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CIAT

Research Report

THE HERITABILITY OF PROTEIN AND METHIONINE IN BEANS (*Phaseolus vulgaris*)

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INTRODUCTION.

As world protein demands increase, one feasible method to meet this demand is to increase through breeding the yield, protein quantity and quality of the widely accepted food legumes. In Latin America beans are the chief food legume and constitute up to 33% of the total daily protein intake in certain Central American countries (5). Although beans have an average protein content of 22% which is high in relation to the cereals, it is much lower than that of soybeans. The poor nutritive quality of bean protein is well established and has been attributed in part to a deficiency in the sulfur containing amino acids (6), the presence of heat labile toxic factor (11), and the resistance to proteolysis of certain bean proteins (14).

Various workers have shown a large range in percent crude protein and available methionine between different bean lines. Tandon (17) reported a range from 3.21% to 4.46% nitrogen with an average of 3.44%. Silbernagel (15) evaluated a large bean collection and obtained protein values from 16% to 30%. Rutger (13) reported a range in protein content from 19% to 31% with a mean of 24.6% in 343 lines grown in a single location in a single year. Tandon (17) also reported a range in methionine content from 0.80 to 1.39 g. per 100 g. of protein with an average of 1.03 g. in the same 25 varieties. Bressani (3) showed a range for percent methionine from 0.087 to 0.355 with an average of 0.183. Kelly (8) screened 3600 bean lines and selections for methionine and obtained 82 with 33% higher microbiologically available methionine than a standard variety Sanilac.

Heritability estimates of percent protein in beans have been reported by 2 workers; Leleji (9) obtained broad sense heritability estimates for protein from 30.7% to 63.7%. Narrow sense estimates were 20.1% for the backcross and 5% and 12% based on the F_3/F_2 regression. Porter (12) calculated a broad sense estimate of 45.4% and narrow sense estimates of 49.4% and 81.8% for backcross and F_3/F_2 regression methods, respectively. He also reported total sulfur content in beans as having a broad sense heritability of 10.2% and a narrow sense estimate based on the F_3/F_2 regression of 77.4%.

The purpose of the present investigation was to study the variability for protein and methionine content which exists in beans and to determine the mode of inheritance of these traits. This paper reports on the progress and results of that study to date.

Material and methods

Thirty bean lines were selected for their differences in protein and methionine content, based on the surveys of Rutger (13), Silbernagel (15) and Kelly (8). These lines were grown in nutrient solution in 1 gallon pots in a growth chamber with a 14 hour daylength, and day and night temperatures of 25°C and 18°C respectively. Single plants of each line were selected and seed from them was increased in the greenhouse. The resulting material was grown in the field in plots of ten plants and four lines were selected as parents for the hybridization study. These selections were based on plant vigor, adaptability and low disease incidence in addition to their protein and methionine levels.

Crosses were made between Bush Blue Lake 240 (BBL 240) and three PI lines, using BBL 240 as the female parent in all the crosses (Table 1). The backcrosses were made using the F_1 hybrid as the pollen parent. The resulting generations of P_1, P_2, F_1, F_2, BCP_1, BCP_2 were grown in the field in Wisconsin (1972)in a completely random design. Individual plants were grown in single hills surrounded by 8 guard plants spaced equidistantly apart to maintain equal competition on all experimental material. Seed was harvested from individual plants and a sample from each was ground in a Wiley mill and passed through a 40-mesh screen. Nitrogen content and protein values (protein = 6.25 X N) were determined by macro-kjeldahl method. Methionine analysis was carried out by the microbiological assay as described by Kelly (7), using the bacterium Streptococcus zymogens.

Broad sense heritability estimates were calculated on the three families using the formula given by Allard (2), and the narrow sense heritability estimates based on the backcross populations were calculated by the Warner method (18).

