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Comparative efficiency of four selection methods for deriving high-yielding lines in mungbean [*Vigna radiata* (L.) Wilczek]

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Abstract The comparative efficiency of four selection methods, viz., honeycomb (HC), pedigree selection (PS), single-seed descent (SSD) and the bulk method (BM), was assessed in three crosses of mungbean. The lines derived by each method, along with check varieties, were yield-tested in a compact family block design in F_5 and F_6 generations during *summer* and *kharif* of 1990. On the basis of the mean of the lines, the range, the number of superior lines over the best check, and the proportion of the top 10% lines in all the crosses and generations, the honeycomb method exhibited superiority over PS, SSD and BM for yield per plant and its component traits. PS, SSD and BM did not differ from each other. The honeycomb and SSD methods were found suitable for deriving superior lines for seed yield and pods per plant in mungbean.

Key words Relative efficiency · Honeycomb
Single-seed descent · Bulk method · *Vigna radiata*

Introduction

Hybridization between desirable homozygous lines followed by selection is the most widely used method to produce superior gene combinations in self-pollinated crops like mungbean. The right choice of an effective selection procedure for handling the segregating populations is the most important decision a plant breeder has to take. The efficiency of most of the conventional selection procedures has been questioned (Gill 1980; Verma 1980) on many grounds. The single-seed descent (Goulden 1941) and honeycomb methods (Fasoulas 1973) were introduced to overcome the limitations of the pedigree and bulk methods. The relative effectiveness of selection procedures for isolating superior genotypes in various crops has been investigated by a number of authors (Dahiya et al. 1986; Nagi et al. 1987; Singh et al. 1987). The honeycomb method has not been exploited so far in mungbean improvement and the literature available on the relative efficiency of different selection methods is also very scanty for this crop. The present study was undertaken to evaluate the comparative effectiveness of pedigree, bulk, single-seed descent, and honeycomb selection methods in three crosses of mungbean [*Vigna radiata* (L.) Wilczek].

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Materials and methods

The material consisted of segregating generations or three crosses, namely ML 433 × ML 267 (cross 1), PS 16 × 11/395 (cross 11) and K 851 TVM 229 (cross 111) of mungbean (*V. radiata*). During *kharif* 1988 (July–October), 1 000 F_2 seeds of each cross were space planted in one plot with row-to-row and plant-to-plant spacings of 45 and 15 cm, respectively, to raise an F_2 population for pedigree selection. In another plot 1 000 seeds of each cross were also grown in a honeycomb arrangement by a plant-to-plant spacing of 27.8 cm in order to maintain a per plant area equal to that occupied by the pedigree selection procedure. The segregating F_2 and subsequent generations, i.e., F_3 during *summer* 1989 (March–June), F_4 during *kharif* 1989, and F_5 during *summer* 1990, were subjected to four methods of selection, viz., honeycomb (HC), single-seed descent (SSD), pedigree selection (PS) and the bulk method (BM). The detailed scheme of handling the segregating generations is outlined in Fig. 1. Lines derived by each method from each cross were evaluated in the F_5 (summer), F_5 (kharif) and F_6 (kharif) season in 1990. In *summer* 1990, half the seed of 120 F_5 progenies of each cross (30 progenies from each of the four selection methods) and three check varieties (ML 267, SML 32 and K 851) were yield-tested in a compact family block design. The cultivars SML 32 and ML 267 are included as appropriate state level checks for the *summer* and *kharif* seasons, respectively, with K 851 serving as a national check suitable for both seasons. Each progeny, along with checks, was grown in a single row (1.5 m length) with 22.5 × 10 cm spacings. Similarly, the balance seed of 120 F_5 and 120 F_6 progenies of each cross, along with checks, were yield-tested in *kharif* 1990 in a compact family design with three replications. Each progeny was grown in a 1.5 m row length with a 30 × 10 cm spacing. Data were recorded on five competitive plants taken at random from each progeny row and check variety for days-to-first pod initiation, days-to-maturity, plant height (cm), plant canopy spread (cm), number of pods per plant, seeds per pod, 100-seed weight (g), and grain yield per plant (g). Data were analysed according to standard statistical procedures. The Student-Newman-Keuls multiple range test, suggested by Federer (1954), was used to estimate the critical difference (C.D.) for range. This tests the significance of differences between maximum and minimum values of the range where 5% C.D for range = SE (means) × W (a constant value from the table "upper percentage points of the studentized range" at n and f degrees of freedom where n is the number of values in the range and f is the error degree of freedom).

