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# An induced brachytic mutant of chickpea and its possible use in ideotype breeding

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**Abstract** Mutations were induced in chickpea (*Cicer arietinum* L.) cultivar 'JG 315' through treatment of seeds with ethyl methane sulphonate (EMS). One of the mutants, named JGM 1, had brachytic growth (compact growth), characterized by erect growth habit, thick and sturdy stem, short internodal and interleaflet distances and few tertiary and later order branches. It was isolated from $M_2$ derived from seeds treated with 0.6% EMS for 6 h. Segregation analyses in $F_2$ progenies of its crosses with normal chickpea genotypes (JG 315, ICC 4929, and ICC 10301) suggested that a single recessive gene controlled brachytic growth in JGM 1. This gene was not allelic to the *br* gene for brachytic growth in spontaneous brachytic mutant E100YM. Thus, the gene for brachytic growth in JGM 1 was designated *br2* and the *br* gene of E100YM was redesignated *br1*. Efforts are being made to use JGM 1 in development of a plant type with short internodes and erect growth habit. Such plant type may resist excessive vegetative growth in high input (irrigation and fertility) conditions and accommodate more plants per unit area.

**Keywords** *Cicer arietinum* · Brachytic · Compact growth · Ideotype breeding · Inheritance · Induced mutation · Short internodes

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## Introduction

Chickpea (*Cicer arietinum* L.) is the second largest grown food legume of the world covering an area of 11.2 million ha across 49 countries (FAOSTAT data 2006). About 97% of the chickpea area is in developing countries, where it is largely grown under marginal conditions of moisture stress and low fertility. One of the reasons for not growing chickpea in high input conditions is that the available varieties do not respond favorably to high fertility and irrigated conditions. As chickpea has indeterminate growth habit, excess water promotes vegetative growth, which acts as competitive sink for developing pods and seeds (Khanna-Chopra and Sinha 1990). Although one or two irrigations considerably enhance the yield, particularly in moisture stress conditions, a decline in yield occurs at higher irrigation levels due to excessive vegetative growth of the plants and poor pod set (Sinha et al. 1985). On the other hands in cereals, the amount of water available after anthesis has a linear relationship with yield (Passioura 1976). Thus, when farmers have fertile soils and assured sources to support higher number of irrigations, they prefer to grow a crop, such as wheat, that respond well to high input conditions. This is evident from the progressive shift of chickpea area from the traditional high productive regions of northern India toward dry regions in central and peninsular India (Lal 1992).

Restructuring of plant type, which was a key to enhancing productivity of wheat and rice, is needed for bringing a breakthrough in chickpea productivity. Attempts have been made to define ideotype of chickpea for different growing conditions. Jain (1975) suggested that major gains in chickpea yield could be achieved by developing a plant type with high harvest index, response to increased plant population per unit area, and early maturity. He further suggested that improvement in harvest index would likely to be associated with determinate and compact growth habit. Bahl and Jain (1977) included erect growth habit, many primary and secondary branches and few tertiary and later order branches in chickpea ideotype. According to them this plant type would intercept more sunlight and permit large population per unit area. Sedgley et al. (1990) also emphasized that an ideotype for high input environments should have erect growth habit and limited branching.

Efforts have been made to breed for erectness combined with tall growth by hybridization between conventional spreading and tall types (Bahl 1980). However, no significant improvement in harvest index was achieved because the internodal length of the resultant progenies was large and substantial assimilates were spent on structural parts of the plant (Khanna-Chopra and Sinha 1987). An emphasis on short internodes and compact growth in the ideotype has been given by several researchers (Ramanujam 1975; Sinha 1977; Gupta and Lal 1981; Dahiya and Lather 1990). Such plant type is expected to give high harvest index accommodate more plants per unit area and resist excessive vegetative growth in high input conditions.