Selections of the F_1 and F_2 hybrid material grown in Wisconsin, were made for differences in percent protein and total methionine. These materials were grown in CIAT in 1973 in row plots spaced 90 cm. apart and the hybrids understudy were interplanted with the variety Tui to have equal competition on the experimental material. Plants were harvested individually and a seed sample of each was analyzed for protein and methionine. Selections of this material were made for high yield only, and enough seed from each selection was sown in a randomised block design in the field in CIAT 1974 to give a 10-plant stand per block using 3 blocks. Each plant was harvested separeately and seed number and seed weight was recorded for each. A five seed sample was taken from each plant and mixed to give a fifty seed sample per block. This sample was then analyzed for protein and methionine.

Heritability estimates were calculated by the regression of the hybrid material on the parent material.

A rat feeding trail was conducted to evaluate the biological value of the four parent lines. The lines understudy were cooked for 45 minutes and diets were prepared with a 10% protein level using beans as the only protein source (Table 15). The assay was continued for 28 days using 6 rats per treatment and a casein diet was included as a control.

Results and Discussion

The variability in protein, methionine and methionine as percent protein between the four selected bean lines is large and is presumed to be genetic in origin (Table 1). PI 207227 is a low protein, low methionine bean line, while PI 229815 is a high protein, low methionine line. PI 302542 has a slightly above average protein and methionine content. The BBL 240 line used as the female parent in the crosses with the three PI lines is a high protein, high methionine line with a superior quality protein. PI 229815 follows a pattern, described by Adams (1), where high protein is associated with low protein quality due to a negative correlation (r = -0.87) between nitrogen and methionine content in the lines studied. His suggestion to fix protein content in beans at 22% and select for high yield and high methionine types doesn't appear necessary in view of the characteristics of the two lines PI 302542 and BBL 240. In the latter two, the increased protein levels are associated with higher methionine content and thus higher protein quality. Dickson (4) reported an independent relation between nitrogen and methionine in 21 bean lines and a positive correlation of 0.78 between methionine and lysine. Thus there exists an excellent opportunity for selecting for high levels of both amino acids at the same time.

The segregation patterns for percent protein in the three families studied are presented in Tables 2-4. BBL 240 X PI 207227 (Table 2) was a cross between high and low protein parents. The F_1 progeny mean is the same as the mid-parent value indicating additive gene action. The mean of the F_2 generation fell within the mid-parent range but was closer to high parent. Figure 1 shows the skewed distribution towards high protein with 6 hybrids falling outside the range of the high parent, indicating partial dominance for high protein over low protein. This is in agreement with work in soybeans (6) but not with the partial dominance of genes for low protein in beans as reported by Leleji (9). The means of the two backcross populations don't differ from the expected values calculated on the assumption of additive gene action. The broad sense heritability estimate for this family was 69.1% while the narrow sense estimate of zero is due to the unusually high variance in the BCP_1 generation. The zero value for narrow sense heritability which indicates the lack of an additive genetic component, is contrary to the trends suggested by the generation means but it shows the large environmental effect on total protein, particularly in the BCP_1 generation.

Table 3 shows the frequency distribution of the different generations of the cross BBL 240 X PI 229815. The F_1 generation has a mean lower than that of the low parent indicating a possible overdominance component for low protein. Leleji (9) observed a similar situation in a cross with the same line PI 229815. The F_2 and backcross generations have means which approach the expected values based on additive gene action, but all are skewed towards the low protein parent.

The broad sense heritability was 71.2% and the narrow sense estimate was zero. Maximum variability exists in the F_2 generation thus the only explanation why the variance in the BCP_1 generation in both these families is higher than in the F_2 is because this generation is much more sensitive to environmental factors, thus causing the abnormally high variances.

