Table 1. Biochemical changes in diseased leaves, shoots and roots of pearl millet infected by downy mildew.

Parameters (units)	Healthy			Diseased		
	Leaves	Shoots (L+S)	Roots	Leaves	Shoots (L+S)	Roots
Total chlorophyll (mg/g, dry wt)	1.36×10^{-3}	—	—	0.49×10^{-3}	—	—
Total phenols (mg/g, fresh wt.)	—	2.584	—	—	3.876	—
Total free amino acids (mg/g, fresh wt.)	—	—	0.686	—	0.294	—
Nitrate reductase (moles of NO_3 transfored/ min/mg protein)	—	0.0090	0.0503	—	0.0140	0.01416

(L = Leaves; S = Stem.)

total chlorophyll in leaves, total phenols and total free amino acids in the shoots and roots of healthy and diseased plants.

Downy mildew sporangia were sprayed on 7-day-old plants of NHB-3 variety raised in 12" pots. Total leaf chlorophyll[1], total phenols[2], total free amino acids[3], nitrate reductase[4], and enzyme-protein[5] were estimated 15 days after appearance of symptoms.

The loss in total chlorophyll confirmed the earlier findings in pearl millet[6] and sorghum[7] during pathogenesis (Table 1). The present results for the total phenols also agree with those in downy mildew-infected plants[8-11].

Lower contents of total free amino acids during pathogenesis support earlier findings with pearl millet[10] and cowpea infected with mosaic virus[12].

Our observations on the activities of nitrate reductase, during pathogenesis, in both roots and shoots of pearl millet are contrary to those observed in rice leaves infected with bacterial blight[13] and the resistant and susceptible cowpea varieties infected with mosaic virus[12]. The possible reasons for the high nitrate reductase activities in the diseased plant-parts could be due to a greater induction of the enzyme during pathogenesis. It may also be possible that the pathogen generates this enzyme in order to utilize the free nitrate present in the host tissues. The roots might be absorbing more nitrate from the soil to meet the demands of both the host and pathogen. In turn, nitrate transformed into nitrite and further into ammonia might be getting incorporated rapidly into the amino acids, thereby enhancing protein metabolism and also helping the host photosynthetic processes to speed up in spite of the loss in total chlorophyll content.

These possibilities remain to be investigated to understand overall biochemical changes during pathogenesis.

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Natural selection in varietal mixtures of greengram (*Vigna radiata* (L.) Wilczek)

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The competitive ability of eight greengram genotypes/ varieties in relation to their respective yield, disease reaction and pod traits was studied. Initial sowing was done by mixing the seed of each variety in equal proportion (12.5%). Single pod from each plant was plucked, identified and number of plants of each variety was counted at harvest. Successive sowing for four seasons was done by taking a large random sample from the

bulked seed of previous harvest. The plot was kept contiguous with other yield testing plots each season which facilitated the comparison of disease and yield data with the competitive ability of varieties in mixture. Seeds per pod, ovule sterility and pods per plant were also recorded. Yielding potential of varieties did not correlate with their competitive ability. Disease data correlated rather closely to yield data, but not to competitive ability. Change in relative proportion was generally due to significant change of pod characters.

THE fact that natural selection plays an important role in the crop plants is well recognized. The rate at which such changes occur has been worked out by various workers in wheat and barley. Harlan and Martini[1] determined the rate of natural selection in a mixture of 11 easily recognized varieties of barley. They conducted the experiment at two locations for 4 to 12 years. Rapid elimination of the less-adapted sorts was observed at all the locations. At most of the places leading variety dominated in the mixture rapidly. In some cases, a particular variety dominated at one place and eliminated at other. Few varieties survived at all locations and few increased for a time and then decreased. Laude and Swanson[2] reported cumulative changes in mixtures of Kanred with Harvest Queen and with Currel at two locations over a period of nine years. The rate of change was so rapid that within nine years the mixture of two paired varieties shifted to almost pure stand of Kanred.

The objectives of the present study were to study the competitive ability of greengram varieties and relationship with their respective yield, disease reaction and pod traits.

In the present experiment conducted at Haryana Agricultural University, Hisar, 150 seeds of eight easily recognized varieties of greengram either on the basis of seedcoat colour, size or plant pigment, were mixed together for the initial seeding in summer 1986 (S-86). Seeds were sown at a distance of 20 cm so that no thinning is required afterwards. Row length was kept 40 m, row-to-row spacing being 40 cm. At the time of harvest, single pod from each plant was plucked, identified and number of plants of each variety was counted. The threshed seed of whole plot was bulked and random sample to raise 1500 plants approximately was taken for next seeding. This plot was contiguous and comparable with other breeding and yield testing plots each season. This facilitated the comparison of disease and yield data with the competitive ability of varieties in mixture. The experiment was continued in a similar way for four seasons, i.e. summer 1986, *kharif* (rainy)-1986 (R-86), summer 1987 (S-87) and rainy 1987 (R-87).

