gamma rays (10, 20, and 30 kR), neutrons (4, 6, and 8 x 10 12n cm^{-2}), ethyl methane sulfonate (EMS 0.05, 0.1, and 0.2% v/v), and methyl methane sulfonate (MMS 0.001 and 0.01% v/v), individually and in combinations. The plants were screened for resistance to *Meloidogyne javanica.* In the M_3 generation, 111 stable progenies were selected and the plants of these progenies were screened in the M_4 and M_5 generations in homogeneously highly infested fields at the Agricultural Research Station, Durgapura, Jaipur. The progenies were planted in two 5-m rows for each of the 3 replications, together with susceptible parents as controls. Ten randomly selected plants from each row were gently uprooted 45 days after germination and roots were washed and scored for nematode infection. Mutants found resistant to *M. javanica* are listed in Table 1.

Table 1. Yield and disease rating of mutants[1] of kabuli chickpea varieties (L 550 and BDL) resistant to *Meloidogyne javanica,* Jaipur, Rajasthan, India.

Mutant	Treatment and dose	Yield $plant^{-1}$ (g)[2]	Disease score[3]
Parent L 550			
MV 2	10 kR	12.3	0
MV 3	10 kR	7.3	1
MV 8	6 x 10 12n cm^{-2}	10.8	0
MV 77-1	30 kR + EMS 0.1%	18.2	0
MV 105-3	10 kR + MMS 0.001%	12.4	1
MV 108-1	10 kR + MMS 0.001%	12.9	1
MV 196-1	6 x 10 12n cm^{-2} + MMS 0.001%	11.6	1
MV 219-2	EMS 0.2%	3.1	1
MV 225-3	30 kR + EMS 0.05%	11.3	0
MV 228-3	30 kR + EMS 0.1%	3.7	0
Parent BDL			
MV 145-3	10 kR + EMS 0.1%	3.5	0
MV 168	10 kR + MMS 0.001%	1.2	0
MV 171-3	10 kR + MMS 0.001%	6.1	0
MV 222-2	30 kR + MMS 0.001%	10.8	0
Controls			
L 550	Untreated	14.2	4
BDL	Untreated	10.1	5
CD 5%		3.1	

1. Mutations induced using various combinations and doses of gamma rays, neutrons, ethyl methane sulfonate (EMS), and methyl methane sulfonate (MMS).
2. Average of 60 plants.
3. 0 = no gall/egg mass, 1 = 1-2 galls/egg masses, 2 = 3-10 galls/egg masses, 3 = 11-30 galls/egg masses, 4 = 31-100 galls/egg masses, and 5 = >100 galls/egg masses $plant^{-1}$.

The chickpea variety L 550 was more responsive to mutagens than BDL. The combinations of physical and chemical mutagenic treatments were more effective than the single treatments, especially the lower doses of MMS in combination with the lower doses of gamma rays. Gamma rays were better in combinations than neutrons.

Mutation breeding has also been used in desi chickpea to produce mutants resistant to root-knot nematode (Bhatnagar et al. 1985).

Reference

Bhatnagar, C.P., Handa, D.K., and **Mishra, A.** 1985. Prospects of utilizing mutation breeding in inducing nematode resistance in chickpea. International Chickpea Newsletter 12:5-7.

Physiology/Agronomy

Improving Harvest Index in Chickpea Through Incorporation of Cold Tolerance

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One of the reasons for low yield in chickpea in the cooler environments of northern India, such as Hisar, Haryana, is that sink potential is not fully realized; this results in a low harvest index (Saxena and Johansen 1988). Low night temperatures induce flower shedding or failure of pod-set (Saxena 1980), thereby causing investment of assimilates in continued vegetative growth and lowering the harvest index.

Genotypic variation for the ability to set pods at low night temperatures was identified in a few segregating plants at ICRISAT Cooperative Center, Hisar. These plants, however, were very poor both in agronomic and in plant-type characteristics and therefore were crossed with H 75-35 (now called Gaurav) and Pant G 114 to produce more desirable segregants. This allowed us to test the hypothesis that:

a. Low harvest indices under those conditions resulted from failure of pod-set, and
b. Early pod-set at low night temperature would result in higher yields. This ability should increase the proportion of pod-set in more favorable soil moisture and thermal regimes, and the duration of flowering and pod-set may also be extended.

Single-plant selections were made on the basis of fruiting ability in cooler environments and classified into 12 groups, based on time of first flower opening, which ranged from 42 to 76 days after sowing. These were grown in plots 4.0 x 3.6 m, with 3 replications; plant spacing was 30 x 10 cm. Sowing was done on 7 Nov 1987 on an Entisol at Government Livestock Farm, Hisar, after one presowing irrigation. The daily minimum temperatures during December and January, when the early genotypes were podding, ranged from -1 to 7°C, with temperatures on most nights falling below 5°C. Each value in a group presented in Table 1 is a mean of 10 progeny selections.

Early flowering and podding indeed resulted in high harvest indices, 50-54%, compared with 39-42 for the late-flowering selections (Table 1). The later groups flower and set pods at the same time as

Table 1. Flowering and podding initiation and duration, shoot mass, yield, and harvest index in 120 cold-tolerant chickpea selections at ICRISAT Cooperative Center, Hisar, India, 1987/88. Values for each group are a mean of 10 selections.

