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Further Studies on Some Morphological Characters of Pulses Collected in the Indian Sub-Continent

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Introduction

From October in 1971 to January in 1972, the writer was sent to India and Ceylon (Sri Lanka). During this trip, 106 strains of pulses were collected.

Grain legumes form a major component of lowland and upland tropical cropping systems. Throughout wet and dry tropics several species and strains are utilized in monoculture, and in complex multiple cropping and bush-fallow practices[13]. Morphological examinations are requested in the world for agronomical usage. In the previous paper[10], the distribution-areas, 6 characters, *i.e.*, length, width, thickness, ratio of length to width, ratio of length to thickness, ratio of width to thickness, and some relations among them were reported. In the present paper, 3 characters, *i.e.*, weight, area and volume of grains, and some mutual relations were mainly described, in order to confirm the morphological characters of grains and as well as to make clear the ecotypic differentiations of those grains.

The characters newly employed here were applied for the investigation of grain morphology in rice and some legumes[11,13], and some noteworthy meanings were shown. So in the present paper, out of these characters a trial was made in order to analyze the strain differentiations.

Materials and Methods

Thirty-three strains, belonging to 7 genera and 10 species, were picked out from 106 strains collected in the Indian Sub-Continent, and were used for morphological investigations of grains.

Strain numbers and species names of those strains are listed up in Table 1. Their collection-number, collection-date, English name and locality were mentioned in Table 1 of the previous paper[10]. Fifty grains were used for the measurement of the respective strains, excepting No. 12 (38 grains). Measurements were done in weight at the individual grain level in mg. Area and volume of the grains were calculated by length × width (mm^2) and length × width × thickness (mm^3), respectively. The whole data referring to the three characters were illustrated by the average values throughout the whole grains. Inquiries were made to fix the variation ranges for 9 characters, *i.e.*, 1 ··· length (mm), 2 ··· width (mm), 3 ··· thickness (mm), 4 ··· ratio of length to width (%), 5 ··· ratio of length to thickness (%), 6 ··· ratio of width to thickness (%), 7 ··· weight (mg), 8 ··· area (mm^2), and 9 ··· volume (mm^3) (Tables 2 and 3). In character Nos. 1–6, the data were cited from the previous paper[10].

To make clear the relationships between practical value and its standard deviations (no table), between the two respective characters noted in view of the practical values (Table 4), between the

Table 1. Materials used in the present experiment, species name and three characters

Strain No.	Species name	Weight (mg)	Area (mm^2)	Volume (mm^3)
1	*Phaseolus aureus*	42.29± 4.18	14.50±1.19	48.89± 5.37
2	〃	48.46± 4.41	18.58±1.18	70.26± 7.00
3	*Phaseolus mungo*	47.70± 6.46	18.38±1.51	59.08± 6.93
4	〃	56.09± 5.57	22.34±1.44	81.86± 9.95
5	〃	61.26± 4.46	23.85±1.36	88.88± 8.17
6	〃	42.71± 4.92	20.23±1.41	71.24± 8.35
7	〃	59.86± 4.86	20.84±1.80	67.14± 6.85
8	〃	32.21± 8.63	19.64±1.32	65.26± 7.90
9	〃	35.61± 6.07	16.57±1.03	49.93± 6.47
10	〃	73.15± 6.20	23.06±1.42	84.88± 6.84
11	*Phaseolus calcaratus*	51.43± 5.12	22.85±2.41	67.83± 9.67
12	〃	47.35± 5.96	20.68±3.40	59.33±13.29
13	〃	69.50± 7.58	31.43±1.95	114.21± 9.48
14	〃	44.27± 1.98	19.83±1.82	64.24± 7.74
15	*Phaseolus aconitifolius*	26.63± 3.25	15.61±0.86	48.09± 3.97
16	*Vigna sinensis*	130.99± 6.51	44.81±3.21	203.94±18.47
17	〃	281.07±24.11	67.91±6.16	407.14±58.28
18	〃	187.37±12.96	48.26±4.23	224.53±24.82
19	〃	281.86±18.50	62.06±4.22	403.17±40.85
20	〃	135.27± 5.17	41.40±2.64	183.18±15.26
21	〃	184.29± 8.83	52.92±4.64	273.31±32.76
22	*Vigna sesquipedalis*	133.64± 8.95	49.83±3.83	175.96±18.32
23	*Cajanus cajan*	89.36± 6.18	27.91±1.57	114.03± 9.52
24	*Clitoria ternatea*	56.26± 4.73	33.74±2.70	86.42± 7.50
25	*Glycine max*	156.52±15.14	49.71±4.16	264.83±30.74
26	〃	150.70± 9.90	51.40±2.79	240.98±20.09
27	〃	194.57±16.57	44.81±2.89	202.65±21.85
28	*Dolichos biflorus*	41.79± 4.17	25.09±1.93	52.50± 5.76
29	〃	27.40± 3.49	25.94±2.10	61.95± 7.60
30	〃	31.98± 5.05	22.59±2.92	44.65± 7.49
31 A	〃	42.40± 4.34	29.51±1.77	73.87± 7.35
31 B	〃	34.36± 5.38	29.26±2.07	60.08± 5.82
32	〃	46.94± 3.89	28.75±2.48	71.35± 8.09
33	〃	46.95± 3.94	27.39±3.12	61.61± 8.14

No. of grains used=50 (38 only in No. 12).

two respective characters fixed in view of the standard deviations (Table 5), and between two respective characters ascertained in view of variation ranges (Table 6), correlation coefficient and linear regression of those were calculated. Moreover, relations between the variation ranges and its average value and its standard deviations were calculated (Table 7). At last, comparisons of the four relation-groups were made, mainly using the data shown in Tables 4, 5 and 6 (Table 8).

In this paper, the following abbreviations were used, *i.e.*, the ratio of length to width (abbreviated as R·L/W, and so forth), ratio of length to thickness (R·L/T), ratio of width to thickness (R·W/T), correlation coefficient (c.c.), linear regression (l.r.) and standard deviations (s.d.).

Results

Part I. Respective character

1. Practical values of weight

The results are given in Table 1. Weights for the individual grain level ranged from 332.7 mg (No. 19) to 18.5 mg (No. 9). In the strain level, the heaviest (281.86 mg) was obtained in No. 19, followed by No. 17 (281.07 mg) and No. 27 (194.57 mg). The lightest (26.63 mg) was noted in No. 15, followed by No. 29 (27.40 mg) and No. 30 (31.98 mg). Mode was found within 40.01 to 50.00 mg (10 strains). The differences in the weight were confirmed to be very large in accordance with each strain. Average and its s.d. through the whole strains were found to be 88.01 ± 70.36.

Values of weight in the genera *Vigna* and *Glycine* were clearly larger than those of other genera. Values of weight in the genus *Phaseolus* were noted in the following order; *P. calcaratus* (53.14 mg in average) > *P. mungo* (51.18 mg) > *P. aureus* (45.38 mg) > *P. aconitifolius* (26.63 mg).

2. Practical values of area

Areas for the individual grain level ranged from 81.00 mm^2 (No. 17) to 11.95 mm^2 (No. 1). In the strain level, the widest (67.91 mm^2) was obtained in No. 17, followed by No. 19 (62.06 mm^2) and No. 21 (52.92 mm^2). The narrowest (14.50 mm^2) was noted in No. 1, followed by No. 15 (15.61 mm^2) and No. 9 (16.57 mm^2). Mode was found within 22.01 to 24.00 mm^2 (5 strains). The differences in the area were confirmed to be large in accordance with each strain. Average and its s.d. through the whole strains were found to be 31.52 ± 14.30.