The rate at which natural selection occurred was determined on the basis of number of plants survived of each variety in the mixture. Various pod characters were also recorded. For each variety, ten randomly selected plants were evaluated ignoring border plants to avoid border effect. Measurements on individual plants were taken for all the following traits.

Number of seeds of ten pods taken at random from each plant was counted and average was worked out.

Ten same pods taken for aforesaid trait were used. Number of chambers in each pod was counted.

Per cent ovule sterility was calculated as:

$$\text{Ovule sterility (\%)} = \frac{(\text{Number of chambers per pod}) - (\text{Number of seeds per pod})}{\text{Number of chambers per pod}} \times 100$$

All the pods in a plant were counted at the time of maturity.

The rate of change in the relative proportion of varieties in mixture (Figure 1) was so rapid as to shift the varietal ratios from equal proportion (12.50%) to more than 70% of MH 309 and K851 together after four seasons. Three varieties, viz. 12/333, MH 85–75 and T–44 were eliminated from the population. To interpret these results, special consideration was given to pod characters, yield and leaf diseases.

It is evident from Table 1 that the average yields over

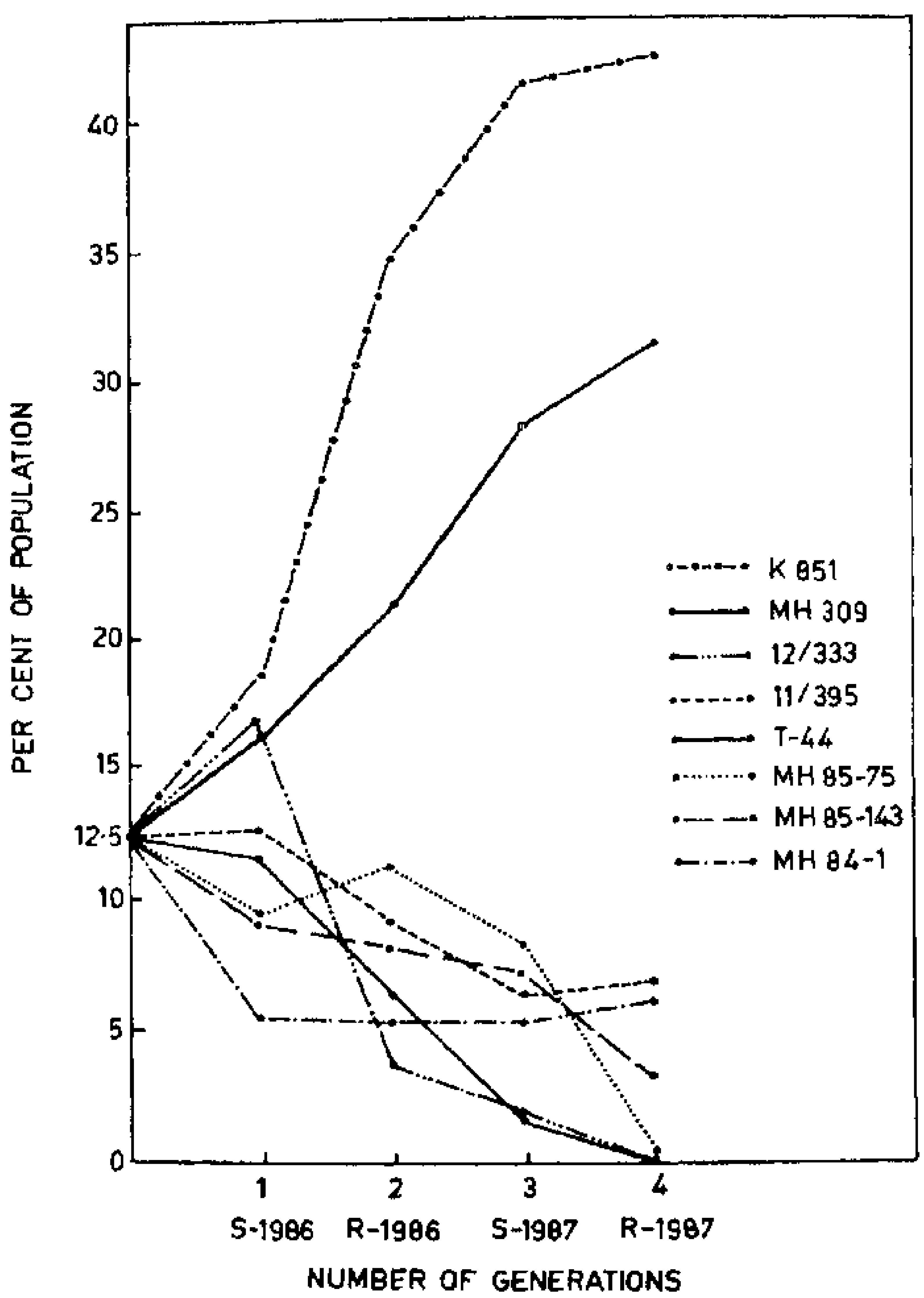

Figure 1. Shift in proportion of eight greengram varieties after four seasons of successive seedlings.