A spontaneous brachytic mutant with short internodes and compact growth habit, E100YM, has been identified (Dahiya et al. 1984) and used in ideotype breeding (Dahiya et al. 1988, 1990a, b; Sandhu et al. 1990; Lather 2000). Promising progenies with compact growth habit and which can be grown at high plant density have been obtained (Lather 2000). The mutant E100YM is presently the only source of short internodes and compact growth habit available in chickpea. This report describes an induced mutant that can be used as an alternative source of short internodes and compact growth habit by chickpea breeders.

## Materials and methods

Mutations were induced in desi chickpea cultivar JG 315, a wilt-resistant popular variety of central India, through treatment with ethyl methane sulphonate (EMS). The details of seed treatment and growing of $M_1$ and $M_2$ generations have been described earlier (Gaur and Gaur 1999, 2003; Gaur et al. 2004). Six major morphological mutants were identified in $M_2$. Five of these mutants—fasciated stem [Jawahar Gram Mutant 2 (JGM 2)] (Gaur and Gour 1999); broad-few-leaflets (JGM 4) and outwardly curved wings (JGM 5) (Gaur and Gour 2003); and variegated leaf (JGM 3) and apical chlorosis (JGM 6) (Gaur et al. 2004), have been reported earlier. The sixth and the last major mutant (brachytic mutant) obtained from this experiment is described here. This mutant was isolated from $M_2$ derived from the seed treated with 0.6% EMS for 6 h.

The brachytic mutant was named JGM 1. The mutant was crossed with its parental cultivar JG 315 and two other accessions of desi chickpea, ICC 4929 (double-podded and pink-veined white flower) and ICC 10301 (simple leaf), for study of inheritance of the mutant trait. A spontaneous brachytic growth mutant, E100YM, has been reported earlier by Dahiya et al. (1984). JGM 1 was crossed with E100YM to determine allelic relationship of genes controlling brachytic growth in the two mutants. The $F_1$ and $F_2$ were grown in normal field conditions and observations were recorded on each segregating trait on individual $F_2$ plants. Inheritance and linkage analyses were performed using the computer program LINKAGE-1 (Suiter et al. 1983).

The segregants with compact growth habit and double-pod trait were selected from the cross-JGM 1 (single-podded) × ICC 4929 (double-podded) and single plant progenies were grown in $F_3$. Further single plant selections were made in $F_3$. One hundred $F_4$ progenies, derived from the selected $F_3$ plants, were evaluated along with 'JG 315.' Each line was grown in a single row of 6 m length, keeping a distance of 30 cm between rows. 'JG 315' was planted after every ten lines. Observations were recorded on ten randomly taken plants in each row.

## Results and discussion

The brachytic growth mutant JGM 1 was identified in $M_2$ of the cultivar JG 315 derived from the seeds treated with 0.6% EMS for 6 h. The mutant had erect and sturdy stem with short internodal and interleaflet distances (Fig. 1). It had few tertiary and later order branches and its seeds were elongated. The mutant bred true in the succeeding generations.

One spontaneous brachytic growth mutant has been earlier reported in chickpea (Dahiya et al. 1984). It was identified from the germplasm line E100Y and was designated E100YM. Although both the mutants had shorter internodes (average internodal distance 1.15 cm in JGM 1 and 0.91 cm in E100YM), closer leaflets, and compact growth habit, they differed from each other for several traits (Table 1; Figs. 1, 2). JGM 1 had less height, lower number of nodes per primary branch, earlier in maturity, higher number of pods per plant, smaller seeds, and higher yield per plant than E100YM. The foliage of E100YM was dark green, whereas JGM 1 had normal green color, most common in chickpea germplasm. The leaves of JGM 1 were straight and more upright, while leaves of E100YM were slightly curved at the terminal end (Fig. 2). The distance between stipule and the first leaflet was higher in JGM 1 as compared to that in E100YM (Fig. 2).