BBL 240 X PI 302542 (Table 4) is a cross between high and above average protein lines. The F_1 mean is the same as that of the high protein parent indicating possible dominance components for high protein. The F_2, BCP_1 and BCP_2 generations resemble closely those of the expected values for the same generations assuming additive gene action. The low broad sense heritability value of 31.9% for this family is expected because of the small difference in percent protein between the two parents. Also the fact that PI 302542 tended to be variable in percent protein emphasizes the relatively strong effect of the environmental variance. The narrow sense heritability value of 49.4% indicates a large additive genetic component which is in agreement with the segregation patterns of F_2 and backcross generations. However since the broad sense heritability is the upper limit that one can expect for this statistic, the values in this family indicate the limitation of the Warner method in the determination of the additive genetic component in this material. Further work is underway to determine this heritability value using F_3/F_2 regression and F_4/F_3 regression analysis in an effort to overcome the obvious inadequancy of the Warner method for the determination of narrow sense heritability in the families under study.

Methionine content (mg/g seed) has a broad sense heritability estimate of 74.4% and a narrow sense estimate of 28.6% for the cross BBL 240 X PI 207227 (Table 5). The mean values of the F_1, F_2 and backcross generations are skewed towards the low parent indicating a partial dominance for low methionine over high methionine content. These results are in agreement with those of Leleji (10) who encountered a similar partial dominance for low methionine in the F_1 and F_2 generations of a cross between low and high methionine parents. Porter (12) reports additive gene action for sulfur content in beans, but with a skewness towards the low sulfur parent.

Methionine as percent protein is a moderately heritable trait with a broad sense heritability estimate of 58.7% and a narrow sense heritability of 87.7%. The four generation means of the F_1, F_2 and backcrosses are skewed towards the low parent with evidence of possible transgressive segregation for low methionine as percent protein in the BCP_2 population.

The regression analysis of the F_3 hybrid material grown in CIAT on the F_2 parent grown in Wisconsin, shown in Tables 9 and 10, indicates a non relation between the two generations. This indicates the difficulty of early generation selection as all the seed on the F_2 plant is segregating and the analysis of a seed sample from a F_2 plant doesn't necessarily represent the potential of the remaining seed.

Tables 11-13 show a similar regression analysis but using the F_4 hybrids on the F_3 parent. A positive regression coefficient was obtained only for one family for the methionine trait, indicating the large environmental effect as demonstrated by the parent material in Table 8.

Currently the F_4 and F_5 progeny of the CIAT grown material shown in Tables 9-13 has been analyzed for protein and methionine. The material was grown to overcome the problems of the two distinct environments. The results of this aspect of the work are not available at this time but will be published in the final thesis.

The negative correlation between yield and protein and methionine content is illustrated in Table 14 but within this material it is still possible to select lines with both high yield and high protein.

Finally Tables 15 and 16 show the composition and results of a rat feeding trail using the 4 parent lines described in this study. Although the differences shown by this assay are small, the line of methionine as percent protein, i.e. BBL 240 has the highest biological value and the other lines likewise shown a lesser value in agreement with their levels of methionine.

This reports have dealt very superficially with the results obtained and analyzed todate. This is because in the next 6 months the author will be studying the results in depth in order to find their true significance and this will be fully discussed in the final thesis, a copy of which will be sent to CIAT.

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Table 1

DESCRIPTION OF SELECTED LINES OF BEANS USED AS PARENTS IN THE PROTEIN AND METHIONINE STUDIES

P.I. No.	Origin	Habit	Seed Color	Percent protein	mg. meth. / g. seed	g. meth. / 100 g. prot
207227	Colombia	Indeterminate	Black	21.5	1.97	0.921
302542	France	Determinate	White	25.1	2.60	1.033
BBL 240	U. S. A.	Determinate	White	28.1	3.39	1.204
229815	U. S. A.	Determinate	Grey	31.9	2.72	0.862

Table 2. Frequency distribution of percent crude protein in Bush Blue Lake 240, PI 207227, and their F_1, F_2 and backcross progeny.

