
STUDIES WITH ^{60}CO-RADIATED GUAR (*CYAMOPSIS TETRAGONOLOBA* (L.) TAUB[1, 2]

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ABSTRACT

Dry seeds of G–II (bushy, fodder type) and G–IV (erect, pod type) varieties of Punjab guar (*Cyamopsis tetragonoloba*) were radiated with gamma rays using ^{60}Co as source of radiation. The doses applied were 5,000, 10,000, 20,000, and 30,000 *r*. The radiation speeded up germination, increased the rate of root growth, and expanded the range of plant height and stem girth in the generation from the radiated seeds (R_1). Other morphological variants in R_1 were: Chlorophyll defects, small-leaved and small-poded types, unusually tall and unusually small plants, and chimaeras for pod and leaf size. In R_2 none of the above characters excepting chlorophyll defects appeared, thus establishing that non-genetic changes were responsible for other variations. In R_2 and R_3, however, segregation was observed for plant height and branching from both G–II and G–IV. In no case were the number of genes involved determined.

Various opinions have been and are being expressed about the usefulness of radiation as a practical measure in solving problems connected with agrarian plants. Whereas there is general skepticism among workers from several disciplines about the potentialities of radiation as a tool in plant breeding, several achievements in the field can not be overlooked. A few of them are the production of: "erectoides" barley (Gustafsson, 1947), stem-rot and leaf-spot resistant groundnut (Gregory, 1956), Svalof Primax white mustard and Regina II summer oil rape (MacKey, 1951), a new strain of ***Penicillium*** (Hollaender, 1945), and a host of other encouraging contributions (Smith, 1958). However, the fact that only one out of one thousand radiation-induced mutations are of economic significance (Gustafsson, 1947) must be the guide line for radiation-breeding programs.

Whereas extensive literature has accumulated on the effect of radiation on grain legumes, there is no satisfactory report on forage legumes, including guar, or *Cyamopsis tetragonoloba.* Guar has cleistogamous flowers, and is valued as

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forage, green manure, vegetable, and a source of mucilage. Studies were carried out on the effect of radiation on this species with a view to determing the mutants of economic or academic interest and results from five years' work (1960–1964) are being reported in this paper.

MATERIAL AND METHODS

Two guar types—G–II (bushy, profusely branching, small-leaved, fodder type) and G–IV (erect, practically branchless, broad-leaved, vegetable type)—were obtained through the courtesy of the Assistant Economic Botanist (Fodders), Punjab, India, and used for the study. Three sources of ^{60}Co-emitting gamma rays were used: Gamma garden of the World Agricultural Fair (American Pavillion) held in New Delhi in 1959–1960; the Atomic Energy Establishment, Trombay, India; and the ^{60}Co plant of the Indian Agricultural Research Institute, New Delhi, India.

Dry seeds of each type were radiated with doses of 5,000, 10,000, 20,000 and 30,000 *r*. Studies were carried out to the third radiation generation (R_3). To study the germination of the material, 1250 seeds of each variety were studied, 250 for each treatment. Of these 250, 100 were germinated in the laboratory in petri dishes and 150 were grown in the field. Plants were grown during June and October and were spaced approximately 2×2½ feet apart. Data from field-grown material were collected from the standing plants as far as possible.

A random sample of the material was taken for the purpose of analysis. The girth of the plant was determined by measuring the base at ground level. A population was taken as having matured when more than 90 percent of the plants had turned brown, the pods hardened, and the apical portion showed no further growth. For cytological work, the flower buds were fixed in an acetic acid-ethyl alcohol (1:3) mixture. For purposes of studying pollen fertility, the anthers were squashed in a drop of one percent aceto-carmine.

EXPERIMENTAL RESULTS

First Radiation Generation (R_1)

Seed germination and root growth. Radiation appeared to increase the rate of germination (Table I). The rate of root growth for the first 96 hours of petri-culture are summarized in Table II. Morphologically the roots from the treated materials were normal.

TABLE I

Cumulative percentages of seed germination in petri-culture in R_1

Hours after culture	Treatment				
	Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:					
24	—	—	4	—	—
36	—	25	37	30	29
48	16	62	76	71	83
60	35	79	94	90	98
72	91	92	94	90	98
G–IV:					
24	—	1	27	5	20
36	—	44	63	33	52
48	49	75	88	64	98
60	67	95	96	72	100
72	96	96	96	85	100

Establishment of the field populations. All the seedlings from the seeds germinated in the field did not survive to maturity. Many died of chlorophyll deficiency at early stages. Several plants had normal chlorophyll development, but died due to some unknown physiological causes. The percentages of survival are given in Table III. Poor survival at maturity is especially evident at 30 *kr*, both in G–II and G–IV.