The efficiency of four selection methods, viz., honeycomb, pedigree selection, single-seed descent and the bulk method, was compared in each cross on the basis of the mean of the derived lines, the range, the number of lines superior to the best check, the proportion of lines in the top 10% group for yield, and the number of pods per plant.

Results and discussion

The results, presented in Tables 1 and 2, are discussed separately for grain yield and pods per plant.

(1) Grain yield per plant

Mean of the derived lines. In the F_5 (summer, 1990), the mean of HC lines was significantly higher than that of the other three groups of lines in all three crosses except that of BM lines in cross-III (Table 1). In the F_5 (kharif, 1990), the lines under test were the same as in the summer, and, except for that of PS lines in cross-III, the HC lines again displayed the highest mean in comparison to the means of the other three methods in cross-II and cross-III. In the F_6 (kharif, 1990), also, the mean of the HC lines was significantly higher than the means of all the three groups of lines in cross-III as well as the means of the PS and SSD lines in cross-I and cross-II. Thus the HC lines demonstrated their superiority in all three tests, i.e., F_5 (summer), F_5 (kharif) and F_6 (kharif).

Range. In the F_5 (summer), the HC lines exhibited the maximum range in comparison to the other three groups of lines in cross-I and cross-III, whereas PS lines displayed a higher than that of the HC lines in cross-II (Table 1). A wider range was observed for HC lines in cross-I, for BM lines in cross-II, and for SSD lines in cross-III in the F_5 (kharif). In the F_6 (kharif), also, the HC lines had a higher range than that of the other three groups of lines in the first two crosses, whereas the SSD lines exhibited the highest range in cross-III. In general, the HC lines maintined the highest variability.

Number of superior lines. The number of lines superior to the best check (i.e., the best check for the particular trait and season, *summer* or *kharif*) was six among HC lines (three each in cross-I and -II) and one each from the PS (cross-II) and BM lines (cross-I) in the F_5 (summer); whereas in the F_5 (kharif), seven superior lines traced back to the HC method (three in cross-I and four in cross-II), five to BM (two each in cross-I and -III and one in Cross-II), two to PS (cross-I), and one to SSD (cross-III). A similar trend was also observed in the F_6 (kharif) where four HC lines (two each in cross-I and -II), followed by three BM (cross-I) lines, two SSD (cross-III) lines and one PS (cross-I) lines, proved superior to their best checks (Table 1). Overall, 17 lines were traced back to the HC, nine to the BM, four to the PS and three to the SSD method.

Proportion of lines in the top 10% group. In the F_5 (summer), the top-yielding group comparised 14 HC, nine BM, seven SSD and six PS lines over the three crosses. In the F_5 (kharif), on an overall basis, the number of HC lines falling in the top 10% group was also higher (14), followed by the PS and BM lines (eight each) and the SSD lines (six). Similarly, in F_6 (kharif), the number of HC lines in this group was again the highest (17) followed by PS and BM (seven each) and SSD (five). On an overall basis of evaluation over the three seasons, the proportion of HC lines was the highest (41.6%) followed by the BM (23.3%), PS (20.4%) and SSD (16.7%) lines.

(2) Pods per plant

Mean of the derived lines. In the F_5 (summer), the mean of the HC lines was significantly higher than that of the other three methods in all of the crosses except that of the SSD lines in cross-I; whereas in F_5 (kharif) the HC lines exhibited superiority over the lines of the other three methods in cross-I only. In F_6 (kharif), the HC method was superior to PS and SSD in cross-I, to PS and BM in cross-II, and to BM only in cross-III, with a high mean in the derived lines.

Range. The HC lines displayed the highest range in the first two crosses for pod number in F_5 (summer). In F_5 (kharif), the BM lines had the maximum range in cross-II and cross-III. In F_6 (kharif), BM lines projected the maximum range in cross-I and cross-III while the HC lines did so only in cross-II. On an overall basis, BM lines occupied the first range in respect of variability for pods per plant.