Population	No. plants/class of % protein								N	$\bar{x}$	s^2	CV
	19.5	21.5	23.5	25.5	27.5	29.5	31.5	33.5				
BBL 240				11	15	22			48	28.1	2.86	4.8
PI 207227	5	14	4						23	21.5	0.91	4.4
F_1		2	8	12	1				23	24.7	1.63	5.2
F_2		15	25	54	31	15	5	1	146	25.8	5.82	9.4
BCP_1 *		1	4	4	4	5	2	1	21	27.2	10.85	12.1
BCP_2 **		8	21	7	2	1			39	23.7	2.51	6.7
Mid-parent										24.8		

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 207227
Broad sense heritability = 69.1%; Narrow sense heritability = 0

Table 3. Frequency distribution of percent crude protein in Bush Blue Lake 240, PI 229815 and their F_1, F_2 and backcross progeny

Population	No. plants/class of % protein									N	$\bar{x}$	s^2	CV
	23.5	25.5	27.5	29.5	31.5	33.5	35.5	37.9	39.5				
BBL 240		11	15	22						48	28.1	2.86	4.8
PI 229815		1	2	2	7	11	1			24	31.9	3.14	5.6
F_1	1	5	3	1						10	26.3	2.13	5.6
F_2	4	10	15	22	8	10	4			73	29.4	9.40	10.4
BCP_1 *	2	5	2	2	2	3	1		1	18	29.6	20.53	15.3
BCP_2 **		2	3	7	5	3				20	30.1	5.37	7.7
Mid-parent											30.0		

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 229815
Broad sense heritability = 71.2%; Narrow sense heritability = 0

Table 4. Frequency distribution of percent crude protein in Bush Blue Lake 240 and PI 302542 and their F_1, F_2 and backcross progeny

Population	No. plants/class of % protein 21.5	23.5	25.5	27.5	29.5	31.5	N	$\bar{x}$	s^2	CV
BBL 240			11	15	22		48	28.1	2.86	4.8
PI 302542	3	7	16	6	1		33	25.1	3.40	7.3
F_1		1	4	8	5	4	22	28.4	4.52	7.5
F_2	1	16	38	24	20	7	106	26.8	5.28	8.6
BCP_1 *		2	3	8	5	1	19	27.3	4.10	7.4
BCP_2 **	3	12	16	12	4		47	25.5	3.85	7.7
Mid-parent								26.6		

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 302542
Broad sense heritability = 31.9%; Narrow sense heritability = 49.4%

Table 5

Means, variances and coefficients of variation for percent protein, methionine content and methionine as percent protein in Bush Blue Lake 240, PI 207227 and the F_1, F_2 and backcross progeny

	Percent protein			Methionine content (mg/g. of seed)			Methionine as percent protein		
Population	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV
BBL 240	28.1	2.86	4.8	3.39	.196	13.0	1.204	.0120	9.1
PI 207227	21.5	0.91	4.4	1.97	.017	6.6	0.921	.0052	7.9
F_1	24.7	1.63	5.2	2.41	.061	10.3	0.978	.0081	9.2
F_2	25.8	5.82	9.4	2.60	.190	16.8	1.006	.0315	11.6
BCP_1 *	27.2	10.85	12.1	3.03	.257	16.7	1.111	.0087	8.4
BCP_2 **	23.7	2.51	6.7	2.18	.050	10.3	0.921	.0060	8.4
Mid-parent	24.8			2.68			1.063		
Broad sense heritability		69.1%			51.9%	-		37.5%	
Narrow sense heritability		-			38.4%			91.1%	

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 207227.

Table 6

Means, variances and coefficients of variation for percent protein, methionine content and methionine as percent of protein in Bush Blue Lake 240, PI 302542 and the F_1, F_2 and backcross progeny.