TABLE II

Root* growth in petri-culture in R_1 population (mm)

Hours after Culture	Treatment				
	Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:					
24	—	—	1.2	—	—
36	—	2.3	2.5	2.0	2.3
48	1.6	5.4	7.9	6.9	4.1
60	3.9	9.5	10.4	12.1	7.5
72	8.9	14.2	21.2	22.5	20.4
84	14.3	21.8	38.3	37.0	36.8
96	25.4	31.7	50.4	48.3	49.6
G–IV:					
24	—	2.5	3.4	1.3	2.2
36	—	3.3	4.9	3.9	4.5
48	2.1	8.4	9.9	9.8	9.1
60	4.5	11.9	13.5	14.3	14.3
72	8.3	20.4	20.9	16.9	22.0
84	11.9	35.0	32.0	21.4	37.8
96	21.9	44.9	45.0	30.4	48.9

*Mean of maximum of 15 roots.

TABLE III

Percentages* of survivals in field populations in R_1

Days after Sowing	Treatment				
	Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:					
12	94	94	92	92	90
21	90	92	88	88	84
30	90	84	82	82	78
At maturity	90	80	78	80	72
G–IV:					
12	92	94	90	92	90
21	90	90	88	88	86
30	88	84	82	82	78
At Maturity	88	80	78	78	72

*Percentage figures were rounded to whole numbers.

Chlorophyll defects. Within the seedling population, studies were made for chlorophyll mutants from the time of germination until maturity. Several types of mutants were recognized. These were, in order of descending frequency: (1) Blotched-yellow, which were essentially yellow leaved, but had patches of varying intensity from greenish-yellow to deep-yellow; (2) Xantha, with white-yellow seedlings—all of which died; (3) Lutescent, which were green at first, but later turned yellow; and (4) Virescent, which were pale yellow at first, but later became green and resumed normal growth. Generally chlorophyll abnormalities were observed to increase with increasing dose (Table IV; Fig. 1). Lutescent and virescent mutants failed to appear in the control population. No albino plants were recovered.

The question arose as to whether the blotched-yellow mutants were due to viral invasion. Extracts from their leaves were therefore rubbed on the surface of artificially wounded parts of the stem and leaves of the control plants. No infection was noted, indicating that the blotched-yellow effect was the result of radiation.