Number of superior lines. In the F_5 (summer), the number of lines superior to the best check (SML 32 or K 851) were two in each of the HC and PS methods and one in each of the SSD and BM methods in cross-I. Five HC, three each of PS and BM and one SSD line in cross-II, compared with one line each of HC and SSD and three BM lines in cross-III, surpassed their best checks. In F_5 (kharif), the number of lines better than the best check were the highest (five) in the case of HC followed by PS (two), SSD and BM (one each) in cross-I. Only one such line was found among the HC lines in cross-II, while in cross-III, three HC and two each of the SSD and BM lines surpassed the best checks. During F_6 (kharif), three HC and two BM lines in cross-I, and two HC and one PS line in cross-II, showed superiority over the best checks; whereas in cross-III, three SSD lines and one HC line were superior. On an overall basis of the three

Table 1 Mean, range, and number of superior lines for seed yield derived by four selection methods in three crosses

Generation	Cross	Selection method	Mean of all the lines	Range	Diff. between min. and max. values or range	Checks			No. of superior lines over best check	No. of lines in top 10% group	
						SML32	ML267	K851		In each cross	Over crosses
F_5 (s)[a]	C I	HC	2.88	1.07–4.07	3.00	1.55	1.18	1.84	3	4	14
		PS	1.96	1.14–2.74	1.60	1.72	1.98	2.98	–	–	6
		SSD	2.08	1.13–3.88	2.75	1.58	1.65	2.99	–	4	7
		BM	2.25	1.20–3.63	2.43	1.53	2.13	2.17	1	4	9
		Mean	2.29								
		CD 5%	0.21	1.23							
	C II	HC	3.92	1.52–5.36	3.84	3.00	3.00	2.32	3	5	
		PS	3.30	2.33–6.40	4.07	3.53	2.52	3.34	1	4	
		SSD	3.22	1.71–4.80	3.09	2.49	3.63	3.65	–	2	
		BM	2.89	1.94–4.11	2.17	2.04	3.06	1.87	–	1	
		Mean	3.33								
		CD 5%	0.36	2.21							
	C III	HC	2.69	1.45–3.87	2.42	3.28	3.05	2.86	–	5	
		PS	2.10	1.20–3.20	2.00	3.35	1.42	2.97	–	2	
		SSD	2.25	1.36–3.54	2.18	2.21	1.79	2.35	–	1	
		BM	2.50	1.77–3.97	2.20	2.93	2.58	2.26	–	4	
		Mean	2.38								
		CD 5%	0.25	1.52							
F_5 (kh)[a]	C I	HC	2.66	1.47–4.33	2.86	1.43	2.26	1.86	3	5	14
		PS	2.61	1.58–3.67	2.09	1.38	2.17	2.02	2	2	8
		SSD	2.60	1.56–3.83	2.27	1.79	2.35	2.76	–	3	6
		BM	2.65	2.19–4.12	1.93	1.02	2.03	1.94	2	2	8
		Mean	2.63								
		CD 5%	0.18	1.27							
	C II	HC	2.51	1.19–3.89	2.70	1.13	2.38	1.91	4	5	
		PS	2.44	1.19–3.82	2.33	1.10	1.90	3.33	–	3	
		SSD	2.27	1.36–3.58	2.22	1.07	1.79	3.25	–	1	
		BM	2.23	1.02–4.31	3.29	1.38	2.76	2.41	1	3	
		Mean	2.36								
		CD 5%	0.17	1.24							
	C III	HC	2.83	1.64–3.93	2.29	1.19	3.08	2.63	–	4	
		PS	2.58	1.50–4.25	2.75	1.93	2.93	2.87	–	3	
		SSD	2.40	1.07–5.25	4.18	1.41	2.22	2.52	1	2	
		BM	2.35	1.42–4.45	3.03	1.05	2.01	1.31	2	3	
		Mean	2.54								
		CD 5%	0.20	1.35							
F_6 (kh)	C I	HC	2.34	1.05–3.46	2.41	1.31	2.01	2.13	2	7	17
		PS	1.95	0.83–2.97	2.14	0.92	1.58	1.70	1	1	7
		SSD	1.99	1.31–2.73	1.42	1.00	2.00	2.09	–	–	5
		BM	2.22	1.27–3.56	2.29	1.91	1.85	1.65	3	4	7
		Mean	2.12								
		CD 5%	0.22	1.24							
	C II	HC	1.80	0.86–3.30	2.44	1.16	1.41	1.17	2	6	
		PS	1.50	0.69–2.50	1.81	0.82	1.36	1.58	–	2	
		SSD	1.54	0.93–2.48	1.55	0.84	1.88	2.36	–	2	
		BM	1.46	0.84–2.64	1.80	1.00	1.75	2.14	–	2	
		Mean	1.57								
		CD 5%	0.20	1.15							
	C III	HC	1.69	1.10–2.58	1.48	1.14	1.65	2.00	–	4	
		PS	1.58	0.81–2.51	1.70	0.81	1.70	2.18	–	4	
		SSD	1.66	0.87–2.69	1.82	1.06	1.12	1.47	2	3	
		BM	1.37	0.62–2.39	1.77	0.74	1.70	2.17	–	1	
		Mean	1.57								
		CD 5%	1.17	1.00							

