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A gene producing one to nine flowers per flowering node in chickpea

P.M. Gaur[1] & V.K. Gour

Department of Plant Breeding and Genetics, Jawaharlal Nehru Agricultural University, Jabalpur 482 004, MP, India; [1]*Present address: International Crop & Research Institute for the Semi-Arid Tropics, Patancheru 502 324, AP, India E-mail: p.gaur@cgiar.org*

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Summary

Chickpea (*Cicer arietinum* L.) has a racemose type of inflorescence and at each axis of the raceme usually one or two and rarely three flowers are borne. Plants producing 3 to 9 flowers, arranged in a cymose inflorescence, at many axis of the raceme, were identified in F_2 of an interspecific cross ICC 5783 (*C. arietinum*) × ICCW 9 (*C. reticulatum*) in which both the parents involved were single-flowered. A spontaneous mutation in one of the two parents or in the F_1 was suspected. However, the possibility for establishment of a rare recombination of two interacting recessive genes could not be ruled out. The number of pods set varied from 0 to 5 in each cyme. Inheritance studies indicated that a single recessive gene, designated *cym*, is responsible for cymose inflorescence. The allelic relationship of *cym* with *sfl*, a gene for double-flowered trait, was studied from a cross involving multiflowered plants and the double-flowered line ICC 4929. The *cym* gene was not allelic to *sfl*, suggesting that two loci control the number of flowers per peduncle in chickpea. The *cym* locus segregated independently of the locus *sfl*, *ifc* (inhibitor of flower color) and *blv* (bronze leave).

Introduction

Chickpea (*Cicer arietinum* L.), a diploid (2n = 2x = 16) member of the family Leguminosae and subfamily Papilionoideae, is the most important pulse crop of South Asia and the third most important pulse crop in the world. Despite extensive breeding efforts, there has not been a substantial increase in the global yield of chickpea. At about 800 kg ha^{-1}, it ranks among the lowest of food crops.

Chickpea yield fluctuates highly in most countries. Drought has been the most important factor for instability of yield as chickpea is mainly grown as rainfed crop on residual moisture. The other important factors providing instability to chickpea yield are ascochyta blight (*Ascochyta rabiei*) fusarium wilt (*Fusarium oxysporum* f. sp. *ciceri*) and pod-borer (*Helicoverpa armigera*).

Several mutant lines are available which produce twin-flowers (double-flowers) per peduncle in lieu of a single-flower per peduncle normally found in this crop. There have been variable reports on yield advantage of double-flowered/double-podded trait. Sheldrake et al. (1978) studied the effects of converting double-podded plants to single-podded ones by cutting off one of the flowers at every double-podded node on the yield and concluded that the double-podded character may increase the yield by 6 to 11%. In the studies of Kumar et al. (2000), the double-podded trait gave an yield advantage of 18% in the F_2 and 7% among recombinant inbred lines. On the other hand, no yield advantage of double-podded trait was observed by Knights (1987) and Rubio et al. (1998). Singh & van Rheenen (1989, 1994) suggested that the double-podded trait enhances yield in certain environments and that it can play an important role in stabilizing chickpea yield. Rubio et al. (1998) also found a positive effect of the double-pod gene on the stability of yield in chickpea.

This report identifies a new gene in chickpea that produces 3 to 9 flowers per peduncle at many flowering nodes. The gene may play an important role in

enhancing chickpea productivity and/or in providing stability to the yield.

Materials and methods

The chickpea genotypes used in this study included three of *C. arietinum* (ICC 4929, ICC 5783, JG 315) and one of *C. reticulatum* (ICCW 9). Four multiflowered plants were identified in an F_2 population of the cross ICC 5783 × ICCW 9. Progenies from these plants were crossed to the *C. arietinum* genotypes ICC 4929 and JG 315, and the *C. reticulatum* accession ICCW 9. All the plants were grown in normal field conditions following standard cultural practices. Each F_1 plant in each cross was harvested separately and advanced to F_2. Each F_2 plant in each F_2 family was tagged and numbered. Visual observations were recorded on the segregating morphological characters, namely foliage colour, flower colour and number of flowers/axis.

Segregation and linkage analyses were performed using the computer program LINKAGE–1 developed by Suiter et al. (1983). This program tests monogenic inheritance using goodness-of-fit χ^2 test, detects linkage using a contingency χ^2 test and calculates recombination fraction (r) and its standard error (SE) using the maximum likelihood formulae.