Values of area in the genera *Vigna* and *Glycine* were clearly larger than those of other genera. Values of area in the genus *Phaseolus* were noted in the following order; *P. calcaratus* (23.61 mm^2 in average) > *P. mungo* (20.61 mm^2) > *P. aureus* (16.54 mm^2) > *P. aconitifolius* (15.61 mm^2).

3. Practical values of volume

Volumes for the individual grain level ranged from 516.65 mm^3 (No. 17) to 29.23 mm^3 (No. 30). In the strain level, the largest (407.14 mm^3) was obtained in No. 17, followed by No. 19 (403.17 mm^3) and No. 21 (273.31 mm^3). The smallest (44.65 mm^3) was noted in No. 30, followed by No. 15 (48.09 mm^3) and No. 1 (48.89 mm^3). Mode was found within 60.01 to 80.00 mm^3 (11 strains). The differences in volume were confirmed to be very large in accordance with each strain. Average and its s.d. through the whole strains were found to be 124.92 ± 98.75.

Values of volume in the genera *Vigna* and *Glycine* were clearly larger than those of other genera. Values of volume in the genus *Phaseolus* were noted in the following order; *P. calcaratus* (76.40 mm^3 in average) > *P. mungo* (71.04 mm^3) > *P. aureus* (59.58 mm^3) > *P. aconitifolius* (48.09 mm^3).

4. Standard deviations of 3 characters mentioned above

In Table 1, the standard deviations, *i.e.*, intra-strain's variations, are given. S.d. of the weight ranged from 24.11 (No. 17) to 1.98 (No. 14). Mode was found within 4.01 to 5.00 (8 strains). The average and its s.d. through the whole strains were found to be 7.28 ± 4.84.

Values of its s.d. in the genera *Vigna* and *Glycine* were clearly larger than those of other genera. Values of its s.d. in the genus *Phaseolus* were noted in the following order; *P. mungo* (5.90 in average) > *P. calcaratus* (5.16) > *P. aureus* (4.30) > *P. aconitifolius* (3.25).

S.d. of the area ranged from 6.16 (No. 17) to 0.86 (No. 15). It may be noted that the value was peculiarly large in No. 17. Modes were found within 1.21 to 1.50 and 1.81 to 2.10 (5 strains each). The average and its s.d. through the whole strains were found to be 2.43±1.27.

Values of its s.d in the genus *Vigna* were clearly larger than those of other genera. Values of its s.d. in the genus *Phaseolus* were noted in the following order; *P. calcaratus* (2.40 in average) > *P. mungo* (1.41) > *P. aureus* (1.18) > *P. aconitifolius* (0.86).

S.d. of the volume ranged from 58.28 (No. 17) to 3.97 (No. 15). It may also be noted that the value was peculiarly large in No. 17. Mode was found within 5.01 to 8.00 (14 strains). The average and its s.d. through the whole strains were found to be 13.73±11.80.

Values of its s.d. in the genera *Vigna* and *Glycine* were clearly larger than those of other genera. Values of its s.d. in the genus *Phaseolus* were noted in the following order; *P. calcaratus* (10.05 in average) > *P. mungo* (7.78) > *P. aureus* (6.19) > *P. aconitifolius* (3.97).

PART II. Ranges among the respective characters

1. Length

Maximum: The results are given in Table 2. In this table, the maximum, the minimum and its range are shown. The longest (10.85 mm) was obtained in No. 17, followed by No. 22 (10.75 mm) and No. 19 (9.95 mm). The shortest (4.70 mm) was noted in No. 1, followed by No. 9 (5.00 mm) and No. 3 (5.35 mm). Average and its s.d. through the whole strains were found to be 7.23±1.69.

Minimum: The longest (8.80 mm) was obtained in No. 22, followed by No. 17 (8.50 mm) and No. 19 (8.00 mm). The shortest (3.90 mm) was noted in No. 1, followed by No. 9 (4.35 mm) and No. 2 (4.40 mm). Average and its s.d. through the whole strains were found to be 5.88±1.34.

Range: The largest (2.35) was obtained in No. 17, followed by No. 18 (2.10) and No. 12 (2.05). The smallest (0.65) was noted in No. 9, followed by No. 14 (0.70). Mode was found in 0.80 (7 strains). Average and its s.d. through the whole strains were found to be 1.32±0.49.

2. Width

Maximum: The widest (7.80 mm) was obtained in No. 19, followed by No. 17 (7.70 mm) and No. 25 (7.10 mm). The narrowest (3.45 mm) was noted in No. 15, followed by No. 1 (3.70 mm) and No. 9 (3.90 mm). Average and its s.d. through the whole strains were found to be 5.20±1.15.

Minimum: The widest (6.30 mm) was obtained in No. 19, followed by No. 17 (6.00 mm) and Nos. 25 and 26 (5.90 mm). The narrowest (2.80 mm) was noted in No. 15, followed by No. 12 (2.85 mm) and No. 1 (2.95 mm). Average and its s.d. through the whole strains were found to be 4.08±0.97.

Range: The largest (1.70) was obtained in No. 17, followed by Nos. 18 and 21 (1.60) and Nos. 30 and 33 (1.55). The smallest (0.65) was obtained in Nos. 2, 9 and 15, followed by Nos. 1, 13 and 14 (0.75). Mode was found in 1.00 (4 strains). Average and its s.d. through the whole strains were found to be 1.12±0.31.

3. Thickness

Maximum: The thickest (7.20 mm) was obtained in No. 19, followed by No. 17 (6.95 mm) and No. 25 (5.75 mm). The thinnest (2.50 mm) was noted in No. 31B, followed by No. 28 (2.55 mm) and No. 33 (2.60 mm). Average and its s.d. through the whole strains were found to be

Table 2. Ranges of 5 characters in the strain level; length (mm), width (mm), thickness (mm), ratio of length to width (%) and ratio of length to thickness (%)