**Fig. 1** Plants of spontaneous brachytic growth mutant E100YM (*left*) and induced brachytic growth mutant JGM 1 (*right*)

Inheritance of compact growth habit of JGM 1 was studied in $F_2$ of three crosses (JGM 1 × JG 315, JGM 1 × ICC 4929, and JGM 1 × ICC 10301). $F_1$s from all three crosses had normal plant type, indicating the dominance of normal plant type over brachytic plant type. The $F_2$ population of each cross-gave a good fit to a ratio of 3:1 for normal and brachytic plant types (Table 2). These results suggest that a single recessive gene controls brachytic growth in JGM 1. The brachytic growth in E100YM has also been reported to be controlled by a single recessive gene, designated *br* (Dahiya et al. 1984).

The allelic relationship of genes controlling brachytic growth in JGM 1 and E100YM was studied by intercrossing these mutants. The $F_1$ from JGM 1 × E100YM had normal plant type, indicating that the genes for brachytic growth in the two mutants are not allelic. The $F_2$ of the cross-JGM 1 × E100YM produced four types of plants—normal type, JGM 1 type, E100YM type, and Dwarf type in a ratio of 9:3:3:1 (Table 2). These results further confirmed that the genes for brachytic growth in the two mutants were not allelic and thus two genes segregated for brachytic growth in JGM 1 × E100YM cross. We propose to designate the gene for brachytic growth in JGM 1 as *br2* and the *br* gene of E100YM as *br1*.

In $F_2$ population, the two types of brachytic growth plants (JGM 1 type and E100YM type) could be distinguished based on the leaf characteristics, foliage color, and growth habit of two mutants. The $F_2$ plants carrying both the brachytic genes in homozygous recessive condition (*br1br1 br2br2* genotype) were very dwarf (Table 3) and had much shorter internodes and closer leaflets than the two mutants. These plants bred true in $F_3$.

The four plant types obtained in $F_2$ of JGM 1 × E100YM were compared for plant biomass, plant height, number of pods per plant, number of seeds per plant, 100-seed weight, yield per plant, and harvest index. Significant differences were found among the four plant types for all these traits (Table 3). The normal type plants were taller, produced more number of pods and seeds per plant and gave higher yield than the remaining plant types. JGM 1 type plants were superior to E100YM type plants in productivity (number of pods and seeds per plant and yield per plant) though E100YM type plants had

**Table 1** Morphological features of induced brachytic growth mutant JGM 1 and spontaneous brachytic growth mutant E100YM of chickpea

| Character | Mean ± SE | |
|---|---|---|
| | JGM 1 | E100YM |
| Days to 50% flowering | 73 ± 0.84 | 88 ± 2.68 |
| Days to maturity | 126 ± 0.84 | 135 ± 0.86 |
| Plant height (cm) | 28.2 ± 0.96 | 42.0 ± 0.87 |
| Number of nodes per primary branch | 19.6 ± 6.55 | 30.5 ± 6.81 |
| Average internodal length (cm) | 1.15 ± 0.037 | 0.91 ± 0.001 |
| Number of primary branches per plant | 3.4 ± 0.24 | 3.3 ± 0.24 |
| Number of secondary branches per plant | 5.4 ± 0.18 | 7.1 ± 0.96 |
| Plant dry weight (g) | 12.13 ± 1.12 | 15.20 ± 1.10 |
| Number of filled pods per plant | 39 ± 5.96 | 14 ± 2.56 |
| Number of empty pods per plant | 5 ± 0.75 | 3 ± 0.44 |
| Number of seeds per plant | 49 ± 8.73 | 14 ± 2.72 |
| Seed yield per plant (g) | 4.9 ± 0.92 | 2.8 ± 0.48 |
| 100 seed weight (g) | 10.8 ± 0.41 | 20.3 ± 0.58 |
| Harvest index | 0.37 ± 0.044 | 0.18 ± 0.022 |

**Fig. 2** Branches of E100YM (*left*) and JGM 1 (*right*). The leaves of E100YM were curved at the terminal end, while the leaves of JGM 1 were straight and upright

slightly larger seeds. The dwarf type plants had lowest mean values for all the traits.