[a] s, summer; kh, kharif

Table 2 Mean, range, and number of superior lines for pods per plant derived by four selection methods in three crosses

Generation	Cross	Selection method	Mean of all the lines	Range	Diff. between min. and max. values or range	Checks			No. of superior lines over best check	No. of lines in top 10% group	
						SML32	ML267	K851		In each cross	Over crosses
F_5 (s)[a]	C I	HC	11.77	4.93–23.70	18.77	7.53	7.80	12.00	2	3	10
		PS	10.09	7.07–16.13	9.06	9.93	11.00	10.87	2	1	7
		SSD	11.74	6.73–22.80	16.07	7.87	9.67	16.13	1	5	8
		BM	10.87	7.63–17.53	9.90	7.93	12.87	9.73	1	3	11
		Mean	11.11								
		CD 5%	0.72	4.12							
	C II	HC	17.74	10.00–30.60	20.60	13.20	13.60	8.53	5	5	
		PS	15.10	10.27–29.93	19.66	15.20	13.27	13.67	3	6	
		SSD	14.57	8.33–20.07	11.74	10.87	12.53	12.63	1	1	
		BM	13.19	8.93–17.67	8.74	9.60	12.20	8.47	3	–	
		Mean	15.15								
		CD 5%	1.27	7.32							
	C III	HC	12.60	6.33–19.33	13.00	11.63	14.07	12.80	1	2	
		PS	10.69	6.60–14.93	8.33	10.93	7.33	9.60	–	–	
		SSD	10.34	5.80–16.67	10.87	9.53	8.27	9.00	1	2	
		BM	10.96	4.60–21.20	16.60	11.47	12.33	5.93	3	8	
		Mean	11.14								
		CD 5%	0..97	5.60							
F_5 (kh)[a]	C I	HC	13.42	8.03–21.87	13.84	7.20	11.27	9.80	5	9	16
		PS	12.42	8.73–17.73	9.00	7.47	10.73	8.87	2	1	6
		SSD	12.24	6.93–17.27	10.34	7.40	12.07	12.53	1	1	8
		BM	12.38	10.07–17.80	7.73	5.67	10.40	10.87	1	1	6
		Mean	12.61								
		CD 5%	0.90	5.20							
	C II	HC	12.12	8.47–19.07	10.60	9.70	13.27	10.80	1	3	
		PS	11.68	6.93–17.40	10.47	5.27	9.20	14.07	–	2	
		SSD	11.48	7.00–15.67	8.67	6.33	9.80	14.60	–	4	
		BM	11.11	7.47–18.27	10.80	7.27	13.40	11.67	–	3	
		Mean	11.59								
		CD 5%	2.70	4.98							
	C III	HC	12.11	7.53–17.87	10.34	6.53	10.67	10.50	3	4	
		PS	12.74	8.73–19.20	10.47	7.80	14.07	14.27	–	3	
		SSD	11.14	6.60–18.93	12.33	6.47	10.00	10.80	2	3	
		BM	11.67	5.07–20.53	15.46	9.00	10.33	6.60	2	2	
		Mean	11.91								
		CD 5%	0.87	4.98							
F_6 (kh)	C I	HC	9.37	4.23–14.60	10.37	6.13	8.07	7.53	3	6	15
		PS	8.70	5.27–12.33	7.06	4.93	7.73	7.30	–	–	6
		SSD	8.90	5.80–12.93	7.13	5.60	8.27	8.50	–	1	6
		BM	10.17	5.60–16.40	10.80	4.87	9.73	8.33	2	5	9
		Mean	9.28								
		CD 5%	0.87	4.98							
	C II	HC	8.19	4.17–14.77	10.60	5.93	6.80	7.60	2	6	
		PS	6.84	3.93–11.33	3.93	4.53	6.47	6.73	1	2	
		SSD	7.76	5.27–10.33	5.06	5.13	8.73	11.73	–	2	
		BM	7.40	3.73–11.87	8.14	5.80	9.20	7.93	–	2	
		Mean	7.54								
		CD 5%	0.71	4.12							
	C III	HC	7.50	4.20–10.40	6.20	5.93	6.13	6.60	1	3	
		PS	7.03	4.53–10.93	6.40	5.53	7.87	7.87	–	4	
		SSD	7.31	4.80–10.60	5.80	5.07	5.53	5.73	3	3	
		BM	6.74	3.33–9.80	6.47	3.47	7.47	9.20	–	2	
		Mean	7.14								
		CD 5%	0.65	3.75							