Strain No.	Length			Width			Thickness			Length/Width			Length/Thickness		
	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range
1	4.70	3.90	0.80	3.70	2.95	0.75	3.65	2.90	0.75	1.38	1.08	0.30	1.42	1.08	0.34
2	5.55	4.40	1.15	4.15	3.50	0.65	4.15	3.50	0.65	1.38	1.15	0.23	1.38	1.17	0.21
3	5.35	4.50	0.85	4.15	3.30	0.85	3.60	2.75	0.85	1.44	1.14	0.30	1.72	1.23	0.49
4	5.80	5.00	0.80	4.50	3.65	0.85	4.05	3.10	0.85	1.45	1.16	0.29	1.66	1.25	0.41
5	6.15	5.20	0.95	4.75	3.70	1.05	4.15	3.40	0.75	1.43	1.16	0.27	1.65	1.32	0.33
6	5.50	4.70	0.80	4.35	3.40	0.95	3.90	2.95	0.95	1.47	1.11	0.37	1.69	1.27	0.42
7	5.80	4.80	1.00	4.50	3.45	1.05	3.70	2.80	0.90	1.51	1.12	0.39	1.95	1.35	0.60
8	5.50	4.70	0.80	4.35	3.50	0.85	3.75	2.80	0.95	1.49	1.20	0.29	1.73	1.33	0.40
9	5.00	4.35	0.65	3.90	3.25	0.65	3.50	2.50	1.00	1.45	1.15	0.30	1.80	1.33	0.47
10	5.80	5.00	0.80	4.70	3.70	1.00	3.90	3.30	0.60	1.53	1.11	0.42	1.62	1.30	0.32
11	6.45	5.00	1.45	4.50	3.20	1.30	3.35	2.55	0.80	1.85	1.33	0.52	2.35	1.48	0.87
12	6.70	4.65	2.05	4.10	2.85	1.25	3.35	2.25	1.10	2.00	1.43	0.57	2.45	1.49	0.96
13	7.75	6.50	1.15	4.75	4.00	0.75	3.90	3.25	0.65	1.79	1.39	0.40	2.16	1.69	0.47
14	6.45	4.75	0.70	4.10	3.35	0.75	3.60	3.00	0.60	1.70	1.26	0.44	1.93	1.33	0.60
15	5.40	4.60	0.80	3.45	2.80	0.65	3.25	2.70	0.55	1.77	1.42	0.35	1.84	1.46	0.38
16	8.90	7.50	1.40	6.10	4.80	1.30	4.90	4.20	0.70	1.65	1.33	0.32	2.02	1.66	0.36
17	10.85	8.50	2.35	7.70	6.00	1.70	6.95	5.20	1.75	1.57	1.25	0.32	1.83	1.40	0.43
18	9.65	7.55	2.10	6.65	5.05	1.60	5.20	4.15	1.05	1.64	1.24	0.40	2.13	1.57	0.56
19	9.95	8.00	1.95	7.80	6.30	1.50	7.20	5.80	1.40	1.40	1.11	0.29	1.50	1.22	0.28
20	8.20	7.05	1.15	6.10	4.80	1.30	4.70	4.00	0.70	1.56	1.24	0.32	1.90	1.54	0.36
21	9.85	7.95	1.90	6.75	5.15	1.60	5.70	4.55	1.15	1.66	1.25	0.41	1.68	1.49	0.39
22	10.75	8.80	1.95	5.75	4.55	1.20	3.95	3.20	0.75	2.08	1.73	0.35	3.20	2.42	0.78
23	6.30	5.50	0.80	5.40	4.45	0.95	4.50	3.35	1.15	1.37	1.04	0.34	1.74	1.22	0.52
24	8.00	6.00	2.00	5.40	4.40	1.00	3.00	2.15	0.85	1.65	1.18	0.47	3.40	2.14	1.26
25	8.90	7.00	1.90	7.10	5.90	1.20	5.75	4.70	1.05	1.47	1.10	0.37	1.78	1.30	0.48
26	8.60	7.50	1.10	6.80	5.90	0.90	5.10	4.20	0.90	1.37	1.16	0.21	1.89	1.53	0.36
27	8.50	6.90	1.60	6.65	5.20	1.45	5.10	3.85	1.25	1.50	1.08	0.42	2.00	1.43	0.57
28	7.00	5.60	1.40	4.70	3.55	1.15	2.55	1.75	0.80	1.73	1.30	0.43	3.49	2.33	1.16
29	6.65	5.30	1.35	5.15	3.95	1.20	2.80	2.10	0.70	1.51	1.18	0.33	3.09	2.15	0.94
30	6.60	4.95	1.65	4.70	3.15	1.55	2.65	1.55	1.10	1.70	1.14	0.56	3.71	2.19	1.52
31A	7.20	6.10	1.10	4.85	3.85	1.00	3.00	2.25	0.75	1.75	1.34	0.41	2.93	2.30	0.63
31B	7.20	6.00	1.20	5.00	4.00	1.00	2.50	1.55	0.95	1.69	1.29	0.40	4.00	2.54	1.46
32	7.50	6.10	1.40	4.95	3.50	1.45	2.75	2.10	0.65	1.87	1.34	0.53	3.24	2.32	0.92
33	7.30	5.60	1.70	5.15	3.60	1.55	2.60	1.80	0.80	1.83	1.15	0.68	3.56	2.19	1.37

4.02±1.18.

Minimum: The thickest (5.80 mm) was obtained in No. 19, followed by No. 17 (5.20 mm) and No. 25 (4.70 mm). The thinnest (1.55 mm) was noted in Nos. 30 and 31B, followed by No. 28 (1.75 mm) and No. 33 (1.80 mm). Average and its s.d. through the whole strains were found to be 3.12±1.04.

Range: The largest (1.75) was obtained in No. 17, followed by No. 19 (1.40) and No. 27 (1.25). The smallest (0.55) was noted in No. 15, followed by Nos. 10 and 14 (0.60) and Nos. 2, 13 and 32 (0.65). Mode was found in 0.75 (4 strains). Average and its s.d. through the whole strains were found to be 0.89±0.25.

4. Ratio of length to width (R·L/W)

Maximum: The largest (2.08) was obtained in No. 22, followed by No. 12 (2.00) and No. 32 (1.87). The smallest (1.37) was noted in Nos. 23 and 26, followed by Nos. 1 and 2 (1.38) and No. 9 (1.40). Average and its s.d. through the whole strains were found to be 1.61±0.19.

Minimum: The largest (1.73) was obtained in No. 22, followed by No. 15 (1.42) and Nos. 31A and 32 (1.34). The smallest (1.04) was noted in No. 23, followed by Nos. 1 and 27 (1.08) and No. 25 (1.10). Average and its s.d. through the whole strains were found to be 1.23±0.14.

Range: The largest (0.68) was obtained in No. 33, followed by No. 12 (0.57) and No. 30 (0.56). The smallest (0.21) was noted in No. 26, followed by No. 2 (0.23) and No. 5 (0.27). Mode was found within 0.29 to 0.30 (6 strains). Average and its s.d. through the whole strains were found to be 0.38±0.10.

5. Ratio of length to thickness (R·L/T)

Maximum: The largest (4.00) was obtained in No. 31B, followed by No. 30 (3.71) and No. 33 (3.56). The smallest (1.38) was noted in No. 2, followed by No. 1 (1.42) and No. 19 (1.50). Average and its s.d. through the whole strains were found to be 2.25±0.75.

Minimum: The largest (2.54) was obtained in No. 31B, followed by No. 22 (2.42) and No. 28 (2.33). The smallest (1.08) was noted in No. 1, followed by No. 2 (1.17) and Nos. 19 and 23 (1.22). Average and its s.d. through the whole strains were found to be 1.62±0.43.

Range: The largest (1.52) was obtained in No. 30, followed by No. 31B (1.46) and No. 33 (1.37). The smallest (0.21) was noted in No. 2, followed by No. 19 (0.28) and No. 10 (0.32). Mode was found within 0.36 to 0.40 (6 strains). Average and its s.d. through the whole strains were found to be 0.64±0.36.

6. Ratio of width to thickness (R·W/T)

Maximum: The results are given in Table 3. The largest (2.90) was obtained in No. 31B, followed by No. 30 (2.71) and No. 28 (2.61). The smallest (1.10) was noted in No. 15, followed by No. 2 (1.12) and No. 1 (1.14). Average and its s.d. through the whole strains were found to be 1.61±0.50.