Table 1. Change in various pod traits in a mixture of eight greengram varieties grown from successive seedings, summer 1986 – rainy 1987.

Variety	Per cent increase (+)/decrease after summer 1987		Ovule sterility (%)			
	Seeds per pod	Pods per plant	Original	S-1986	R-1986	S-1987
MH 309	+ 11.67	+48.59 *	1.02	1.00	0.97	0.89
K 851	+ 10.68	+43.28 *	1.32	1.13	1.22	1.52
MH 85–143	− 29.84 *	− 20.21 *	11.00	12.00	13.85	18.75 *
MH 84–1	+ 16.67 *	− 18.16 *	2.20	1.37	2.00	0.50
11/395	+ 2.30	− 24.95 *	4.80	5.06	5.12	3.98
12/333	− 39.19 *	− 65.81 *	11.20	13.44	16.70	18.29 *
MH 85–75	− 32.34 *	+ 2.74	13.70	15.05	19.75	23.42 *
T-44	− 14.61 *	− 32.55 *	1.32	1.14	1.95	2.89

S, Summer season; R, Rainy season; *Significant at P=0.05.

seasons of the component varieties comparably grown from S-86 to R-87 placed the varieties in the order MH 309, MH 84–1, K 851, 11/395, T-44, 12/333, MH 85–75 and MH 85–143. Variety MH 309 remained at the top, MH 85–75 at seventh and MH 85–143 at the last position in all the seasons. MH 84–1 was at the top (at par with MH 309) during R-86 and second during S-87 and R-87. This, when related to Figure 1, is conclusive evidence that the relative yield of a variety is not necessarily a criterion of its ability to survive in competition with other varieties. In the case of T-44 and MH 85–143 there was a continuous decline in proportion without a single significant resurgence due to any seasonal yield advantage for the variety and it was just opposite for K 851 and MH 309. In the case of 12/333 one upturn (S-86) and three precipitous declines (R-86, S-87, and R-87) were observed. None of these could be explained from the variety yield data in respective years.

Prevalence of yellow mosaic virus was extremely severe during rainy 1987, whereas, summer 1987 was relatively disease-free period (Table 2). The differences in yield of component varieties during S-87 were not conspicuously reflected during R-87 in changing the relative proportions accordingly. During the disease-free period, yield of all the varieties was numerically maximum when compared to other seasons. However, remarkable decline in relative proportion during next season (R-87) was noticed in T-44, 12/333, MH 85–75 and MH 85–143. Whereas, variety 11/395 exhibited a non-significant increase in its proportion during R-87 after two declines in previous seasons (Figure 1). Thus, the disease data relate rather closely to yields, but not to competitive ability.

The difference in number of seeds per pod, pods per plant and ovule sterility was reflected in next season in changing the relative proportion. The significance was tested using paired t test for pod traits in all the seasons (Table 3). The rate of increase in the relative proportion of MH 309 and K 851 was attributed to corresponding significant increase in production of number of pods per plant, whereas, decline in the proportion of 11/395 during R-86 and S-87 was ascribed to significant decrease in pods per plant. There was drastic decline in proportion of MH 84–1 during S-86, afterwards it increased slowly. This decline was ascribed to significant less production of pods per plant and slower increase to more production of pods per plant and seeds per pod. Continuous progressive decline was observed in MH 85–143. This was due to significant decrease in pods per plant, seeds per pod accompanied by increased ovule sterility (Table 1). In MH 85–75 and 12/333, one upturn (R-86 and S-86 respectively) and three declines were noted. Upturn in MH 85–75 was due to significant increase in pods per plant and seeds per pod and in 12/333 due to more pods per plant (Table 3). Declines in proportion were generally due to significant reduction

Table 2. Yield and disease reactions in greengram varieties, summer 1986–rainy 1987.