In addition to *Br2*, two other loci, *Sfl* (one of the two loci involved in controlling number of flower per axis; Srinivasan et al. 2006) and *Ifc* (the recessive allele at this locus inhibits flower color without affecting vein color; Gaur and Gour 2001) segregated in $F_2$ of JGM 1 × ICC 4929 and one locus *Slv* (the locus that controls simple leaf type; Ekbote 1937) in $F_2$ of JGM 1 × ICC 10301. The *Br2* locus segregated independently of these loci (data not shown). Thus, it was possible to combine these traits.

The mutant E100YM has been used in developing a plant type with erect and upright growth habit, so that yield per unit area can be increased by enhancing plant density (Dahiya et al. 1988, 1990a, b; Lather 2000; Sandhu et al. 1990). Progenies were obtained which were erect and compact in growth with strong and reasonably tall stem and few but erect secondary and later order branches. One of these lines, H96-99, recorded a yield of about 4.0 t $ha^{-1}$ under high plant density of 50 plants $m^2$. The plant density generally recommended for chickpea is 33 plants $m^2$ (Lather 2000).

We found that the compact growth habit plants generally have lower number of pods per plant than the normal plants due to reduction in tertiary and later order of branches. From $F_2$ of JGM 1 (single-podded) × ICC 4929 (double-podded) cross, we selected plants with compact growth habit with double-pod traits, so that number of pods per plant can be enhanced. $F_3$ progenies were grown from these plants and 100 single plants were selected based on plant type and number of pods per plant. The $F_4$ progenies were subjected to preliminary yield evaluation along with the variety ‘JG 315.’ A comparison

**Table 2** Goodness-of-fit $\chi^2$-test for brachytic growth in $F_2$ of different crosses in chickpea

| Cross | Observed frequencies in $F_2$ phenotypic classes | | | | Expected genetic ratio | $\chi^2$ | P |
|---|---|---|---|---|---|---|---|
| | Normal type | JGM 1 type | E100YM type | Dwarf type | | | |
| JGM 1 × JG 315 | 280 | 106 | – | – | 3:1 | 1.25 | 0.26 |
| JGM 1 × ICC 4929 | 180 | 50 | – | – | 3:1 | 1.30 | 0.25 |
| JGM 1 × ICC 10301 | 168 | 44 | – | – | 3:1 | 2.04 | 0.15 |
| JGM 1 × E100YM | 200 | 76 | 64 | 20 | 9:3:3:1 | 1.55 | 0.68 |

**Table 3** Morphological features of different plant types observed in $F_2$ of JGM 1 × E100YM

| Character | Mean ± SE | | | |
|---|---|---|---|---|
| | Normal type | JGM 1 type | E100YM type | Dwarf type |
| Plant dry weight (g) | 38.9 ± 1.42 | 23.5 ± 1.59 | 9.6 ± 1.38 | 2.8 ± 0.56 |
| Plant height (cm) | 43.4 ± 0.54 | 40.6 ± 0.74 | 32.5 ± 0.64 | 21.8 ± 1.99 |
| Number of filled pods per plant | 94.6 ± 4.78 | 69.1 ± 4.96 | 17.7 ± 2.35 | 4.5 ± 1.50 |
| Number of empty pods per plant | 7.1 ± 0.51 | 5.6 ± 0.73 | 2.5 ± 0.41 | 1.0 ± 0.00 |
| Number of seed per plant | 108.1 ± 5.28 | 74.6 ± 5.17 | 18.4 ± 2.41 | 4.0 ± 1.00 |
| Seed yield per plant (g) | 17.9 ± 0.89 | 11.2 ± 0.81 | 3.35 ± 0.47 | 0.55 ± 0.25 |
| 100-seed weight | 16.5 ± 0.32 | 14.9 ± 0.47 | 18.6 ± 0.97 | 13.0 ± 3.00 |
| Harvest index | 0.44 ± 0.02 | 0.44 ± 0.02 | 0.34 ± 0.03 | 0.23 ± 0.07 |