Minimum: The largest (1.70) was obtained in No. 31B, followed by Nos. 29 and 30 (1.56) and No. 24 (1.53). The smallest (1.00) was noted in Nos. 1, 2 and 15, followed by Nos. 6, 14 and 19 (1.01). Average and its s.d. through the whole strains were found to be 1.18±0.21.

Range: The largest (1.20) was obtained in No. 31B, followed by No. 30 (1.15) and No. 28 (1.11). The smallest (0.10) was noted in No. 15, followed by No. 2 (0.12) and No. 1 (0.14). Mode was found within 0.31 to 0.35 (6 strains). Average and its s.d. through the whole strains were

Table 3. Ranges of 4 characters in the strain level; ratio of width to thickness (%), grain weight (mg), grain area (mm^2) and grain volume (mm^3)

Strain No.	Width/Thickness			Grain weight			Area			Volume		
	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range	Max.	Min.	Range
1	1.14	1.00	0.14	50.0	26.0	24.0	16.92	11.95	4.97	57.51	34.66	22.85
2	1.12	1.00	0.12	59.1	40.0	19.1	23.03	16.28	6.75	95.57	56.98	38.59
3	1.38	1.04	0.34	59.3	31.9	27.4	21.67	15.02	6.65	76.93	45.06	31.87
4	1.32	1.07	0.25	69.0	47.9	21.1	26.10	19.35	6.75	104.40	64.00	40.40
5	1.28	1.03	0.25	70.8	53.9	16.9	28.91	19.61	9.30	118.53	66.67	51.86
6	1.32	1.01	0.31	51.0	33.8	17.2	22.79	17.00	5.79	83.97	54.40	29.57
7	1.50	1.03	0.74	71.2	50.9	20.3	25.08	17.42	7.66	89.03	54.00	35.03
8	1.32	1.05	0.27	60.0	19.5	40.5	23.65	16.80	6.85	86.10	47.04	39.06
9	1.48	1.06	0.42	47.2	18.5	28.7	19.31	14.52	4.79	67.59	41.63	25.96
10	1.36	1.05	0.31	83.9	61.5	22.4	25.87	19.06	6.81	100.82	66.71	34.11
11	1.53	1.21	0.32	63.5	43.1	20.4	27.09	16.80	10.29	90.45	44.51	45.93
12	1.40	1.03	0.37	56.1	31.0	25.1	25.46	13.25	12.21	80.07	29.81	50.26
13	1.32	1.13	0.19	89.9	60.3	29.6	35.02	26.00	9.02	132.54	92.30	40.24
14	1.23	1.01	0.22	48.3	41.3	7.0	26.45	16.56	9.89	88.61	49.68	38.93
15	1.10	1.00	0.10	32.0	20.0	12.0	17.42	13.02	4.40	56.62	35.15	21.47
16	1.33	1.04	0.29	143.7	120.0	23.7	53.68	36.96	16.72	257.66	169.10	88.56
17	1.31	1.03	0.28	319.7	251.0	68.7	81.00	53.55	27.45	516.65	278.46	238.19
18	1.40	1.05	0.35	234.0	171.4	62.6	64.17	38.13	26.04	333.68	183.02	150.66
19	1.20	1.01	0.19	332.7	259.0	73.7	71.52	51.35	20.17	498.89	302.97	195.92
20	1.42	1.10	0.32	148.1	128.0	80.1	48.79	35.52	13.27	219.56	142.08	77.48
21	1.29	1.04	0.25	202.2	170.0	32.2	65.48	41.72	23.76	360.14	196.08	164.06
22	1.70	1.30	0.40	154.5	120.0	34.5	61.81	43.00	18.81	244.15	146.61	97.54
23	1.56	1.07	0.49	102.4	78.0	24.4	31.27	25.20	6.07	134.46	91.92	42.54
24	2.40	1.53	0.87	70.9	49.2	21.7	39.90	29.28	10.62	110.66	74.38	36.28
25	1.28	1.13	0.15	185.1	132.4	52.7	63.19	41.60	21.59	360.18	199.68	160.50
26	1.51	1.24	0.27	166.0	135.2	30.8	57.62	45.43	12.19	282.34	195.35	86.99
27	1.47	1.17	0.30	224.1	165.5	58.6	53.87	37.80	16.07	258.58	152.16	106.42
28	2.61	1.50	1.11	49.2	33.8	15.4	30.08	21.24	8.84	63.50	38.33	25.17
29	2.19	1.56	0.63	33.5	21.5	12.0	31.42	22.47	8.95	87.98	48.43	39.55
30	2.71	1.56	1.15	44.5	24.0	20.5	29.70	16.70	13.00	57.60	29.23	28.37
31A	2.04	1.40	0.64	51.2	29.1	22.1	34.92	25.60	9.32	90.72	54.29	36.43
31B	2.90	1.70	1.20	46.3	25.5	20.8	34.00	25.92	8.08	71.45	50.63	20.82
32	2.25	1.40	0.85	55.2	40.0	15.2	35.25	22.93	12.32	96.94	54.87	42.07
33	2.44	1.43	1.01	53.0	40.0	13.0	35.75	20.72	15.03	80.44	46.62	33.82

found to be 0.44±0.31.

7. Weight

Maximum: The heaviest (332.7 mg) was obtained in No. 19, followed by No. 17 (319.7 mg) and No. 18 (234.0 mg). The lightest (32.0 mg) was noted in No. 15, followed by No. 29 (33.5 mg) and No. 30 (44.5 mg). Average and its s.d. through the whole strains were found to be 103.8±80.0.

Minimum: The heaviest (259.0 mg) was obtained in No. 19, followed by No. 17 (251.0 mg) and No. 18 (171.4 mg). The lightest (18.5 mg) was noted in No. 9, followed by No. 8 (19.5 mg) and No. 5 (20.0 mg). Average and its s.d. through the whole strains were found to be 75.7±65.8.

Range: The largest (80.1) was obtained in No. 20, followed by No. 19 (73.7) and No. 17 (68.7). The smallest (7.0) was noted in No. 14, followed by Nos. 15 and 29 (12.0) and No. 33 (13.0). Mode was found within 20.1 to 25.0 (11 strains). Average and its s.d. through the whole strains were found to be 29.8±18.7.

8. Area

Maximum: The widest (81.00 mm^2) was obtained in No. 17, followed by No. 19 (71.52 mm^2) and No. 21 (65.48 mm^2). The narrowest (16.92 mm^2) was noted in No. 1, followed by No. 15 (17.42 mm^2) and No. 9 (19.31 mm^2). Average and its s.d. through the whole strains were found to be 37.89±17.39.

Minimum: The widest (53.55 mm^2) was obtained in No. 17, followed by No. 19 (51.35 mm^2) and No. 26 (45.43 mm^2). The narrowest (11.95 mm^2) was noted in No. 1, followed by No. 15 (13.02 mm^2) and No. 12 (13.25 mm^2). Average and its s.d. through the whole strains were found to be 26.11±11.87.

Range: The largest (27.45) was obtained in No. 17, followed by No. 18 (26.04) and No. 21 (23.76). The smallest (4.40) was noted in No. 15, followed by No. 9 (4.79) and No. 1 (4.97). Mode was found within 6.01 to 7.00 (6 strains). Average and its s.d. through the whole strains were found to be 11.78±6.24.