Results and discussion

An interspecific cross between the accession ICC 5783 (bronze foliage) of *C. arietinum* and the accession ICCW 9 of *C. reticulatum* was made for genetic studies. The F_2 derived from this cross had only 18 plants. Hence, the population was discarded from genetic studies and left in the field. At flowering, a conspicuous plant with profuse flowering and unusual flowering arrangement was observed. On examination, the plant was found to have 3 to 9 flowers at many flowering nodes. The remaining 17 plants of the F_2 family were then critically examined and three more plants were found to have similar flowering behavior. All four multiflowered plants had bronze foliage and produced reticulated or partially reticulated seeds suggesting that they were genuine recombinants from the interspecific cross under study. Each of these four plants bred true for the multiflowered trait in the F_3 and succeeding generations.

Chickpea has a racemose type of inflorescence and at each axis of raceme usually one or two flowers are borne. The multiflowered plants identified in this study had more than two flowers, arranged in cymose inflorescence, at many nodes of the raceme. In each cyme, the main axis ended in a flower and at the same time it produced two lateral younger flowers (biparous). Each lateral axis further produced successive flowers but only one at a time (uniparous) and on the same side (helicoid) (Figures 1 & 2). A maximum of nine flowers were seen in a cyme. However, the number of pods set in each cyme varied from 0 to 5. The multiflowered plants had profuse flowering (Figure 1) and podding (Figures 2, 3 & 4). Chickpea lines are known which produce three flowers/pods at some flowering nodes (Janoria & Sharma, 1983; Singh & Chaturvedi, 1998). However, this report is the first on occurrence of clusters of more than three flowers per peduncle in chickpea.

Although the F_2 population was not sufficient to test any genetic hypothesis, the trait appeared to fit a 3:1 monogenic ratio. The F_3 progenies grown from these four multiflowered plants and the remaining 14 single-flowered F_2 plants further provided support on monogenic inheritance of this trait. All four multiflowered plants and five single-flowered plants bred true, whereas each of the nine remaining single-flowered plants segregated for single-flowered and multiflowered plants in the F_3. It was interesting to note that both parents (ICC 5783 of *C. arietinum* and ICCW 9 of *C. reticulatum*) involved in this cross were single-flowered. Spontaneous recessive mutation at a single locus in one of the parents or in the F_1 may possibly be the reason for occurrence of the multiflowered trait. However, there may also be a possibility that two genes tightly linked in repulsion phase may have come to coupling phase due to a rare recombination and the two recessive genes now closely residing on the same chromosome are interacting to give multiflowers.

The multiflowered plants were crossed to ICCW 9, the *C. reticulatum* accession used as a parent in the original cross from which these plants were isolated. Multiflowered plants were also crossed to two genotypes of *C. arietinum,* which included the well known single-flowered wilt-resistant cultivar JG 315 and a double-flowered germplasm line ICC 4929. The multiflowered plants had bronze colored foliage, whereas the remaining genotypes had normal green foliage. The accession ICC 4929 had pink-veined white flowers, whereas all other parental lines, including multiflowered plants, had pink flowers.