of the performance of the best five lines with the check variety ‘JG 315’ revealed that these lines were 2–6 days late in maturity, had reduced plant height, more number of pods as well as seeds per plant, at par or higher grain yield per plant and smaller seeds than ‘JG 315’ (Table 4). A comparison of the morphological features of the check cultivar JG 315 and the new plant types is provided in Figs. 3 and 4. A major improvement in these new plant type lines is needed for seed size and maturity duration. The line ICC 4929 used as source of double-podded trait was not a good choice as it has small seeds and late maturity. The selected lines are now being crossed with early maturing, large seeded and high yielding cultivars for improvement of seed size and reduction in maturity duration.

We expect that the new plant type lines with short internodes will restrict excessive vegetative growth in irrigated conditions. Another trait that could be useful for restricting excessive vegetative growth in chickpea is determinate growth habit. There are reports in other legumes on successful exploitation of this trait in cultivar development, e.g., soybean (Cooper et al. 2004), common bean (Saindon et al. 1996), cowpea (Mligo 1989), mungbean (Sandhu et al. 2003), white lupin (Gataulina et al. 2005), and pea (Scott and Goulden 1993). In soybean, determinate line resisted lodging under high N fertilization, while the indeterminate check cultivar had high lodging, leading to disease infestation, and substantial yield decreases (Wallace et al. 1990). In white lupin, determinate types are better adapted to cool and wet conditions where they are harvestable earlier, and have greater and more stable yields than determinate types (Juller et al. 1993). A mutant with determinate growth habit was identified in chickpea (van Rheenen et al. 1994) but its usefulness could not be assessed as it was sterile. A semi-determinate high yielding and high protein mutant, released as ‘Hypersola’ in Bangladesh, was found responsive to supplemental N as compared to its indeterminate parental cultivar Faridpur-1 (Shamsuzzamam et al. 2002). More efforts are needed on identifying/inducing determinate genotypes in chickpea and their exploitation in varietal development.

The spontaneous brachytic mutant, E100YM, has been the only source of short internodes and compact growth habit available in chickpea. The induced

**Table 4** Performance of the check cultivar JG 315 and best five $F_4$ new plant type lines (NPT) developed from JGM 1 × ICC 4929 cross

| Character | Mean ± SE | | | | | |
|---|---|---|---|---|---|---|
| | JG 315 | NPT 15 | NPT 18 | NPT 58 | NPT 61 | NPT 65 |
| Days to flowering | 110 ± 1.3 | 114 ± 1.6 | 115 ± 1.8 | 115 ± 1.4 | 112 ± 1.0 | 116 ± 1.5 |
| Plant height (cm) | 52.6 ± 2.0 | 46.0 ± 1.6 | 42.0 ± 1.5 | 45.6 ± 1.8 | 38.2 ± 1.0 | 41.0 ± 1.3 |
| Number of primary branches per plant | 5.5 ± 1.2 | 6.8 ± 2.1 | 5.7 ± 1.3 | 7.2 ± 2.2 | 6.3 ± 1.4 | 5.2 ± 1.2 |
| Number of secondary branches per plant | 18.1 ± 3.8 | 16.5 ± 2.4 | 14.2 ± 2.0 | 17.4 ± 2.6 | 14.2 ± 2.3 | 13.4 ± 2.1 |
| Number of pods per plant | 53.0 ± 8.0 | 93.0 ± 15.2 | 79.3 ± 9.4 | 91.8 ± 13.2 | 76.6 ± 11.6 | 63.0 ± 9.7 |
| Double-podded nodes (%) | 0.0 ± 0.0 | 19.4 ± 3.0 | 26.1 ± 4.1 | 22.4 ± 3.8 | 27.4 ± 4.3 | 30.9 ± 4.8 |
| Number of seeds per pod | 1.2 ± 0.1 | 1.1 ± 0.1 | 1.0 ± 0.1 | 1.1 ± 0.1 | 1.1 ± 0.1 | 1.3 ± 0.2 |
| Number of seeds per plant | 64.0 ± 8.3 | 102.3 ± 15.6 | 82.5 ± 10.1 | 92.7 ± 13.8 | 84.3 ± 12.2 | 81.9 ± 10.6 |
| Seed yield per plant (g) | 9.2 ± 2.4 | 11.3 ± 2.3 | 10.1 ± 2.0 | 10.8 ± 2.5 | 9.4 ± 2.3 | 11.1 ± 2.6 |
| 100-seed weight (g) | 14.3 ± 0.7 | 11.0 ± 0.5 | 12.2 ± 0.6 | 11.6 ± 0.7 | 11.1 ± 0.6 | 13.5 ± 0.9 |