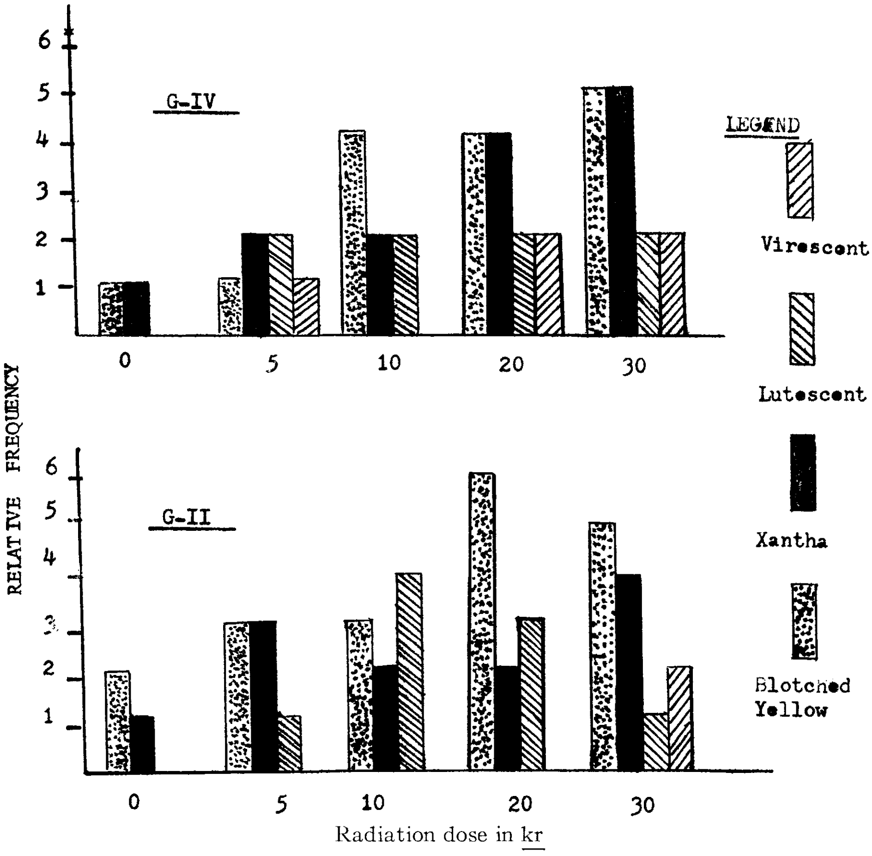


FIGURE 1

FIGURE 1. Histogram showing the frequency of chlorophyll defects in R_1.

Morphology at maturity. Stem. In all treated populations, the color of the stem was similar to that in the control (grey). Plants varied in stem diameter (at base), branching habit, and height. In G–II, the base girth of control plants ranged from 6.5 to 8.3 cm, as compared with 5–16 cm recorded in the treated population. In G–IV, the range for the treated population was from 4 to 7.9 cm, as compared with 6 to 7.8 cm for the control. Treatments apparently changed the range without changing the mean.

In one plant treated with 10 *kr* in G–II and another plant from 10-*kr*-treated G–IV, the stem was seen to be dichotomized at the base. Both of the so-called

TABLE IV

Type and frequency of chlorophyll mutants in R_1

	Type of Mutant	Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:						
	Total population	135	120	117	120	108
	Blotched yellow	2	3	3	6	5
	Xantha	1	3	2	2	4
	Lutescent	—	—	4	3	1
	Virescent	—	1	—	—	2
	Total	3	7	9	11	12
	Percent of population	2.3	5.8	7.7	9.1	11.1
G–IV:						
	Total population	132	120	116	117	108
	Blotched yellow	1	1	4	4	5
	Xantha	1	2	2	4	5
	Lutescent	—	2	2	2	2
	Virescent	—	1	—	2	2
	Total	2	6	8	12	14
	Percent of population	1.5	5.0	6.7	10.2	13.1

TABLE V

Data on the girth of treated population from R_1 (cm)

		Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:						
	Range	6.5–8.3	5.0–12.0	6.0–10.0	6.0–16.0	5.0–12.0
	Average	8.0	8.3	7.9	8.1	8.1
G–IV:						
	Range	6.0–7.8	4.0–7.5	5.5–7.3	5.0–7.8	5.0–7.9
	Average	7.0	6.8	7.1	7.2	7.1

main branches of these stems were equally thick. The general branching pattern of the treated material remained unaltered. Occasionally, a branch or two were seen growing towards the apical part of otherwise branchless G–IV.

Height of the treated population also increased. It varied from 109 to 200 cm in G–II (control 104 to 160 cm) and 115 to 290 cm in G–IV (control 122 to 190 cm). Frequency distribution of height of radiated and control materials are given in Table VI.

Leaf. Leaves appeared normal for the major part of the radiated population. Variations in the leaf size were observed with doses of 20 and 30 *kr* in G–II and with 10 and 20 *kr* in G–IV. These plants had miniature leaves (Figs. 2 and 3) measuring (central leaflet) on an average $3.2 \times 2.6 \pm 0.31 \times 0.27$ cm in G–II (control, $10.9 \times 8.9 \pm 0.18 \times 0.25$ cm) and $7.1 \times 5.2 \pm 0.41 \times 0.42$ cm in G–IV (control, $12.3 \times 8.5 \pm 0.12 \times 0.54$ cm). The frequency of the small-leaved plants was 12 and 27 in the 20- and 30-*kr*-treated G–II populations, respectively; and 8 and 3 in the 10- and 20-*kr*-treated materials of G–IV, respectively. In G–II it was not necessarily the whole plant that was affected, but quite often only a few branches of

Table VI

Frequency distribution of height in R_1 expressed in percentage of surviving population at the time of maturity

Treatment	Range in centimeters								
	100–125	125–150	150–175	175–200	200–225	225–250	250–275	275–300	Mean
G–II:									
Control	46	49	5	—	—	—	—	—	128.4
5 *kr*	42	56	2	—	—	—	—	—	128.6
10 *kr*	32	40	21	7	—	—	—	—	139.4
20 *kr*	38	25	22	15	—	—	—	—	142.1
30 *kr*	31	22	29	18	—	—	—	—	146.0
Mean	33.8	38.4	15.8	12.0	—	—	—	—	136.9
G–IV:									
Control	2	49	48	1	—	—	—	—	149.5
5 *kr*	—	2	47	35	12	—	—	—	170.2
10 *kr*	—	16	13	13	34	6	2	16	250.2
20 *kr*	16	15	8	14	18	23	14	2	213.2
30 *kr*	9	11	9	36	34	1	—	—	182.0
Mean	3.4	18.6	25.0	19.8	19.6	5.8	3.2	3.6	184.0