	Percent Protein			Methionine content (mg/g. of seed)			Methionine as percent protein		
Population	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV
BBL 240	28.1	2.86	4.8	3.39	.196	13.0	1.204	.0120	9.1
PI. 302542	25.1	3.40	7.3	2.60	.052	8.8	1.033	.0068	8.0
F_1	28.4	4.52	7.5	3.45	.293	15.7	1.215	.0229	12.5
F_2	26.8	5.28	8.6	3.02	.318	18.7	1.123	.0229	13.5
BCP_1 *	27.3	4.10	7.4	3.21	.159	12.4	1.161	.0145	10.4
BCP_2 **	25.5	3.85	7.7	2.76	.231	17.5	1.075	.0164	11.9
Mid-parent	26.5			3.00			1.118		
Broad sense heritability		31.9%			43.3%			39.3%	
Narrow sense heritability		54.5%			77.4%			65.1%	

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 302542.

Table 7

Means, variances and coefficients of variation for percent protein, methionine content and methionine as percent of protein in Bush Blue Lake 240, PI.229815 and F_1, F_2 and backcross progeny

	Percent Protein			Methionine content (mg/g of seed)			Methionine as Percent Protein		
Population	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV	$\bar{x}$	s^2	CV
BBL 240	28.1	2.86	4.8	3.39	.196	13.0	1.204	.0120	9.1
PI. 229815	31.9	3.14	5.6	2.72	.105	11.9	0.862	.0057	8.8
F_1	26.3	2.13	5.6	2.49	.069	10.5	0.945	.0042	6.9
F_2	29.4	9.40	10.4	2.76	.278	19.1	0.934	.0184	14.5
BCP_1*	29.6	20.53	15.3	3.10	.483	22.4	1.046	.0292	16.3
BCP_2**	30.1	5.37	7.7	2.58	.115	13.1	0.858	.0073	10.0
Mid-parent	30.0			3.05			1.033		
Broad sense heritability		71.1%			55.6%			60.3%	
Narrow sense heritability		-			-			-	

* BCP_1 Backcross to BBL 240; ** BCP_2 Backcross to PI 229815.

Table 8

Comparison of the means for percent protein, methionine content and methionine as percent protein of the four bean lines grown in the two locations, Wisconsin and CIAT.

P.I. No.	Percent protein		Methionine content (mg/g. of seed)		Methionine as percent protein	
	Wisc.	CIAT	Wisc.	CIAT	Wisc.	CIAT
207227	21.5	22.4 **	1.97	2.01	0.921	0.895
302542	25.1	26.1 *	2.60	3.05 **	1.033	1.179 **
BBL 240	28.1	28.0	3.39	4.39 **	1.204	1.567 **
229815	31.9	28.4 **	2.72	2.65	0.862	0.935 **

* and ** significantly different at 5% and 1% levels, respectively.

Table 9

PERCENT PROTEIN, METHIONINE CONTENT AND METHIONINE AS PERCENT PROTEIN FOR F_2 PLANTS AND THEIR F_3 PROGENY FOR THE CROSS BUSH BLUE LAKE 240 WITH PI. 207227.

Number of plants included in F_3 mean.	Percent protein		Methionine content (mg/g. of seed)		Methionine as % protein	
	F_2	F_3	F_2	F_3	F_2	F_3
3	26.4	24.7	2.42	2.39	0.917	0.967
4	26.0	26.5	2.62	2.40	1.008	0.907
3	26.4	24.4	2.15	2.30	0.814	0.942
6	22.9	26.2	2.06	2.76	0.900	1.053
6	24.5	24.3	2.35	2.31	0.959	0.953
5	24.8	26.1	2.20	2.72	0.887	1.025
5	23.9	25.5	2.90	2.52	1.213	0.990
5	25.1	27.2	2.44	3.18	0.972	1.058
6	26.5	25.6	2.64	2.49	0.996	0.971
4	24.6	24.9	2.52	2.33	1.024	0.930
3	23.9	24.4	2.25	2.47	0.941	1.005
Regression coefficient	-.0609		-.1357		-.0496	

Table 10

PERCENT PROTEIN, METHIONINE CONTENT AND METHIONINE AS PERCENT PROTEIN FOR F_2 PLANTS AND THEIR F_3 PROGENY FOR THE CROSS BUSH BLUE LAKE 240 WITH PI. 302542.