**Fig. 3** Plants of chickpea cultivar JG 315 (*left*) and a new plant type line (*right*) that was developed from a cross-JGM 1 × ICC 4929 and combined compact growth habit of JGM 1 and double-pod trait of ICC 4929

brachytic mutant JGM 1 reported here will provide an alternative source of these desired traits to chickpea breeders. The preliminary results from its utilization

**Fig. 4** Branches of JG 315 (*left*) and a new plant type line (*right*). New plant type lines had a greater number of pods per primary branch

as base material in developing an erect plant type with shorter internodes are encouraging. However, further efforts are needed to improve seed size and evaluate the selected lines in different plant density and irrigated conditions.

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## References

Bahl PN (1980) Kabuli-desi introgression and genesis of new plant type in chickpea. In: Proceedings of the international workshop on chickpea improvement, ICRISAT, Patancheru, AP, India, pp 75–80

Bahl PN, Jain HK (1977) Association among agronomic characters and plant ideotypes in chickpea (*Cicer arietinum* L.). Z Pflanzenzuechtung 79:154–159

Cooper RL, Mendiola T, St Martin SK, Fioritto RJ, Dorrance ARJ (2004) Registration of 'Stalwart' soybean. Crop Sci 44:1019–1020
Dahiya BS, Lather VS (1990) A breakthrough in chickpea yields—Paper 1. Int Chickpea Newsl 22:6–8
Dahiya BS, Lather VS, Solanki IS, Kumar R (1984) Useful spontaneous mutants in chickpea. Int Chickpea Newsl 11:5–7
Dahiya BS, Lather VS, Kumar R (1990) A brachytic mutant of chickpea. Int Chickpea Newsl 22:42–43
Dahiya BS, Mehta BS, Lather VS (1990) A new approach to chickpea breeding. Crop Improv 17:104–110
Dahiya BS, Naidu MR, Waldia RS, Kumar R, Mehta BS (1988) Introduction of major phenological changes in chickpea to improve biological and seed yield. Int Chickpea Newsl 19:4–6
Ekbote RB (1937) Mutations in gram (*Cicer arietinum* L.). Curr Sci 5:648–649
FAOSTAT data (2006) http://faostat.fao.org/faostat/(last updated 24 January 2006)
Gataulina GG, Lukashevich MI, Medvedeva NV (2005) Producing early maturing white lupin varieties with a determinate type of growth. Kormoproizvodstvo 6:8–10
Gaur PM, Gour VK (1999) An induced fasciated mutant of chickpea. Indian J Genet 59:325–330
Gaur PM, Gour VK (2001) A gene inhibiting flower colour in chickpea. Indian J Genet 61:41–43
Gaur PM, Gour VK (2003) Broad-few-leaflets and outwardly curved wings: two new mutants of chickpea. Plant Breed 122:192–194
Gaur PM, Gour VK, Singh K (2004) Induction and genetics of a variegated leaf and an apical chlorosis mutant in chickpea. Indian J Genet 64:208–211
Gupta VP, Lal S (1981) Developmental allometry and plant type in chickpea. Int Chickpea Newsl 4:8–9
Jain HK (1975) Breeding for yield and other attributes in grain legumes. Indian J Genet 35:169–187
Juller B, Huyghe C, Papineau J, Milford GFJ, Day JM, Billot C, Mangin P (1993) Yield and yield stability of determinate and indeterminate autumn-sown white lupins (*Lupinus albus*) at different locations in France and the UK. J Agric Sci 121:283–287
