Table 1. *Continued.*

Correlated traits	Number of trials: Analyzed	Number of trials: Correlation not significant	Values of significant correlation coefficient: Positive $P=0.05$	Positive $P=0.01$	Negative $P=0.05$	Negative $P=0.01$
DFGLP[1] x Flowering date	7	-	-	0.89	-	-
			-	0.75	-	-
			-	0.76	-	-
			-	0.66	-	-
			-	0.77	-	-
			-	0.48	-	-
			-	0.44	-	-
Number of plants m^{-2} x Seed yield	11	7	0.52	0.76	-	-
			-	0.88	-	-
			-	0.80	-	-
Number of plants m^{-2} x 1000-seed mass	11	10	0.48	-	-	-
Number of plants m^{-2} x Number of pods $plant^{-1}$	11	9	0.59	-	0.55	-
Number of plants m^{-2} x Plant height	11	9	0.41	0.73	-	-
Number of plants m^{-2} x DFGLP	11	7	0.69	0.77	-	-
			0.59	-	-	-
			0.45	-	-	-

1. DFGLP = Distance from ground to the lowest pods.

Utility of Desi x Kabuli Crosses In Chickpea Improvement

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Crossing among genetically/geographically divergent groups within a species has often resulted in an increase of heterosis and genetic variability and introgression of desirable genes into each other. Introgression of alien genes has resulted in increasing the yield levels, and resistance to diseases and pests in a few crop species such as wheat, maize, etc. In chickpea, there are two distinct types--desi and kabuli. The desi type is considered to be primitive and the kabuli type to be of recent origin. Both types had been geographically isolated for many years.

Desi chickpeas are usually small seeded, with seed colors ranging from white to black, and the seed surface is reticulated. The aerial plant parts usually have anthocyanin pigmentation and the plants usually have pink or purple flowers. They are mostly distributed in South and Southeast Asia, although desi types are cultivated to some extent in Ethiopia, Mexico, and Iran. They are specially adapted to winter sowing in the subtropics and in the hilly areas of tropics.

The kabulis on the other hand, are usually large seeded with white or pinkish seed coat. The plants are green without anthocyanin pigmentation and the flowers white. The kabuli chickpeas are distributed mainly in the Middle East and Mediterranean region, and adapted to spring sowing at higher latitudes.

Apart from morphological differences, each type possesses unique characteristics. Useful characteristics can be transferred (introgressed) from one type into the other. For example, the resistance to fusarium wilt in desi has been transferred to kabuli types; and the resistance to ascochyta blight in kabuli is being transferred to desis.

Having been separated geographically, these two types may have different gene blocks for important yield components, and therefore by introgression, improvement in yields may be achieved. However, these were theoretical expectations, and we decided to study and document the utility of desi x kabuli crosses in chickpea improvement. We initiated the desi x kabuli introgression studies at ICRISAT in 1979 with the following objectives: (1) to study variability generated in desi x desi, desi x kabuli, and kabuli x kabuli crosses, and (2) to introgress desirable characteristics from desi types to kabuli types and vice-versa. We chose three desi (CPS 1, BG 203, and Pant G 114) and three kabuli varieties (C 104, K 4, and P 9800). We made a diallel of these six lines in 1979/80, advanced their F_1 in 1980 off-season, and studied the 15 F_2s in the 1980/81 season. A wide range of segregants was obtained for seed shape, size, and color in the desi x kabuli crosses. Overall, the proportion of desi-type seeds was higher than that of the kabuli type (Table 1). Apart from these two types, a range of intermediate seed types was also obtained, the proportion of which was higher than that of the kabulis but less than that of the desi types. The actual ratios, however, varied from cross to cross. For example, the kabuli line K 4 produced a relatively high proportion of desi and intermediate seed types. For C 104, the opposite was observed.

We studied F_2 single plants and F_3 randomly derived progenies to assess variability generated in different crosses. In general, the extent of variability generated by a desi x kabuli cross was similar to that of a desi x desi or a kabuli x kabuli cross. The variability was more related to the geograpical divergence of the parents involved in a cross than to the seed type. The desi parents, however, increased the variability for the pod number plant^{-1} and the number of seeds pod^{-1}, while the kabulis increased variability for plant height and 100-seed mass.

We separated the desi, kabuli, and intermediate seed type segregants in the F_2 of nine desi x kabuli crosses, and put these seed bulks for replicated testing. The replicated test of F_3 bulks was vitiated, hence it was repeated as F_4 bulk trial. We chose the highest-yielding desi (D), kabuli (K), and intermediate (I) bulks based on replicated F_4 bulk tests. Each of the three bulks was crossed to a fourth desi (WR 315) and kabuli variety (No. 501) to initiate a second cycle of introgression. In the F_2 of the second cycle, we observed that the recovery of kabuli seed type segregants is higher than D or I types, when kabuli or intermediate seed type bulks were crossed to the fourth kabuli parent. The recovery of kabuli-type segregants when desi seed type bulk was crossed to kabuli parent was similar to the desi x kabuli cross F_2 of the first cycle of crossing.