9. Volume

Maximum: The largest (516.65 mm^3) was obtained in No. 17, followed by No. 19 (498.89 mm^3) and No. 25 (360.18 mm^3). The smallest (56.62 mm^3) was noted in No. 15, followed by No. 1 (57.51 mm^3) and No. 30 (57.60 mm^3). Average and its s.d. through the whole strains were found to be 160.42±126.81. It may be noted that s.d. value was peculiarly large.

Minimum: The largest (302.97 mm^3) was obtained in No. 19, followed by No. 17 (278.46 mm^3) and No. 25 (199.68 mm^3). The smallest (29.23 mm^3) was noted in No. 30, followed by No. 1 (34.66 mm^3) and No. 15 (35.15 mm^3). Average and its s.d. through the whole strains were found to be 95.20±73.51. It may be noted that s.d. value was peculiarly large.

Range: The largest (238.19) was obtained in No. 17, followed by No. 19 (195.92) and No. 21 (164.06). The smallest (20.82) was noted in No. 31B, followed by No. 15 (21.47) and No. 1 (22.85). Mode was found within 31.01 to 40.00 (10 strains). The differences in the value were confirmed to be very large in accordance with each strain. Average and its s.d. through the whole strains were found to be 65.22±55.04. It may be noted that s.d. value was peculiarly large, too.

Part III. Relations between the two respective characters

1. Relations between the two respective practical value

C.c. and l.r. of the practical value on another practical value among 36 combinations were calculated, and are shown in Table 4. Nineteen, 1 and 2 combinations showed significances at 0.1%, 1% and 5% levels, respectively. For example, c.c. of length on area through the whole strains was +0.9527 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally

Table 4. Correlation coefficient and linear regression of the practical value (Y) on another practical value (X) in 36 combinations

Combination	Correlation coefficient	Linear regression	Combination	Correlation coefficient	Linear regression
1·2	0.8520***	Y=0.594X−0.112	3·7	0.8888***	Y=0.463X+1.882
1·3	0.5924***	Y=0.599X−0.630	3·8	0.7717***	Y=0.402X+0.723
1·4	0.2929	—	3·9	0.9328***	Y=0.717X+2.484
1·5	0.1875	—	4·5	0.6200***	Y=0.338X−1.690
1·6	0.0966	—	4·6	0.3422*	Y=0.158X−2.163
1·7	0.8056***	Y=0.424X+1.478	4·7	−0.1580	—
1·8	0.9527***	Y=0.502X+1.055	4·8	−0.0015	—
1·9	0.8623***	Y=0.670X+2.097	4·9	−0.2156	—
2·3	0.7843***	Y=1.155X−0.695	5·6	0.9438***	Y=0.800X−0.011
2·4	−0.2104	—	5·7	−0.2050	—
2·5	−0.1203	—	5·8	−0.2975	—
2·6	0.0188	—	5·9	−0.2907	—
2·7	0.6082***	Y=0.459X+0.975	6·7	−0.2921	—
2·8	0.9587***	Y=0.724X+1.385	6·8	−0.0208	—
2·9	0.9860***	Y=1.099X+3.566	6·9	−0.3734*	Y=−0.523X−6.870
3·4	−0.5022**	Y=−0.594X−2.883	7·8	0.9503***	Y=0.952X−2.107
3·5	−0.7947***	Y=−0.513X−2.925	7·9	0.9280***	Y=1.371X+0.378
3·6	−0.6392***	Y=−0.351X−2.671	8·9	0.9930***	Y=1.464X+2.742

Character number (0 point); 1 ··· length (7.00 mm), 2 ··· width (5.10 mm), 3 ··· thickness (3.95 mm), 4 ··· ratio of length to width (1.53), 5 ··· ratio of length to thickness (2.25), 6 ··· ratio of width to thickness (1.58), 7 ··· weight (155.00 mg), 8 ··· area (41.00 mm^2), 9 ··· volume (230.00 mm^3).

***, **, *; significant at 0.1%, 1% and 5% levels, respectively. d.f.=32.

speaking, the larger is the length, the larger is the area. L.r. of length on area was calculated as follows; Y=0.502X+1.055, where Y and X indicate length and area, respectively. This formula indicates that the length becomes 0.502 mm longer, by becoming 1 degree larger the area (0 points, 7.00 mm and 41.00 mm^2 in length and area, respectively).

The remaining 14 combinations showed no significance even at 5% level.

2. Relations between the practical value and its s.d.

C.c. of practical value on its s.d. among the weights through the whole strains was +0.9779 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the heavier is the practical value of weight, the larger is its s.d. L.r. of practical value on its s.d. was calculated as follows; Y=1.424X+0.788, where Y and X indicate practical value and its s.d.,

respectively. This formula indicates that the practical value becomes 1.424 mg heavier, by becoming 1 degree larger the s.d. (0 points, 155.0 mg and 2.13 in practical value and its s.d., respectively).

C.c. of practical value on its s.d. among the areas through the whole strains was +0.8623 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the practical value of area, the larger is its s.d. L.r. of practical value on its s.d. was calculated as follows; $Y=1.475X+0.194$, where Y and X indicate practical value and its s.d., respectively. This formula indicates that the practical value becomes 1.475 mm^2 larger, by becoming 1 degree larger the s.d. (0 points, 41.00 mm^2 and 3.45 in practical value and its s.d., respectively).

C.c. of practical value on its s.d. among the volumes through the whole strains was +0.9039 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the practical value of volume, the larger is its s.d. L.r. of practical value on its s.d. was calculated as follows; $Y=1.195X+1.567$, where Y and X indicate practical value and its s.d., respectively. This formula indicates that the practical value becomes 1.195 mm^3 larger, by becoming 1 degree larger the s.d. (0 points, 230.00 mm^3 and 30.50 in practical value and its s.d., respectively).

3. Relations between the s.d. of the two respective characters

C.c. and l.r. of s.d. on another s.d. among 36 combinations were calculated, and are shown in Table 5. Fifteen, 3 and 4 combinations showed significances at 0.1%, 1% and 5% levels, respec-

Table 5. Correlation coefficient and linear regression of the standard deviations (Y) on another standard deviations (X) in 36 combinations

Combination	Correlation coefficient	Linear regression	Combination	Correlation coefficient	Linear regression
1·2	0.6167***	Y=1.004X−0.437	3·7	0.7148***	Y=0.431X−0.422
1·3	0.4059*	Y=0.772X+0.389	3·8	0.6065***	Y=0.430X−1.223
1·4	0.4381**	Y=0.928X−0.626	3·9	0.7101***	Y=0.535X+0.331
1·5	0.3536*	Y=0.419X−0.722	4·5	0.7669***	Y=0.429X−0.167
1·6	0.0864	—	4·6	0.6341***	Y=0.428X−0.069
1·7	0.3073	—	4·7	−0.0850	—
1·8	0.8432***	Y=1.096X+1.825	4·8	0.1734	—
1·9	0.5669***	Y=0.784X+2.521	4·9	−0.1844	—
2·3	0.5861***	Y=0.685X+0.598	5·6	0.9590***	Y=1.136X+0.643
2·4	0.6066***	Y=0.820X−0.126	5·7	−0.2706	—
2·5	0.4282*	Y=0.324X−0.340	5·8	0.0804	—
2·6	0.4204*	Y=0.383X−0.086	5·9	−0.2652	—
2·7	0.4950**	Y=0.349X+0.590	6·7	−0.3060	—
2·8	0.6924***	Y=0.574X+0.706	6·8	−0.0406	—
2·9	0.4814**	Y=0.424X+1.149	6·9	−0.3232	—
3·4	0.0522	—	7·8	0.7272***	Y=0.856X−2.342
3·5	0.0644	—	7·9	0.8947***	Y=1.120X+1.055
3·6	0.0000	—	8·9	0.8820***	Y=0.938X+1.888

Character number (0 point); 1 ··· length (0.35), 2 ··· width (0.27), 3 ··· thickness (0.26), 4 ··· ratio of length to width (0.10), 5 ··· ratio of length to thickness (0.21), 6 ··· ratio of width to thickness (0.16), 7 ··· weight (2.13), 8 ··· area (3.45), 9 ··· volume (30.50).