[a] s, summer; kh, kharif

crosses and the three seasons, 23 HC, 12 BM, 11 PS and 7 SSD lines performed better than the best checks.

Proportion of lines in the top 10% group over three crosses. Ten lines derived by the HC method, eight by each of SSD and BM, and seven by PS method, constituted this group is F_5 (summer). In F_5 (kharif), 12 HC, eight each of BM and SSD, and six PS lines were included in the top 10% group. A similar pattern was also observed in the F_6 (kharif), the distribution being 15 HC, 9 BM, 6 PS and 6 SSD. On an overall basis, the proportion of HC lines was the highest (38.3%) followed by BM (23.4%), SSD (20.5%) and PS (17.8%).

(3) Lines performing well in both kharif and summer

In all the crosses, ranking of the top-yielding 10% lines developed by the four methods of selections in F_5 (summer) and F_5 (kharif) was carried out to determine whether there were common lines performing well in both seasons. The results are presented in Tables 3–5. Three lines in cross-I, two in cross-II, and three in cross-III, were common in these two seasons and were included in the top-yielding group. Out of these eight lines (over three crosses), four emanated from HC, with two each from the SSD and BM methods. None of the PS lines performed well in both the kharif and summer seasons.

Amongst the crosses, cross-I (ML 433 × ML 267) produced the maximum number of superior lines (17), followed by 11 and five by cross-II (PS-16 × 11/395) and cross-III (K 851 × TVM 229), respectively, for grain yield per plant (Table 6). Similarly, for the number of pods per plant, cross-I again yielded the maximum number of superior lines (20) while cross-II and cross-III yielded 16 lines each. On the basis of the above criteria, i.e., the mean of all the lines, the range, the number of

Table 3 Ranking of the top 10% high-yielding lines in F_5 (summer)

S.N.	Cross I			Cross II			Cross III		
	Line no.	Yield/plant (g)	Selection method	Line no.	Yield/plant (g)	Selection method	Line no.	Yield/plant (g)	Selection method
1	23	4.07	HC	184	6.40	PS	273	4.89	HC
2	25	3.93	HC	133	5.36	HC	267	4.04	HC
3	88	3.88	SSD	166	5.33	PS	375	3.97	BM
4	128	3.63	BM	142	5.26	HC	372	3.96	BM
5	6	3.40	HC	237	4.94	BM	291	3.87	HC
6	95	3.23	SSD	162	4.93	HC	388	3.82	BM
7	75	3.19	SSD	136	4.92	HC	275	3.81	HC
8	114	3.12	BM	169	4.91	PS	342	3.54	SSD
9	106	3.07	BM	167	4.81	PS	393	3.52	BM
10	27	2.93	HC	216	4.80	SSD	328	3.35	PS
11	96	2.89	SSD	220	4.36	SSD	270	3.30	HC
12	121	2.88	BM	241	4.11	BM	327	3.20	PS
Best check		2.99			3.65			3.35	
CD 5%		0.21			0.36			0.24	

Table 4 Ranking of the top 10% high-yielding lines in F_5 (kharif)