Table VII

Mean number of seeds and mean pod length (cm) in R_1*

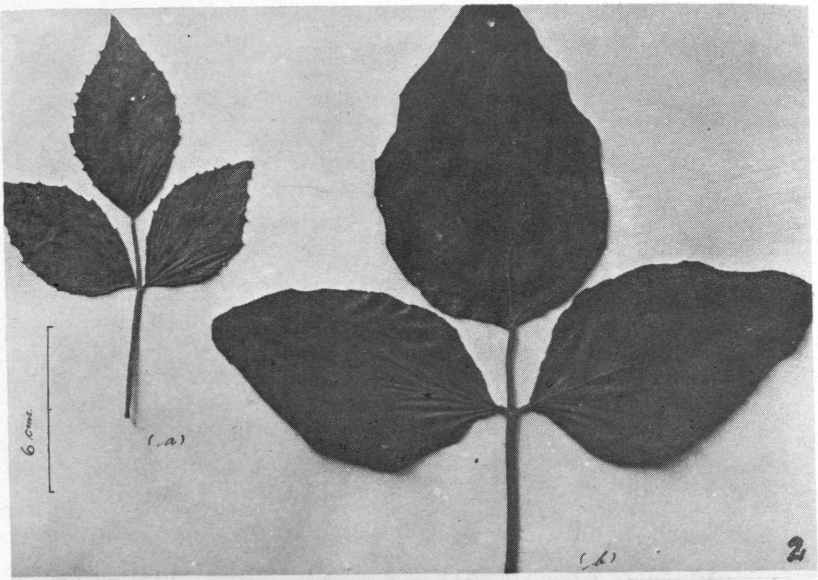
	Treatment				
	Control	5 *kr*	10 *kr*	20 *kr*	30 *kr*
G–II:					
Seeds per pod	8.9	8.9	8.0	8.0	8.1
Pod length	5.9	5.6	5.9	5.8	5.8
G–IV:					
Seeds per pod	9.4	9.2	7.8	8.4	8.2
Pod length	6.6	5.5	5.9	5.8	5.1

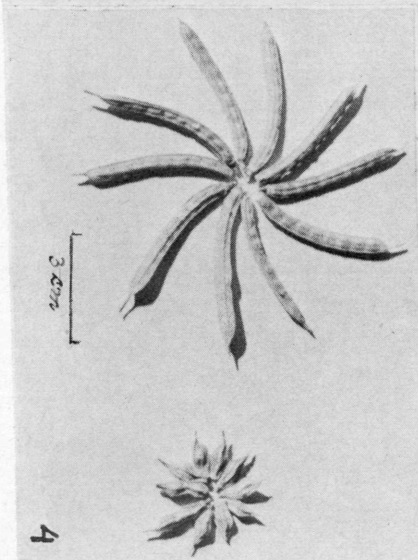
*Average of 100 pods.

the otherwise normal-looking plant, thus giving a chimaeric status to the plant. No other leaf abnormalities were observed. Among the control groups, no small-leaved plants were found.

Pod. An interesting variant in fruit size was dwarf fruit—*ca.* 2 cm long, both in G–II and G–IV, as compared with the corresponding figures of 5.9 and 6.6 cm in the control. These miniature pods had 1 to 3 seeds per pod, whereas normal pods carry about 8 to 10 seeds in G–II and 9 to 11 in G–IV (fig. 4). Another type of result was a pod with constrictions between the seeds, as if the seeds at the positions of the constrictions had not developed. Control plants expressed no such abnormalities. The small and constricted pods usually had smaller clusters of three to five pods per cluster, against those of 10 and 14 in normal G–II and G–IV respectively. Sometimes a part of the rachis bearing these small pods was naked. In a few cases, the clusters of such variant pods contained one or two normal pods intermixed with them.