We then evaluated F_3 bulks from first and second cycle of crossing to compare the extent of variability among the two. It appeared that the second cycle bulks have reduced variability for many of the characteristics studied, as compared to first cycle of crosses.

Based on our studies the broad conclusions are as follows:

1. The desi x kabuli crosses do not produce increased variability. The variability is related to the

Table 1. Desi, kabuli, and intermediate seed types in F_2 populations of desi x kabuli crosses, ICRISAT Center, 1980/81.

Cross	Total plants	Seed type (%)		
		Desi	Intermediate	Kabuli and near kabuli
CPS 1 x K 4	810	71.9	9.9	18.2
CPS 1 x P 9800	684	50.0	26.5	23.5
CPS 1 x C 104	724	30.8	51.9	17.3
Pant G 114 x K 4	779	63.8	19.8	16.4
Pant G 114 x P 9800	734	61.1	26.4	12.5
Pant G 114 x C 104	720	25.0	57.5	17.5
BG 203 x K 4	856	75.1	9.9	15.0
BG 203 x P 9800	713	58.5	25.8	15.7
BG 203 x C 104	743	32.3	49.7	18.0

divergence of parents involved in the cross.

2. The recovery of kabuli-type segregants in a desi x kabuli cross is low compared to desi or intermediate seed types. The segregation pattern varies with the parents involved in the cross.
3. The frequency of kabuli-type segregants can be increased by backcrossing the kabuli or intermediate seed type bulks to any other kabuli parent.
4. The variability in the second cycle of crossing gets reduced as compared to the first cycle.
5. There seems to be no significant yield improvements by introgression, although some segregants seemed to be vigorous vegetatively.

The Double-Podded Gene in Chickpea Improvement

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Flowers in chickpeas are normally produced singly in axillary racemes, but with the so-called "double-podded" mutant, two flowers arise from the peduncle. Although the second flowers are often irregular, they may form pods at variable frequency. The potential therefore seems to exist for a significant increase in pods and yield in double-podded genotypes. In view of this apparent potential, it is surprising that no information is available yet on the effects on yield of the double-podded gene. Hitherto, the effects of double-poddedness have been evaluated only by the removal of the second flower in double-podded genotypes (Sheldrake et al. 1978). The authors concluded that the double-podded characteristic can confer an yield advantage of 6-11% where the characteristic is well expressed, but no information of course was provided on the effects of the double-podded gene itself. Hence, the aim of the experiment reported here was to quantify the effects of the double-podded gene by comparing single- and double-podded genotypes having an otherwise similar genetic background.

The experimental material consisted of three sets of inbred lines, each set representing a different cross. Each set, consisting of both single- and double-podded lines, was derived from a single F_3 plant that was heterozygous at the podding-habit locus. The pedigrees and composition of the inbred sets are given in Table 1.

Table 1. Pedigree and composition of inbred sets, Agricultural Research Centre, Tamworth, Australia, 1982-83.

Inbred set	Pedigree	Number of inbred lines: Single-podded	Double-podded
A	WWC1[1]/CPI 7118	3	5
B	WWC1/CPI 61227	3	4
C	WWC1/CPI 59296-B	4	10

1. WWC1 = Double-podded parent.

The inbred sets were evaluated in an early- and a late-sown trial over 2 years (1982-83) at Wagga Wagga, in southern New South Wales. Only those trials in which the mean plant density of single- and double-podded lines did not differ significantly (5% level) were used for the single/double-podded comparisons. The respective mean yields and 100-seed mass of single- and double-podded lines are shown in Table 2.

In none of the nine trials, representing three different genetic backgrounds, was the mean yield of double-podded lines significantly more than that of single-podded lines. Conversely, the mean yield of double-podded lines was significantly less in two of the trials. Averaged over trials, the mean yield of double-podded lines, relative to single-podded lines, was 94.2%, 94.0%, and 100.5% for the three different backgrounds. For the seed mass the double-podded gene was associated with mean reductions of 4.4% and 3.3% in two of the backgrounds, and an increase of 3.1% in the third.

The results obtained in this study suggest that, in some genetic backgrounds at least, the adverse effects of the double-podded gene can outweigh any benefits due to increased sink size. Such an hypothesis is not inconsistent with the findings of Sheldrake et al. (1978) where either no effect or a reduction in yield resulted from removal of the second flower. It could be argued that the double-podded genotypes used by Sheldrake and coworkers had an inherent yield disadvantage, and that removal of the second flower in some cases reduced yield through a smaller sink size.

The gene for double-poddedness is found in many chickpea breeding programs. In some it is intentionally used (perhaps mistakenly) to secure an increase in yield. In others its presence is incidental, but in these it may not have been deliberately selected