Khanna-Chopra R, Sinha SK (1987) Chickpea: physiological aspects of growth and yield. In: Saxena MC, Singh KB (eds) The chickpea. CAB International, Wallingford, Oxon, UK, pp. 163–190
Khanna-Chopra R, Sinha SK (1990) What limits the yield of pulses? Plant processes or plant type. In: Sinha SK, Sane PV, Bhargava SC, Agarwal PK (eds) Proc international congress in plant physiology, vol 1. Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India, pp 268–278
Lal S (1992) Pulses production in India—perspectives and possibilities for 2000 AD. In: Sachan JN (ed) New frontiers in pulses research and development. Directorate of Pulses Research, ICAR, Kanpur, India, pp 5–13
Lather VS (2000) Promising chickpea ideotype for higher plant density. Int Chickpea Pigeonpea Newsl 7:26–27
Mligo JK (1989) VULI-1, an extra-early maturing cowpea variety for Tanzania. Trop Grain Legume Bull 36:39–40
Passioura JB (1976) Physiology of grain in wheat growing on stored water. Aust J Plant Physiol 3:559–565
Ramanujam S (1975) Genetic diversity, stability and plant type in pulse crops. In: Proceedings of the international workshop on grain legumes, ICRISAT, Patancheru, AP, India, pp 167–176
Saindon G, Mundel HH, Huang HC (1996) Registration of 'AC Skipper' navy bean. Crop Sci 36:207
Sandhu JS, Brar HS, Verma MM (1990) Inheritance of a plant type mutant and its utilization in chickpea. Euphytica 48:111–112
Sandhu JS, Brar HS, Singh S, Phul PS, Kumar R (2003) PBM 1: a new variety of kharif mungbean for south-west regions of Punjab State. J Res Punjab Agric Univ 40:305
Scott RE, Goulden DD (1993) Apex garden pea (*Pisum sativum* L.). NZ J Crop Hortic Sci 21:263–264
Sedgley RH, Siddique KHM, Walton GH (1990) Chickpea ideotypes for Mediterranean environments. In: van Rheenen HA, Saxena MC, Walby BJ, Hall SD (eds) Chickpea in the nineties: proceedings of the second international workshop on chickpea improvement. ICRISAT, Patancheru, AP, India, pp 87–91
Shamsuzzaman KM, Gibson AH, Oram RN, Shaikh MAQ (2002) Assimilation and partitioning of dry matter and nitrogen in Hypersola, a more determinate mutant of chickpea, and in its parental cultivar. Field Crops Res 77:51–59
Sinha SK (1977) Food legumes: distribution, adaptability and biology of yield. Food and Agriculture Organization of the United Nations Plant Production and Protection Paper, No. 3, FAO, Rome, p 124
Sinha SK, Aggarwal PK, Khanna-Chopra R (1985) Phenological and physiological irrigation in India. Adv Irrigation 3:130–212
Srinivasan S, Gaur PM, Chaturvedi SK, Rao BV (2006) Allelic relationships of genes controlling number of flowers per axis in chickpea. Euphytica 152:331–337
Suiter KA, Wendel JF, Case JS (1983) LINKAGE-1: a PASCAL computer program for the detection and analysis of genetic linkage. J Hered 74:203–204
van Rheenen HA, Pundir RPS, Miranda JH (1994) Induction and inheritance of determinate growth habit in chickpea (*Cicer arietinum* L.). Euphytica 78:137–141
Wallace SU, Blanchet R, Bouniols A, Gelfi N (1990) Influence of nitrogen fertilization on morphological development of indeterminate and determinate soybeans. J Plant Nutr 13:1523–1537