Chimaeras were noted as to pod size also. In several instances, in G–II, a part of the plant carried large, normal pods with the remaining part bearing small pods. Such chimaeras were not observed in G–IV. The G–II population on the whole included 12 chimaeras in 20-*kr* treatment and 2 fully small-podded plants and 25 chimaeras in 30-*kr* treatment. The plants or branches carrying small pods always had small leaves.





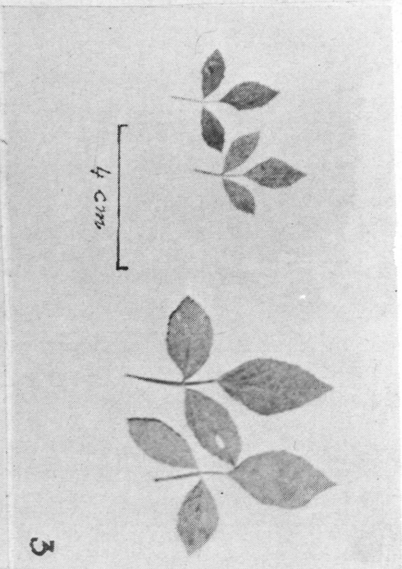


FIGURE 2. Leaf samples from types G–II (a) and G–IV (b). Untreated Controls.
FIGURE 3. Miniature leaves from R_1; G–II (left) and G–IV.
FIGURE 4. Normal (left) and miniature pod types from R_1. Specimen from G–IV.

In G–IV, but not in the G–II population, the number of seeds per pod and the pod length were reduced in the treated material. The means, based on samples of 100 pods, are given in Table VII. In the case of G–IV treated with 5 *kr*, the number of seeds per pod was not reduced, in spite of the fact that the pod size did decrease slightly.

There was no difference in the weight of 100 seeds between the treated and untreated materials. The seed weight averaged about 380 mg in G–II and 400 mg in G–IV. Even the seeds from small pods were not appreciably different in this regard.

Maturity. All the lines appeared to mature at the same time as the control. It took about 141 days for G–II (control) and 100 days for G–IV (control) to reach maturity. Three plants in G–II (10-*kr* line) and 6 in G–IV (2 from 20-*kr* and 4 from 30-*kr* line) were late in maturity by about 15 days. The seed of these plants was isolated and further studied in R_2. On the whole, no noteworthy differences were recorded between the treated and control materials.

Cytology. Pollen-stainability studies were made in R_1. Every plant was separately studied. Pollen fertility for most of the plants of both varieties was between 85.5 and 100 percent, with the exception of one plant from 20-*kr*-treated G–II, which had only 41.5 percent stainable pollen. This plant was known to be the result of a translocation between chromosome number 1 and chromosome number 2 and has already been reported elsewhere (Vig, 1965). A sample of 15 plants having less than 92 percent fertility was analysed for its meiotic behaviour, but no irregularities were observed. In a few cases, however, one or more components of the tetrad were noted to be less developed than others.

Second Radiation Generation (R_2)

This generation was studied for two reasons: first to find out about the genic status of the above described variants, and second, to establish any superior isolates of economic significance. It was not possible to grow all the collections made in R_1. A random sample of different representatives was therefore selected for the study of the different characters discussed below.

Small-leaved variants. Without consideration of the treatment given originally, 60 seeds of each of the 15 small-leaved plants of G–II from R_1 and 60 each of the 11 plants of G–IV were sown. No differences were observed either in the growth rate or growth pattern of the leaves, when compared with plants within or between treatments or with those of the control. All plants had normal leaves.

Small-podded variants. Because the plants with small leaves always had small pods, the same sample used for the leaf-size studies were employed in this determination. As above, the progeny of the small-podded plants had normal pod length.

Chimaeric population. Seed samples of the large- and small-podded branches of all the plants expressing chimaeric constitution in R_1 were sown. Among the sample of 60 offspring from each R_1 plant, no variations were noted to reappear in R_2.

Maturity. A sample of 60 seeds obtained from each of the nine late-maturing plants from R_1 apparently did not inherit the trait for lateness.

Tall- and small-sized plants. A composite sample of seeds of 10 tall plants and another sample of 10 small individuals isolated in the previous generation were obtained in variety G–II and another, duplicate set in type G–IV. G–II plants were considered tall when over 160 cm, whereas tall heights for G–IV began at 205 cm. Small-sized G–II plants were always below 100 cm; small G–IV plants were less than 120 cm. Sample populations from 60 tall plants and dwarf plants of R_1 all produced offspring which were normal in height (120–140 cm for G–II and 140–160 cm for G–IV). Only one line descending from a 10-*kr*-treated G–II plant originally 105 cm tall in R_1 gave, in R_2, a uniformly tall (between 181 and 202 cm; mean 189 cm) progeny of 58 plants. However, there were two exceptions, which were only 108 and 126 cm tall. A few of the R_2 plants obtained from tall R_1 parents maintained tallness, whereas other R_2 individuals were normal. Their ancestry and habit are given in Table VIII. These were also carried to R_3 and their progenies noted for tallness (discussed later). All the dwarf plants of R_1 produced normal progenies.