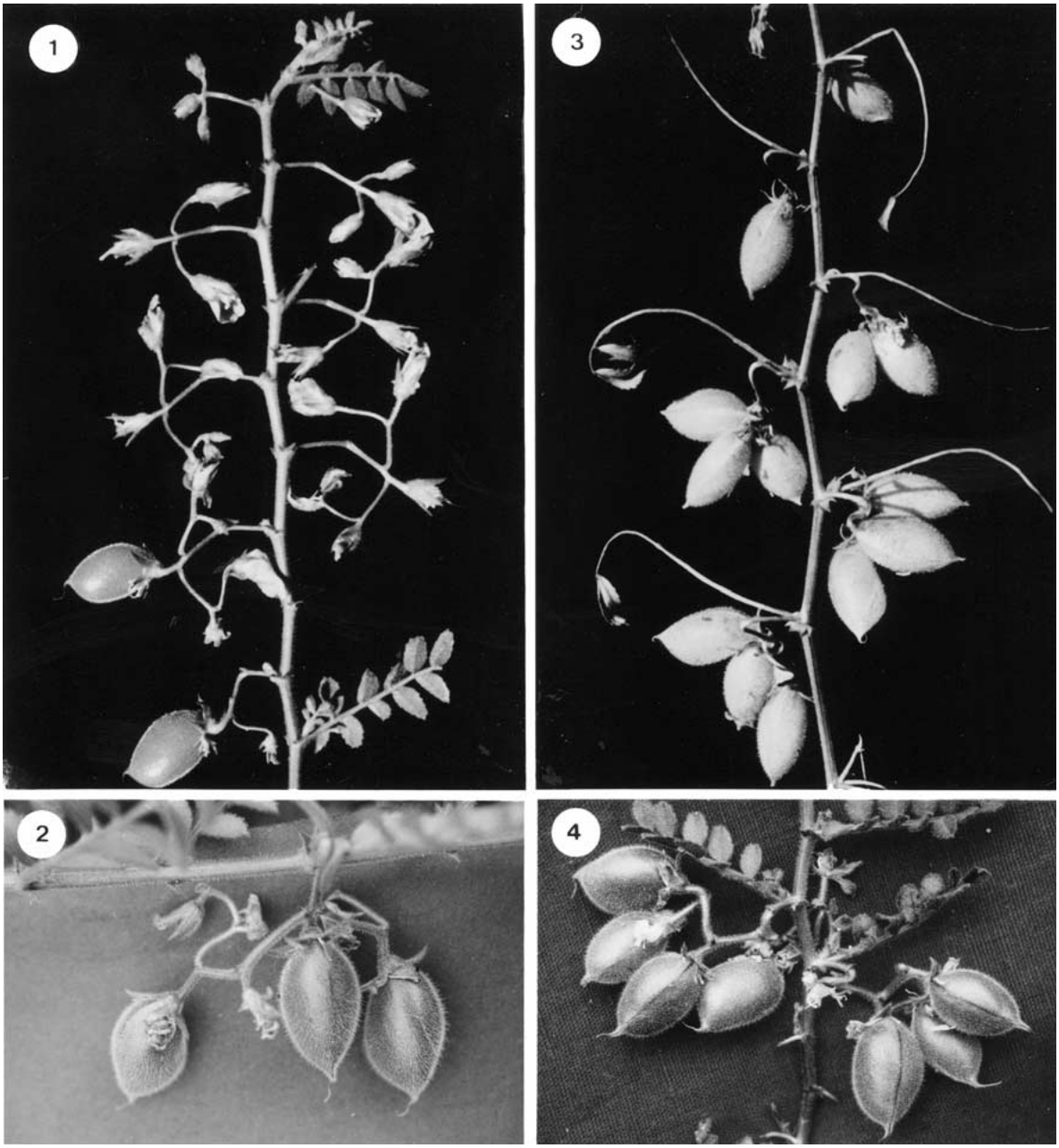

Figure 1. A new multiflowered trait identified in chickpea. Chickpea normally has racemose type of inflorescence and at each axis of the raceme only one or two flowers are borne. In this newly identified multiflowered trait more than two flowers, arranged in a cymose inflorescence, were observed at many axis of the raceme. In each cyme, the main axis ended in a flower and at the same time it produced two lateral younger flowers (biparous). Each lateral axis further produced successive flowers but only one at a time (uniparous) and on the same side (helicoid). *Figures 2–4:* The multiflowered plants showing formation of more than two pods at many flowering nodes.

Table 1. F_2 segregation for number of flowers/axis in chickpea

Cross	Phenotype of F_1	Observed F_2 phenotypic classes and number of plants in each class				χ^2	P
		Single-flowered	Double-flowered	Multi-flowered	Double-multi-flowered		
Multiflowered × JG 315 (single-flowered)	Single-flowered	200	–	56	–	1.33[a]	0.25
Multiflowered × ICCW 9 (single-flowered)	Single-flowered	157	–	40	–	2.32[a]	0.13
ICC 4929 (double-flowered) × Multiflowered	Single-flowered	166	71	65	18	3.72[b]	0.30

[a] Expected ratio 3:1.
[b] Expected ratio 9:3:3:1.