***, **, *; significant at 0.1%, 1% and 5% levels, respectively. d.f.=32.

tively. For example, c.c. of s.d. of length on s.d. of area was +0.8432 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the s.d. of length, the larger is the s.d. of area. L.r. of s.d. of length on s.d. of area was calculated as follows; $Y=1.096X+1.825$, where Y and X indicate s.d. of length and s.d. of area, respectively. This formula indicates that the s.d. of length becomes 1.096 larger, by becoming 1 degree larger the s.d. of area (0 points, 0.35 and 3.45 in s.d. of length and s.d. of area, respectively).

The remaining 14 combinations showed no significance even at 5% level.

4. Relations between the variation ranges of the two respective characters

C.c. and l.r. of variation range on another range among 36 combinations were calculated, and are shown in Table 6. Fourteen, 4 and 4 combinations showed significances at 0.1%, 1% and 5% levels, respectively. For example, c.c. of variation ranges of length on ranges of area was +0.8529 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the range of length, the larger is the range of area. L.r. of ranges of length on ranges of area was calculated as follows; $Y=1.323X+1.382$, where Y and X indicate variation ranges of length and of area, respectively. This formula indicates that the range of length becomes 1.323 larger, by becoming 1 degree larger the range of area (0 points, 1.48 mm and 15.50 mm^2 in the range of length and range of area, respectively).

Table 6. Relations between the respective two characters noted in view of the ranges among 36 combinations

Combination	Correlation coefficient	Linear regression	Combination	Correlation coefficient	Linear regression
1·2	0.7918***	Y=1.263X−2.717	3·7	0.5711***	Y=0.827X−2.957
1·3	0.4594**	Y=0.842X+0.650	3·8	0.5622***	Y=0.476X−3.221
1·4	0.4208*	Y=0.815X−1.425	3·9	0.6971***	Y=0.679X−0.945
1·5	0.3450*	Y=0.474X−1.217	4·5	0.6342***	Y=0.450X−0.395
1·6	0.2033	—	4·6	0.6081***	Y=0.475X−0.815
1·7	0.4617**	Y=1.225X−0.533	4·7	−0.2533	—
1·8	0.8529***	Y=1.323X+1.382	4·8	0.1833	—
1·9	0.8059***	Y=1.440X+5.039	4·9	−0.1733	—
2·3	0.0624	—	5·6	0.8908***	Y=1.008X−1.115
2·4	0.4667**	Y=0.567X+0.807	5·7	−0.3321	—
2·5	0.3823*	Y=0.329X+0.951	5·8	0.0244	—
2·6	0.2679	—	5·9	−0.1545	—
2·7	0.4773**	Y=0.794X+1.285	6·7	−0.2977	—
2·8	0.9024***	Y=0.878X+2.604	6·8	−0.0302	—
2·9	0.6425***	Y=0.720X+3.621	6·9	−0.3669*	Y=−0.422X−1.277
3·4	0.0379	—	7·8	0.5915***	Y=0.346X−1.179
3·5	−0.0704	—	7·9	0.7511***	Y=0.506X+0.549
3·6	−0.0081	—	8·9	0.9027***	Y=1.039X+2.468

Character number (0 point); 1 ··· length (1.48 mm), 2 ··· width (1.13 mm), 3 ··· thickness (1.13 mm), 4 ··· ratio of length to width (0.44), 5 ··· ratio of length to thickness (0.88), 6 ··· ratio of width to thickness (0.63), 7 ··· weight (43.00 mg), 8 ··· area (15.50 mm^2), 9 ··· volume (125.00 mm^3).

***, **, *; significant at 0.1%, 1% and 5% levels, respectively. d.f.=32.

The remaining 14 combinations showed no significance even at 5% level.

5. Relations between the average value and its variation ranges

C.c. and l.r. of average value on its variation ranges among 9 characters were calculated, and are shown in left column of Table 7. Six, 2 and 1 character showed significances at 0.1%, 1% and 5% levels, respectively. For example, c.c. of practical value of volume on variation ranges of volume was +0.9568 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the practical value of volume, the larger is the variation range of volume. L.r. of practical value of volume on variation ranges of volume was calculated as follows; $Y=0.838X-0.145$, where Y and X indicate practical value and variation range of volume, respectively. This formula indicates that the practical value of volume becomes 0.838 mm^3 larger, by becoming 1 degree larger the variation range of volume (0 points, 230.00 mm^3 and 125.00 in the practical value and variation range, respectively).

Table 7. Correlation coefficient and linear regression of the average value and its standard deviations (Y) on its variation ranges (X) in 9 characters

Character	Average		Standard deviations	
	Correlation coefficient	Linear regression	Correlation coefficient	Linear regression
1	0.5158**	Y=0.200X−0.642	0.9992***	Y=0.553X+0.088
2	0.5974***	Y=0.520X−1.736	0.9097***	Y=0.508X−0.891
3	0.3817*	Y=0.195X−0.233	0.8760***	Y=0.481X−0.272
4	0.4714**	Y=0.291X−2.062	0.8675***	Y=0.454X−0.166
5	0.7846***	Y=0.630X−1.124	0.9545***	Y=0.607X+0.235
6	0.9189***	Y=0.982X−0.276	0.9602***	Y=0.574X−0.719
7	0.7911***	Y=1.519X−2.924	0.7868***	Y=1.037X−2.672
8	0.7940***	Y=0.891X−1.468	0.9623***	Y=0.631X−1.025
9	0.9568***	Y=0.838X−0.145	0.9762***	Y=0.693X−1.482

Character number (0 points in average, standard deviations and variation range); 1 ··· length (7.00, 0.35, 1.48), 2 ··· width (5.10, 0.27, 1.13), 3 ··· thickness (3.95, 0.26, 1.13), 4 ··· ratio of length to width (1.53, 0.10, 0.44), 5 ··· ratio of length to thickness (2.25, 0.21, 0.88), 6 ··· ratio of width to thickness (1.58, 0.16, 0.63), 7 ··· weight (155.00, 2.13, 43.00), 8 ··· area (41.00, 3.45, 15.50), 9 ··· volume (230.00, 30.50, 125.00).