TABLE VIII

The ancestory and height of individual tall plants in R_2

R_1 parents			R_2 progeny	
Variety	Treatment	Height (cm)	Height (cm)	Accession Number
G–II:	30 *kr*	189	187 182	227 241
G–IV:	5 *kr*	242	215 225	258 278
	20 *kr*	250	225	374
	20 *kr*	261	244 225	436 459

TABLE IX

Data on segregation for plant habit in R_2

S. No.	Accession Number (R_1)	Treatment to R_1 (*kr*)	Total plants Studied in R_2	Segregants Erect	Segregants Bushy
G–II:					
1.	7	5	52	34	18
2.	18	5	51	26	25
3.	29	5	54	31	23
4.	44	10	48	24	24
5.	64	20	52	41	11
6.	67	20	49	39	10
7.	89	30	56	32	24
8.	92	30	51	28	23
Total for G–II:			413	255	158
G–IV:					
9.	102	5	46	31	15
10.	123	5	50	25	25
11.	129	10	52	41	11
12.	132	10	50	29	21
13.	142	10	46	29	17
14.	148	10	53	37	16
15.	159	20	49	22	27
16.	168	20	56	40	16
17.	175	20	48	25	23
18.	178	30	52	40	12
19.	188	30	54	31	23
20.	191	30	49	13	36
21.	194	30	55	32	23
Total for G–IV:			660	395	265
Grand total for G–II and G–IV:			1073	650	423

Segregated Traits. It was not possible to study the progeny of all the R_1 plants for character segregation. A sample of 200 R_1 plants was selected and it included the plants already discussed in connection with leaf, pod, and other variations. In all, the seeds from 129 R_1 plants from G–II and 71 R_1 plants from G–IV were sown. A total of 12,000 seeds, at the rate of 60 seeds per R_1 plant sampled, were sown. Segregation was recorded for chlorophyll defects and for bushy (G–II) versus erect (G–IV) type of growth habit.

Among the 526 plants of G–II progenies from 14 R_1 plants, only 54 plants with chlorophyll defects were observed. Only 83 were noted among 534 plants of G–IV progenies in 17 R_1 plants. All the chlorophyll-deficient plants died within 32 days of sowing. No attempt was made to classify the plants as to degree of chlorophyll deficiency.

Careful attention was given to the bushy versus non-bushy character of the segregating populations. In G–II the progeny from 8 R_1 plants segregated for this character and in G–IV, from 13. Details are given in Table IX. Bushy populations from G–II gave a total of 413 plants, segregating into 255 erect and 158 bushy. Out of a total of 660 G–IV descendants, 395 were erect and 265 were bushy. No ordinary mendelian ratio could be worked out to fit these data. It was therefore decided to carry the samples from these segregating lines further, to R_3, to study whether these deviations from any genetic ratio were due to the nongenetic modifications brought about by radiation.

Third Radiation Generation (R_3)

This generation was studied to select the desirable genotypes and to analyse the genetic makeup of the segregants for growth habit. Of a total of 1073 plants collected from the segregating lines of R_2, a random sample of 284 individuals was selected. It included the bushy and erect character in equal numbers. Here a rather large population of 200 seeds from each individual was sown and data collected at maturity. Three types of genotypes were diagnosed for the parent R_2's: one, the bushy plants of R_2, which produced, uniformly, bushy plants only; second, the tall or erect phenotype of the parental R_2 plants which either (1) bred true for erectness or (2) segregated further into a combination of erect and bushy types in R_3. The latter class came only from the progenies of 30 R_2 plants. A total of 4247 plants obtained from all these 30 plants gave 2767 erect plants, together with 1480 bushy plants. Details of the data are reported in Table X.

Because of unexpected heavy rains during the period of work with R_3 and the uneven level of the field, certain lines were uneven and had a very poor stand, some with as low as 64 plants only. Even if the number of plants per row had been large in this generation, no final conclusion could yet be reached as to the number of genes involved in the control of growth habit; bushiness versus erectness. Chi square did not reveal any uniformity for the ratios except a tentative 3:1 fit in cases indicated in Table X.