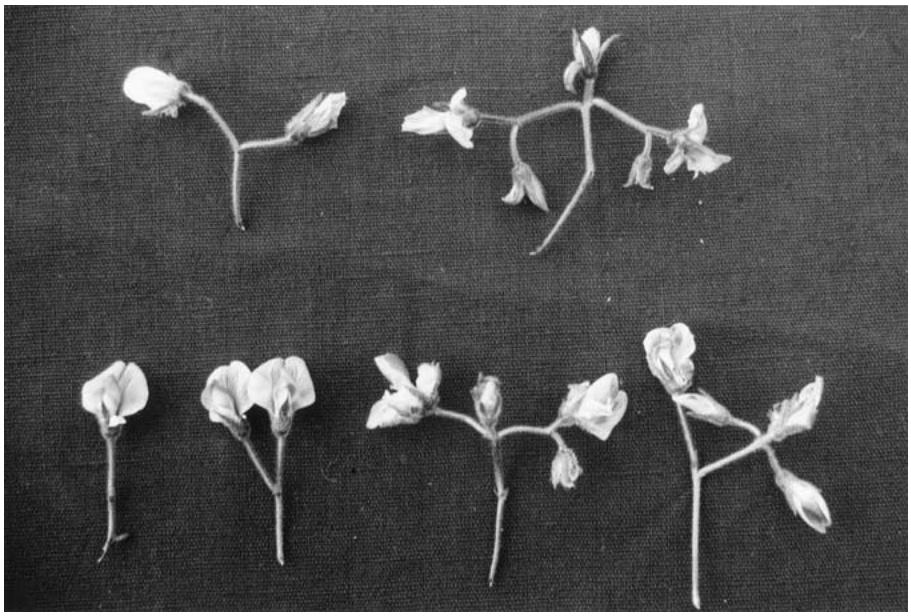

Figure 5. F_2 segregation for number of flowers/axis in chickpea from a cross between double-flowered (ICC 4929) × multiflowered parents. Top row: Flowers of two parents – double-flowered (*left*) and multiflowered (*right*). Bottom row: The four phenotypic classes for number of flowers/axis observed in F_2 from the above cross – single-flowered, double-flowered, multiflowered, and double-multiflowered (*left to right*). Note that in single-flowered and in multiflowered types, one floral peduncle originates from the racemal peduncle, whereas in double-flowered and in double-multiflowered types, two floral peduncles originate from the racemal peduncle.

The F_1s from multiflowered × single-flowered plants were single-flowered suggesting that the single-flower trait is dominant over multiflowers. The F_2s from multiflowered × ICCW 9 and multiflowered × JG 315 crosses gave a good fit to a 3:1 ratio for single-flowered and multiflowered plants (Table 1), confirming monogenic inheritance of the multiflowered trait. A gene symbol *cym* is proposed for the recessive gene responsible for producing multiflowers arranged in cymose inflorescence at most nodes of the raceme.

The genetics of double-flowered (or double-podded) trait of chickpea has been thoroughly worked out (Khan & Akhtar, 1934; Ahmad, 1964; Singh, 1965; Patil, 1966; D'Cruz & Tendulkar, 1970; More & D'Cruz, 1976; Yadav et al., 1978; Pawar & Patil, 1983; Rao & Pundir, 1983; Singh & van Rheenen, 1994). A single recessive gene, designated *s* by Khan & Akhtar (1934) and *sfl* by D'Cruz & Tendulkar (1970), has been reported to govern double-flowered/double-podded trait. The triple-podded trait

has also been reported to be monogenic and controlled by a recessive gene *trp* (Singh & Chaturvedi, 1998). The allelic relationship of *sfl* and *trp* is not known.

The possible allelic relationship of *cym* with *sfl* was investigated in this study using the cross ICC 4929 (double-flowered) × multiflowered. F_1s from this cross were single-flowered and the F_2 gave a good fit to 9 single-flowered: 3 double-flowered: 3 multiflowered: 1 double-multiflowered plants (Table 1, Figure 5). These results suggest that the gene for double-flowers and the gene for multiflowers are not allelic. Thus, we conclude that two independent loci control the number of flowers per axis in chickpea.

Linkage relationships of *cym* was studied with the genes *sfl*; *ifc* that inhibits flower color without inhibiting vein-color of the vexillum, producing pink-veined white flower in ICC 4929 (Gaur & Gour, 2001); and *blv* for bronze leaves (Bhapkar & Patil, 1963) from the cross multiflowered × ICC 4929. The linkage relationship of *cym* and *blv* was also studied from the cross multiflowered × JG 315. No linkage was detected among these genes (data not shown).

Preliminary observations indicate that the multiflowered trait may give an yield advantage to chickpea by giving higher number of pods per plant. However, more studies would be necessary to examine the effect of multiflowered (multipodded) trait on seed size and conclusively demonstrate the value of this trait in chickpea breeding.

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