***, **, *; significant at 0.1%, 1% and 5% levels, respectively. d.f.=32.

6. Relations between the standard deviations and its variation ranges

C.c. and l.r. of s.d. on its variation ranges among 9 characters were calculated, and are shown in the right column of Table 7. Whole characters showed significances at 0.1% level. For example, c.c. of s.d. of length on variation ranges of length was +0.9992 to the degree of freedom of 32, which was obviously significant at 0.1% level. Generally speaking, the larger is the s.d. of length, the larger is the variation range of length. L.r. of s.d. of length on variation ranges of length was calculated as follows; $Y=0.553X+0.088$, where Y and X indicate s.d. and variation range of length, respectively. This formula indicates that the s.d. of length becomes 0.553 larger, by becoming 1 degree larger the variation range of length (0 points, 0.35 and 1.48 in s.d. of length and variation range of length, respectively).

Table 8. Comparisons of 7 relation-groups; relations between the respective 2 characters noted in view of practical values (A), standard deviations (B), variation ranges (C), summing-up of A, B and C groups (D), relations within the same characters noted in view of practical value and its standard deviations (E), practical value and its variation range (F), standard deviations and its variation range (G)

Group	Character	Character								
		Length	Width	Thick-ness	R·L/W	R·L/T	R·W/T	Weight	Area	Vol-ume
	Width	***								
	Thickness	***	***							
	R·L/W	—	—	**						
A	R·L/T	—	—	***	***					
	R·W/T	—	—	***	*	***				
	Weight	***	***	***	—	—	—			
	Area	***	***	***	—	—	—	***		
	Volume	***	***	***	—	—	*	***	***	
	Width	***								
	Thickness	*	***							
	R·L/W	**	***	—						
B	R·L/T	*	*	—	***					
	R·W/T	—	*	—	***	***				
	Weight	—	**	***	—	—	—			
	Area	***	***	***	—	—	—	***		
	Volume	***	**	***	—	—	—	***	***	
	Width	***								
	Thickness	**	—							
	R·L/W	*	**	—						
C	R·L/T	*	*	—	***					
	R·W/T	—	—	—	***	***				
	Weight	**	**	***	—	—	—			
	Area	***	***	***	—	—	—	***		
	Volume	***	***	***	—	—	*	***	***	
	Width	3								
	Thickness	3	2							
	R·L/W	2	2	1						
D	R·L/T	2	2	1	3					
	R·W/T	0	1	1	3	3				
	Weight	2	3	3	0	0	0			
	Area	3	3	3	0	0	0	3		
	Volume	3	3	3	0	0	2	3	3	
E	Average & s.d.	***	*	**	**	***	***	***	***	***
F	Average & range	**	***	*	**	***	***	***	***	***
G	s.d. & range	***	***	***	***	***	***	***	***	***

***, **, *; significant at 0.1%, 1% and 5% levels, respectively.

Figure used in column D shows the number of significant relations in the respective combination, in disregard of the grade of significances.

7. Comparisons of the four relation-groups

From the data obtained in the previous paper[10] and the present experiment, relations between the two respective characters were compared, and are shown in Table 8. In this table, at first, 3 relation-groups, *i.e.*, relations between the two respective practical values (A group in the table), relations between the two respective s.d. (B group) and relations between the two respective variation ranges (C group), were shown. In addition to these, summing-up-data from groups A, B and C were regulated, and are shown in D group, provided that the calculation was made only by the significance in disregard of significant levels. And thirdly, 3 relations within the same characters, *i.e.*, between the practical value and its s.d. (E), between practical value and its variation range (F) and between s.d. and its variation range (G), are shown in the last column.

In summing-up-data from the former groups, 16, 7 and 4 combinations showed significances in 3, 2 and 1 groups, respectively. The remaining 9 combinations showed no significance through the whole cases. It may be noted that the combinations constructed by width and thickness in one or both components, showed significances through the whole cases.

On correlations between the latter groups, the whole characters showed significances in the whole cases.

Discussion

1. A number of hypotheses regarding the putative indigenous centres of pulses have been published, and some ones are concluded as it to be India. However, no archaeological evidence in India has been proved. In Sumanic Complex (B.C. 5,000-4,000), which was originated in West Africa and expanded eastward, about 30 crop species were brought forth to the cultivated status[5]. In the other viewpoints, India together with the central Asiatic center, has been believed to be the home of some species of grain legumes. Hitherto the oldest records of both *Phaseolus mungo* and *P. aureus* are from Chalcolithic site, Navdatoli-Maheshwar dated to be B.C. 1,600–1,440[18].

On the other hand, New World species of cultivated *Phaseolus* excel those of the Old World in the ways that are almost exactly parallel, and the species of both the hemispheres are diploid[4].

2. In the meanings of the wild species and evolution, the following items might be mentioned here. The situation in the wild species in the result of a compromise between the adaptation for germination in the crowded communities and the adaptation for seed dispersibility and reproductive output of the species[17]. During domestication of the species whose seeds constituted an element of food production, the controlled evolution was channelled on to the increase of seed weight rather than seed number[20].

The domestication of common bean has followed the pathway mentioned below; the wild forms of these species are characterized by the production of a large number of small seeds while the cultivated varieties bear much heavier seed[16]. Moreover, the domestication of the old world pulses has followed a very precise pathway; a gradual and continuous increase in seed size with temporal overlapping of the wild and cultivated forms[20].

The total benefits from growing legumes are recently ignored in the commercial cropping systems, but the positive aspects of growing tropical and subtropical legumes have been emphasized on account of aims such as collecting germplasm[10,15]. Moreover, the following items are reported. The most striking effect of domestication is the seed size increase[7]. A seed size suitable for cultivation was easily obtainable during the early domestication phases[8]. This is confirmed as follows; to attribute to the common bean a multiple domestication, starting from an ancestral species wide-

spread and polymorphic.

In view of agronomical significances, seed size inheritance was studied in a cross between a wild accession and a cultivated variety of *Phaseolus vulgaris* L.[14]. The data help in understanding the evolution of this species under anthropic selection. From the data using soybeans[3], however, it is anticipated that the late flowering type will bring about enough growth within a span of short-day to permit machine-harvest without requiring an extremely long growing season.

On the other hand, black gram (*Phaseolus mungo* ROXB.) is currently confirmed to be useful crop plant as to be adopted in an inter-cropping system[12]. Grain legumes have been cultivated widely in the whole land of India[6]. So, grain legumes are naturally to be put into consideration in a scheme of agricultural improvement.

3. In view of the s.d., *i.e.*, intra-strain's variations, the followings were ascertained. S.d. in the most species and strains in view of the morphological characters, have been looked upon as relatively small (Table 2). These phenomena were noted to be the same as those of the previous paper[10]. In general aspect, the smaller is the s.d., the longer is the history of cultivation. So, it may be concluded that they have a long history since they were introduced or migrated here, fitting well to the natural conditions and/or agricultural practices in the respective areas.

However, in the genus *Vigna*, the s.d. were calculated to be 12.15, 3.59 and 27.92 in weight, area and volume being in the average values, respectively. Those of the strains collected in Nauru, which were detected as wild species, were found to be 5.49, 1.92 and 10.66 in the same order, respectively[11]. It does not necessarily follow that s.d. is certainly smaller in cultivars than in wild status.