For several characters, including branching, height, pod, and leaf characters, R_3 was rather uniform within the descendants of the same R_2. However, differences were noted for height and number of branches among the progenies from different R_2 plants. A sample of 13 R_2 plants (descendants of one 195-cm-tall R_1 originally from 10-*kr* treatment of G–II) gave all tall progenies in R_3 in all the 13 cases studied (R_2 descendants had a mean height of 184 cm). From the individual tall plants of the previous generation (Table VIII) Acc. 227 and 241 from G–II and Acc. 258, 374, and 436 from G–IV appeared to breed true for height. All these lines have been isolated for use in breeding work. These studies were made, however, from seed samples of only 60 seeds for each R_2 selected plant.

Fruit set in this generation was not uniform and varied even within the descendants of the same R_2 plant. Fifty heavy-fruited plants have been isolated and are to be carried further for a study of the usefulness of their descendants in breeding heavy-setting varieties of the G–IV type. A similar sample of 50 bushy plants with good branching and profuse growth has been collected to study the possibility of breeding some high-forage-yielding lines.

TABLE X

Data on segregation of plant habit in R_3*

S. No.	Total plants studied in R_3	Segregant types	
		Erect	Bushy
1.	182	119	63
2.**	154	110	44
3.**	96	72	24
4.	64	27	37
5.	118	79	39
6.**	169	128	41
7.	126	78	48
8.**	197	145	52
9.**	121	90	31
10.	75	50	25
11.	112	71	41
12.	109	68	41
13.	134	92	42
14.	101	67	34
15.	159	94	65
16.	157	100	57
17.**	157	115	42
18.	174	120	54
19.	145	89	56
20.	154	87	67
21.**	187	135	52
22.	197	115	82
23.	129	70	59
24.	113	62	51
25.**	146	109	37
26.	182	127	55
27.**	175	127	48
28.**	122	86	36
29.**	119	83	36
30.	173	52	121
Total	4247	2767	1480

*All parent plant lines from R_2 were erect type.
**Lines showing close fit to 3:1 ratio ($p > 0.05$).

DISCUSSION

Radiation has been used to cause non-heritable modifications and heritable mutations. Stimulations on the growth of various organs of the treated materials have been well studied and discussed by several workers (Read, 1959). In the present case there was a direct correlation between the radiation dose and the rate of germination of the seeds. In 10-*kr*-treated material, both in G–II and G–IV varieties, germination was faster in early stages, but later 30-*kr*-treated material outyielded others. Such non-linear results have been obtained with *Vicia faba* by Sjodin (1962). In the treated material, the ability to germinate was not impaired, an observation contradictory to several reports on other materials (Dhesi and Nandpuri, 1964; Jagathesan and Sastry, 1963).

Kersten *et al.* (1943), working with X-rayed corn, observed the stimulating effect of radiation on growth of roots. Read (1959) suggested stimulating effects of radiation based on observations on *Vicia*. Brown and Cane (1954) observed similar effects on the pollen of *Lilium*. Transport inhibition or inhibition of production of diffusible growth substances has been suggested as the cause of growth retardation in several irradiated plant populations (MacKey, 1951). Even though the present studies agree with the findings that radiation speeds up the growth of roots, yet there appears to be no correlation between rate of root elongation and size of dose. No serious root abnormalities, as recorded by many others (Sjodin, 1962), were observed in the present material.

The surviving populations were affected, however, especially those treated with a 30-*kr* dose. Germination percentage in all the treatments was good. The death before maturity may be attributed either to (1) chlorophyll defects or (2) unidentifiable physiological disturbances brought about by the radiation. Somewhat parallel results have also been obtained for *Vicia faba* treated with X-rays (Sjodin, 1962).

Chlorophyll mutations were observed both in R_1 and R_2. It is futile to compile all the literature on chlorophyll mutants, which appear in nearly all the radiation cultures. The types of mutants reported in the literature differ, however, depending upon the type and intensity of radiation, the genotype, and the environment under which the radiation was carried out. The chlorophyll mutants reported here have also been observed in other materials, especially legumes (Read, 1959; Zacharias, 1956; Sjodin, 1962). Albinism, a characteristic of several radiation-treated materials, was not observed in this species. Frequency of chlorophyll mutations was approximately the same in G–IV and G–II, both in R_1 and R_2 (Table IV). The pattern of inheritance could not be worked out precisely in any case.