S.N.	Cross I			Cross II			Cross III		
	Line no.	Yield/plant (g)	Selection method	Line no.	Yield/plant (g)	Selection method	Line no.	Yield/plant (g)	Selection method
1	6	4.33	HC	238	4.31	BM	332	5.25	SSD
2	5	4.16	HC	147	3.94	HC	377	4.45	BM
3	113	4.12	BM	154	3.91	HC	318	4.26	PS
4	23	4.04	HC	138	3.89	HC	291	3.93	HC
5	82	3.83	SSD	170	3.82	PS	288	3.88	HC
6	36	3.67	PS	140	3.76	HC	374	3.82	BM
7	88	3.64	SSD	156	3.75	HC	269	3.71	HC
8	68	3.61	SSD	193	3.59	PS	344	3.69	SSD
9	126	3.57	BM	220	3.58	SSD	273	3.66	HC
10	15	3.51	HC	178	3.38	BM	315	3.38	PS
11	9	3.49	HC	241	3.25	PS	373	3.36	BM
12	71	3.44	SSD	182	3.23	PS	393	3.21	BM
Best check		2.76			3.33			2.93	
CD 5%		0.18			0.17			0.12	

Table 5 Common lines for the *summer* and *kharif* seasons

Cross	Line no.	Selection method	F_5 (summer)		F_5 (kharif)	
			Yield/plant (g)	Rank	Yield/plant (g)	Rank
Cross I	6	HC	3.40	5	4.33	1
	23	HC	4.07	1	4.04	4
	88	SSD	3.88	3	3.64	7
	Best check		2.99		2.76	
Cross II	220	SSD	4.36	11	3.59	9
	241	BM	4.11	12	3.25	10
	Best check		3.65		3.33	
Cross III	273	HC	4.79	1	3.66	9
	291	HC	3.87	5	3.93	4
	393	BM	3.52	9	3.21	12
	Best check		3.35		2.93	

Table 6 Comparative performance of three crosses for producing superior lines over the best check in three seasons

Cross	No. of superior lines of grein yield[a]				No. of superior lines for pods per plant[a]			
	F_5 (s)	F_5 (kh)	F_6 (kh)	Total	F_5 (s)	F_5 (kh)	F_6 (kh)	Total
Cross I	4	7	6	17	6	9	5	20
Cross II	4	5	2	11	12	1	3	16
Cross III	–	3	2	5	5	7	4	16

[a] s, summer; kh, kharif

lines superior to the best checks, and the proportion of lines in the top 10% group studied for grain yielding and the number of pods per plant, the honeycomb method showed a marked superiority over the other three methods. In mungbean, no studies on the comparative efficiency of the honeycomb method with the other methods are available in literature. However, Bhatia (1978) in barley, as well as Nagi et al. (1987) and Singh et al. (1987) in cotton, reported the higher efficiency of the honeycomb method in comparison to the others in isolating superior genotypes. The advantage of the honeycomb method over the other methods may be due to a substantial reduction in the influence of the environment on the selected individuals. The superiority is thus due to the fact that plants were selected in comparison to their six immediate neighbours showing not only the same macro-environment but also the same micro-environment. Additionally, in mungbean, the number of pods per plant, the number of grains per pod, and the 100-grain weight are also important yield components and the results of these component traits were almost similar to those for grain yield per plant. Amongst the other methods, pedigree selection, single-seed descent and bulk methods were equally effective in deriving the superior lines in the present study. These conclusions are in agreement with the findings of Hadded and Muehlbauer (1981) in lentil, Voigt and Wober (1960) in soybean, and Ntare et al. (1984) in cowpea. While PS, SSD and BM did not differ from each other, the success in pedigree selection is conditional in that it requires a large sample of plants to be selected from a large F_2 segregating population. Additionally, the trait under study should be highly heritable and predominantly controlled by additive gene effects. The single-seed descent method is free from these limitations of the bulk and pedigree methods. Moreover, it is economical in time, space and energy. Under these situations, the SSD method is more suitable either PS or BM. To conclude, in the present study the HC method was found to be highly effective for deriving superior lines with high seed yield and pod number. However, among the other methods, the SSD method may be preferred for the time required and the cost effectiveness in handling segregating generations of mungbean.

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