Variety	Grain yield (t/ha)					Per cent plants affected: Yellow mosaic virus				Per cent plants affected: Leaf crinkle			
	S-86	R-86	S-87	R-87	Average	S-86	R-86	S-87	R-87	S-86	R-86	S-87	R-87
MH 309	1.65	1.57	1.71	1.52	1.61	4.82	3.05	0.02	8.43	7.18	2.91	2.00	2.79
K 851	1.63	1.25	1.64	1.18	1.42	3.20	6.00	2.00	55.00	3.20	2.13	3.00	7.50
MH85–143	0.77	0.75	0.87	0.47	0.71	5.00	8.50	1.43	21.00	8.21	2.81	—	4.81
MH84–1	1.62	1.57	1.68	1.48	1.59	1.73	2.90	0.50	9.93	6.20	0.91	2.00	3.90
11/395	1.35	1.51	1.48	1.15	1.37	2.81	0.86	1.00	18.00	5.30	2.64	1.75	4.40
12/333	1.34	1.21	1.44	1.05	1.26	3.75	7.25	2.12	14.31	2.63	2.66	—	4.20
MH85–75	0.81	0.81	0.83	0.63	0.77	2.00	2.40	2.37	38.00	3.51	1.24	2.00	1.20
T-44	1.39	1.41	1.51	1.00	1.33	1.42	1.51	1.00	23.00	3.35	2.27	1.20	2.35
C.D. (5%)	0.19	0.17	0.21	0.20	—	—	—	—	—	—	—	—	—

—, Data not recorded.

Table 3. Comparison of differences in performance of varietal mixture over seasons for pod characters in greengram.

Variety and characters	t-values between seasons**					
	1 and 2	1 and 3	1 and 4	2 and 3	2 and 4	3 and 4
MH 309						
Seeds per pod	0.87	0.92	1.97	0.42	1.82	1.81
Pods per plant	2.12	3.79*	6.79*	2.75*	4.89*	2.41*
Ovule sterility	0.001	0.081	0.090	0.001	0.007	0.003
K 851						
Seeds per pod	0.98	0.89	2.22	0.00	0.21	0.12
Pods per plant	5.71*	9.93*	13.97*	3.02*	3.89*	1.67
Ovule sterility	0.091	0.070	0.107	0.171	0.268	0.112
MH85–143						
Seeds per pod	1.63	1.71	5.27*	0.02	2.63*	2.01
Pods per plant	0.73	1.01	4.81*	0.93	2.22	1.81
Ovule sterility	0.071	0.098	2.321*	0.097	2.270*	1.992
MH 84–1						
Seeds per pod	0.24	0.97	3.98*	0.31	2.85*	1.71
Pods per plant	2.72*	3.89*	5.16*	1.57	2.72*	0.92
Ovule sterility	0.172	0.087	1.27	0.872	0.921	1.07
11/395						
Seeds per pod	0.39	0.00	0.47	0.39	0.81	0.51
Pods per plant	2.60*	5.89*	6.23*	2.71*	3.30*	0.92
Ovule sterility	0.872	0.881	0.732	0.001	1.08	1.21
12/333						
Seeds per pod	0.81	4.59*	8.71*	2.02	3.81*	1.21
Pods per plant	8.21*	12.71*	27.29*	6.79*	10.21*	2.10
Ovule sterility	0.932	2.281*	2.920*	1.071	2.263*	1.09
MH 85–75						
Seeds per pod	0.09	2.71*	5.89*	2.67*	5.02*	2.88*
Pods per plant	2.89*	2.01	1.89	2.27*	2.70*	1.96
Ovule sterility	0.822	2.770	3.320*	2.171	2.321*	2.001
T-44						
Seeds per pod	0.81	0.93	2.70*	0.35	2.35*	2.01
Pods per plant	3.01*	5.31*	6.78*	2.81*	4.21*	2.17
Ovule sterility	0.071	0.102	0.981	0.341	0.999	0.721

**1, Original population; 2, Summer 1986; 3, Rainy 1986; 4, Summer 1987.
* Significant at $P = 0.05$.

of seeds per pod, pods per plant accompanied by increased ovule sterility.

Thus, a mixture of eight greengram varieties grown for four seasons brought practical extinction for three of the component varieties, viz. T-44, 12/333 and MH 85-75. T-44 is a released variety for commercial cultivation and has better leaf diseases record except for R-87 when yellow mosaic virus attack was extremely severe. K 851 is also a released variety and MH 309, MH 84–1 and 11/395 are in the pipeline. MH 84–1 stood second as far as the average yield over seasons is concerned (Table 2) but its proportion was significantly reduced in the population. Suneson and Wiebe[2], on the basis of their study on barley, suggested that the bulked population method of breeding would not necessarily perpetuate either the highest yielding or the most disease-resistant progenies, but that the otherwise intangible character of competitive ability might measure other very important plant characteristics, seems to be a possible interpretation of the present study in greengram.

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