4. In the present state of affairs, it is not clear whether variation ranges could be used in analyzing strain differentiations or not. These characters were used in wild species of *Vigna* and some useful informations were obtained[11]. That is the reason why character was attempted for this paper. In conclusion, it may be said that variation ranges might be looked upon as a useful character and having a sort of universal validity as one of indices for examining species and strain differentiations in pulses. For example, grains of No. 17 showed the maximum or near maximum values in length, width, thickness, weight, area and volume, in spite of the small values shown in R·L/W, R·L/T and R·W/T. It meant that the latter three characters of this strain were genetically in a stable status. Grains of No. 15 showed, on the other hand, the minimum or near minimum values in the whole characters. It meant that characters used here were genetically in possession of a stable character.

It was noticeable that strains belonging to genera *Phaseolus*, *Cajanus* and *Clitoria* showed relatively small variation ranges through the whole characters. This meant that they were genetically in a stable status. These findings propose a quite interesting problem concerning the strain differentiations.

5. Character R·W/T was recently reported to be useful one for analysing grain morphology[9,10,19]. In the present experiment, the same results were obtained.

In the present experiment, weight, area and volume showed significances in 5, 5 and 6 combinations among 8 instances in view of the practical values, respectively. So, it meant that volume is relatively of stable character in these three characters.

Among 36 combinations, 14 cases showed no significance even at 5% level. In other words, 61.1% of the cases showed significances. It may be concluded that several characters are exhibited fundamentally independent of other characters. One (thickness), 1 (volume), 4 (length, width, weight, area), 1 (R·W/T) and 2 (R·L/W, R·L/T) characters showed significant correlations in 8, 6,

5, 4 and 3 combinations, respectively. Three ratio-characters showed, in general, a few significances.

6. Correlation coefficients of the intra-strain's variation of the respective characters were expectedly decided to be positively significant in 22/36 cases, *i.e.*, 61.1%. Generally speaking, the larger is the variation in the one character, the larger is the variation in another character. It may be said that, through almost all characters, strains which were considered to be stable or unstable showed negligible or considerable variations, respectively.

One (width), 1 (length), 3 (thickness, area, volume), 3 (R·L/W, R·L/T, weight) and 1 (R·W/T) characters showed significant correlations in 8, 6, 5, 4 and 3 relations, respectively. It may be noted that width showed significances through the whole combinations, and R·W/T showed significance only in 3 cases.

7. As to the relations between the two respective characters in view of ranges, among 36 combinations, 22 cases, *i.e.*, also 61.1% of them, showed significances. It meant that the larger is the range in a certain character, the larger is the range in another character. In other words, most of them were genetically in a stable state.

In a stricter sense, character specificities were found in some degree. One (length), 2 (width, volume), 2 (weight, area), 3 (thickness, R·L/W, R·L/T) and 1 (R·W/T) characters showed significant correlations in 7, 6, 5, 4 and 3 relations, respectively. In the previous paper[11], it was reported that weight showed significant correlations only in 2 relations, *i.e.*, area and volume, and it was assumed that the weight of grains is exhibited fundamentally independently of length, width and thickness, but dependently on area and volume. In the present experiment, however, weight showed significant correlations in 5 cases. It meant that the weight of grains is exhibited fundamentally dependent on length, width, thickness, area and volume. These discrepancies may be partly due to the fact that wild and cultivated samples were used in the previous and the present experiments, respectively. Indeed, it was reported that seed weight showed the positive correlations of yield and was on an environmental stability[1].

8. Correlation coefficients of the practical value on its s.d. and of the practical value on its variation ranges, were expectedly of significance through the whole characters. These phenomena were decided to be results wholly reversed from those of the previous paper[11]. These discrepancies may be explained by the fact mentioned just above.

9. Correlation coefficients of s.d. on its variation ranges of the respective character were expectedly decided to be significant without any exception. Moreover, they were shown to have some high levelled relationships in 0.1% level. These phenomena were quite the same as those reported in the previous paper. Generally speaking, the larger is the s.d., larger is the variation range. Concerning the three relation-groups, from the data obtained in the previous and the present experiments, it may be concluded that these two components were of the most stable characters, and were intimately correlated each other through the whole pulses in disregard of the species-status, wild or cultivated.

10. Three relations were summed-up, and are shown in Table 8. In D column in the table, the figure shows the number of the significant relations in three respective combinations. In the table, 66/108 cases, *i.e.*, 61.1% of them, showed significances at 0.1%, 1% or 5% levels. In detail, length, width, thickness, R·L/W, R·L/T, R·W/T, weight, area and volume showed significances in 18, 19, 17, 11, 11, 10, 14, 15 and 17 cases, respectively. It was noticeable that they were divided into three groups, *i.e.*, high, medium and low correlation-groups, showing the gaps noted in 16 and within 13 to 12 relations. Length, width, thickness and volume belonged to the first group, weight and area belonged to the second group, and R·L/W, R·L/T and R·W/T belonged to the third group,

respectively. In other words, three ratio-characters showed a few significances.

11. Many characters were used in analysing species or strain differentiations, but several characters used here were disregarded in the previous experiments. In the present experiment, significant correlations in these characters were found, for example, relations between length and width, between length and volume in view of variation ranges, etc. So, it may be requested that these characters or these combinations are to be used in analysing strain differentiations in the future. Moreover, it was confirmed that such indices or ideas can be used as an useful index to these experiments.

The importance or gravity found in grain morphology are to be proved in accordance with the following report. Seed sizes represent alternative strategies in the exploitation of the reproduction resources of a crop plant[2].

Summary

Succeeding to the previous paper, some morphological studies on grain characters and considerations on ecotypic differentiations of 34 strains, belonging to 10 species and to 7 genera, collected in the Indian Sub-Continent, were reported in the present experiment. The results obtained here were summarized as follows:

Weight, area and volume of grains were found to be 88.01 mg, 31.52 mm^2 and 124.92 mm^3 in average values, respectively. Variation ranges in length, width, thickness, R·L/W, R·L/T, R·W/T, weight, area and volume were found to be 1.32 mm, 1.12 mm, 0.89 mm, 0.38, 0.64, 0.44, 29.8 mg, 11.78 mm^2 and 65.22 mm^3 in average values, respectively.

Concerning correlation coefficients between the two respective characters among 36 combinations noted in view of the practical values, 19, 1 and 2 cases showed significances at 0.1%, 1% and 5% levels, respectively. Concerning correlation coefficients between the two respective characters among 36 combinations noted in view of s.d., 15, 3 and 4 cases showed significances at 0.1%, 1% and 5% levels, respectively. Concerning correlation coefficients of these noted in view of variation ranges, 14, 4 and 4 cases showed significances at 0.1%, 1% and 5% levels, respectively.

Concerning correlation coefficients between the average values and its variation ranges among 9 characters, 6, 2 and 1 cases showed significances at 0.1%, 1% and 5% levels, respectively. Concerning correlation coefficients between the s.d. and its variation ranges among 9 characters, all the cases showed significances at 0.1% level.

In the data summing-up from the former three relation-groups, 16, 7, 4 and 9 combinations showed significances in 3, 2, 1 and 0 groups, respectively. Concerning correlation among the 3 components in the same character, *i.e.*, between average and its s.d., average and its variation ranges, and s.d. and its variation ranges, all the characters showed significances through the whole cases.

Varietal and ecotypic differentiations were extensively discussed in values found in 9 characters, in 6 correlation-relationships, and derived from phylogenetic status.

Characters and character-combinations used here were to be looked upon as useful having some universal validities as indices in the examination of species and strain differentiations.

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