, **24:** 77–85.
10. K. J. Frey. 1976. Plant breeding in the seventies: useful genes from wild plant species. Egypt. J. Genet. Cytol., **5:** 160–182.
11. B. D. Singh, H. K. Jaiswal, R. M. Singh and A. K. Singh. 1984. Isolation of early flowering recombinants from the interspecific cross betwen *C. arietinum* ICC 8923 × *C. reticulatum* JM 2106. International Chickpea Newsletter, **11:** 14.
12. B. I. Hayman. 1958. The separation of epistatic from additive and dominance variation in generation means. Heredity, **12:** 371–390.
13. J. L. Jinks and R. M. Jones. 1958. Estimation of the components of heterosis. Genetics, **43:** 223-224.
14. V. G. Panse and P. V. Sukhatme. 1967. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.
15. K. Mather. 1949. Biometrical Genetics. The Study of Continuous Variation. Dover Publication Inc., New York.

16. B. I. Hayman and K. Mather. 1955. The description of gene action in continuous variation. Biometrics, **11:** 69–82.

17. L. L. Cavalli. 1952. An analysis of linkage in quantitative inheritance. *In:* Quantitative Inheritance (eds. E. C. R. Rieve and G. H. Waddington). H.M.S.O. London: 135–144.

18. H. Ketata, L. H. Edwards and E. L. Smith. 1976. Inheritance of eight agronomic characters in a winter wheat cross. Crop Sci., **16:** 19–22.

19. H. Ketata, E. L. Smith, L. H. Edwards and R. W. McNew. 1976. Detection of epistatic, additive and dominance variation in winter wheat (*T. aestivum* L. em Thell.). Crop Sci., **16:** 1–4.

20. S. Singh and R. B. Singh. 1978. A study of gene effects in three wheat crosses. J. Agric. Sci. Camb., **91:** 9–12.