Group	Flowering[1]		Podding[1]		Shoot mass (t ha^{-1})	Yield (t ha^{-1})	Harvest index (%)
	Initiation	Duration	Initiation	Duration			
1	42	39	50	38	2.24	1.19	54.4
2	46	40	53	38	2.65	1.33	50.4
3	46	40	53	40	2.72	1.34	49.7
4	46	45	54	43	2.58	1.36	53.8
5	48	38	55	38	2.69	1.35	52.1
6	51	40	58	39	2.94	1.28	44.5
7	54	36	61	36	2.81	1.32	47.4
8	54	44	62	42	3.15	1.31	40.7
9	65	49	72	46	4.06	1.67	42.0
10	70	45	79	41	3.67	1.49	41.3
11	73	37	81	35	3.27	1.36	41.1
12	76	39	82	40	3.46	1.44	38.9
SE	±1.2***	±1.7***	±1.3***	±1.7***	±0.184***	±0.083*	±1.7***
CV (%)	12	23	11	24	33	33	20

1. Initiation = days after sowing; duration = number of days.
* = significant at $P < 0.05$; *** = significant at $P < 0.001$.

conventional cultivars such as Pant G 114. The cold-tolerant early-podding selections (Groups 1-5) produced lower yields than the mean of genotypes in Group 9; however, progenies of some plant selections in the early groups gave mean yields (average of 3 replications) similar to the highest yielding selections in Group 9. Flowering and podding duration in early-flowering and early-podding groups did not extend as expected (Table 1). It was the longest in Group 9, which also gave the highest yields.

We believe that the yield potential of early-podding cold-tolerant selections was not fully expressed because the agronomic practices adopted were those recommended for conventional long-duration cultivars. Therefore we are now studying the agronomic practices appropriate for expression of yield potential of these selections and analyzing yields of these unconventional genotypes.

We postulate that there would be other advantages of these cold-tolerant selections:

1. Excessive vegetative growth is inhibited.
2. The crop escapes terminal drought and heat stress.
3. Incidence of foliar diseases such as ascochyta blight and botrytis gray mold may be reduced because excess vegetative growth is reduced (Y.L. Nene, ICRISAT, personal communication 1987).
4. Podding during the cold period may enable escape from *Heliothis* damage (W. Reed, ICRISAT, personal communication 1987).

Some of these aspects are currently being studied at ICRISAT. We are also carefully observing the changes that this new plant type is likely to cause in plant x environment interactions and their possible consequences; for example, bird damage during podding may increase because birds have limited alternative food sources at that time of the year. These factors will receive consideration when we develop chickpea cultivars incorporating cold tolerance and plan strategies for introducing this material onto farms.

References

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Agronomic Assessment of Some Sicilian Populations of Spring-Sown Chickpea

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A few years ago, the Institute of General Agronomy of Palermo, Sicily, began a study intended to safeguard Sicily's germplasm of chickpea and to improve the genetic and agronomic characteristics of this crop species (Poma et al. 1985; Sarno and Stringi 1979; Sarno et al. 1985). The collected material is catalogued and preserved in the Institute of General Agronomy of Palermo. This report presents the results of an evaluation trial of some of the chickpea populations collected in western Sicily. Studies were carried out over 2 years at the experimental teaching farm, "Orleans," at Palermo.

The soil used for the experiment was a Mediterranean red earth with moderately alkaline reaction; it was well supplied with nutritive elements. When the soil was tilled, 120 kg ha^{-1} of P_2O_5 was applied. Twenty-one chickpea populations were assessed in randomized-block experiments with 3 replications. Plot size was 10 m^2. Experiments were sown on 19 Jan 1982 and 14 Mar 1983 at a population density of 13 plants m^{-2}. No irrigation was applied during crop growth. Rainfall and temperature have been recorded both for the preceding winter and during crop growth (Fig. 1).

Data for the 2 years were pooled and the significance of differences between genotypes tested for the characters measured, using Duncan's Multiple Range Test (Table 1). Full pod formation differences were small, with population 22 being the earliest (79 days to full pod formation) and populations 4 and 8 the latest (84 days). Plant height ranged from 49.0 to 55.6 cm. On an average, plant height was 18 cm more in the first season than in the second season. Average seed yield was quite high, at 1925 kg ha^{-1}; range, 1500 to 2370 kg ha^{-1}. Populations 8, 12, 17, 20, and 24 had the highest yields, of over 2100 kg ha^{-1}. Except for population 17, all these populations had medium to small seed size. There was little difference in mean values of seed yield between seasons (1930 and 1920 kg ha^{-1}). Genotypic ranking in seed yield was similar for the two seasons.

Table 2 shows the relationships between the various characters measured. The negative correlation between seed yield and seed size is clearly indicated. Seed yield was positively correlated with all other characters studied. We suggest that the good correlation between seeds $plant^{-1}$ and number of fertile branches be exploited in breeding programs. It is also interesting to note that seed protein level is positively correlated with all plant characters except 100-seed mass, and that average protein levels are quite high.

These data indicate that the Sicilian environment favors medium- to small-seeded genotypes of relatively