Height and branching also seemed to be affected by radiation. The effect was more pronounced in certain individuals of a common descent. Here doses of 20 and 30 *kr* appeared to be most effective for G–II and those of 20 *kr* for G–IV. Such radiation-induced stimulation has also been described by Micke (1961). Not all the individuals so varying were the results of simple effects of stimulation, because it appeared from the breeding behaviour of several sibs (other plants in the same generation) that their parental plants had been affected at the genic level (hence true-breeding tall plants in R_2 and R_3). Because height is usually a quantitative character, no conclusions could be drawn as to its genetic basis from the available number of segregants.

Formation of small leaves and small pods in R_1 of the treated material was an interesting effect of radiation, since no such variants were recorded in the normal, untreated controls. These modifications did not repeat faithfully in the next generation, thus establishing non-genic components as the bases. The development of small-leaved and small-podded plants, or complete branches thereof, suggests the permanent inactivation of some substance(s) (cytoplasmic?) affecting the growth and development of leaves and pods in at least the immediate generation. Such leaf and pod abnormalities have also been recorded by Arya (1963) in his work with guar. Abnormalities in the form of unifoliate and trumpet-shaped leaves have also been observed in other cultures of legumes treated with radiation (*e.g. Vicia faba*; Sjodin, 1962). Some of these are known to be the results of heritable mutations, and thus to breed true. Different pod-type variants, including small and constricted pods, have also been recorded in *Vicia faba*, but are due to heritable, genic differences (Sjodin, 1962).

Another point of interest is the radioresistance of guar chromosomes. As high a dose as 30,000 *r* showed no detectable effect on the chromosomes. The only meiotic anomalies recorded were the depression of a few tetrads, or one or more of their components, thus reducing fertility (Vig, 1965). This might be a delayed effect of radiation. The procurement of only one translocation (Vig, 1965) and no other abnormality, besides the one discussed above, in the meiotic processes of chromosomes suggests the radioresistance of the guar chromosomes. Plants with small chromosomes, as is guar also, are known to have high radioresistance (cf. Dhesi and Nandpuri, 1964). Certain genomes have high radioresistance in spite of their large chromosomes. Radiation-resistance is thus thought to be governed by the genotype of the organism and legumes are notorious for this. One of the established cases is that of *Lupinus*, wherein Hackberth (1955) obtained no fertility differences between the treated and control materials of these species. Tedin and Hagberg (1952) had similar observations with *L. luteus* treated with 12,500, 15,000, and 17,500 *r* of X-rays. No significant differences in fertility of the treated and the control populations were recorded by Genter and Brown (1941) working with *Phaseolus vulgaris*, or by Mohanty (1960) working with ^{32}P-treated guar. Among the plants of other families, those which have the critical doses of 100,000 *r* are *Linum usitatissimum*, *Brassica rapa*, *Sinapis spp.*, and *Lallermantia iberica*, and those with critical doses of 50,000 *r* are *Ricinus* and *Sesamum* (Sanduleac, 1963). The *Brassica napus* genome was also found to have resistance up to doses of 64,000 *r*.

A convincing alternative suggestion made by Zacharias (1956) for *Glycine max* may be applicable to the present material. According to him, the lethal effect of X-rays in the plants which have chimaeras for their apical cell populations may be suppressed after radiation by virtue of a faster growth of the normal cells than that of the "abnormal" cells. Heavy reduction in the fertility of the irradiated material has been recorded in several species: barley (Gustafsson, 1944), *Pisum* (Gottschalk and Scheibe, 1960), *Vicia faba* (Sjodin, 1962), and *Alopecurus pratensis* (Whorman, 1955).

Height of the plant in the present study was a segregating character. In this autogamous plant (Hooker, 1872; personal observation), the bushy type always bred true in R_3, whereas erect plants showed two genotypic categories—heterozygous and homozygous. One rather definite conclusion is that the gene(s) controlling bushyness are recessive to the one(s) responsible for erectness. The lack of evidence of Mendelian segregation may be due to several expected disturbances at the genetic level in the irradiated populations and its unstable descendants.

No attempt was made to analyse the changes in the yield potentials of the irradiated material and its progenies. Wide differences casually observed could be due to radiation-caused instability. It is, however, known that yield is guar is largely an environmentally controlled character with a low heritability (Sanghi *et al.*, 1964).

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