Number of plants included in F_3 mean.	Percent protein		Methionine content (mg/g. of seed)		Methionine as % protein	
	F_2	F_3	F_2	F_3	F_2	F_3
5	31.1	26.2	3.19	3.34	1.208	1.222
2	26.4	27.2	4.10	3.30	1.318	1.256
1	28.5	24.1	2.62	2.43	0.919	1.008
1	27.3	23.7	3.26	3.03	1.194	1.278
2	23.8	26.2	2.52	3.46	1.089	1.339
4	31.6	26.4	3.44	3.55	1.041	1.327
1	25.6	29.1	3.45	3.97	1.348	1.364
3	28.4	26.5	3.58	3.46	1.261	1.306
2	30.4	26.8	3.69	3.06	1.214	1.142
2	30.0	28.0	3.90	3.92	1.300	1.403
2	31.1	27.5	3.65	3.33	1.174	1.212
Regression coefficient	.0012		.3745		.4990	

Table 11

PERCENT PROTEIN; METHIONINE CONTENT AND METHIONINE AS PERCENT PROTEIN FOR F_3 PLANTS AND THEIR F_4 PROGENY FOR THE CROSS BUSH BLUE LAKE 240 with PI 207227.

Number of plants included in F_4 mean.	Percent protein.		Methionine content (mg/g. of seed).		Methionine as % protein.	
	F_3	F_4	F_3	F_4	F_3	F_4
4	24.6	29.8	2.53	3.08	1.028	1.174
2	23.4	28.5	2.23	2.64	0.953	0.928
5	24.4	28.7	2.51	2.85	1.029	0.989
3	26.8	26.9	2.43	2.54	0.907	0.932
4	23.5	27.1	2.50	2.70	1.064	1.000
6	30.1	27.0	3.02	2.74	1.003	1.018
5	22.3	25.6	2.48	2.77	1.112	1.071
4	22.4	26.5	2.15	2.36	0.960	0.900
4	26.8	26.7	2.11	2.37	0.787	0.889
3	26.3	25.9	2.72	2.53	1.034	0.976
3	23.0	27.3	2.26	2.89	0.983	1.055
3	27.2	26.5	2.99	3.48	1.099	1.241
4	24.0	26.1	2.59	3.29	1.079	1.249
4	26.0	25.1	2.50	2.42	0.962	0.969
5	26.3	26.8	2.37	2.66	0.901	0.994
5	26.5	23.5	2.38	2.15	0.898	0.915
5	27.7	25.5	2.76	2.23	0.996	0.872
3	24.3	25.2	2.52	2.54	1.037	1.009
4	26.3	24.6	2.23	2.14	0.848	0.870
3	25.6	27.2	2.23	2.39	0.871	0.902
Regression coefficient	-.1485		.6688 *		.9182 **	

* Significant at the 5% level; ** Significant at the 1% level.

Table 12

PERCENT PROTEIN, METHIONINE CONTENT AND METHIONINE AS PERCENT PROTEIN FOR F_3 PLANTS AND THEIR F_4 PROGENY FOR THE CROSS BUSH BLUE LAKE 240 WITH PI. 302542.

Number of plants included in F_4 mean.	Percent protein.		Methionine content (mg/g. of seed)		Methionine as % protein	
	F_3	F_4	F_3	F_4	F_3	F_4
3	24.5	25.8	2.60	3.03	1.061	1.163
2	26.4	27.9	2.13	3.33	0.807	1.226
2	25.0	26.2	2.48	3.20	0.992	1.225
3	29.8	26.7	4.06	3.76	1.362	1.408
4	27.2	25.8	2.72	3.06	1.000	1.178
4	25.2	24.7	2.50	2.73	0.992	1.089
1	30.2	24.2	3.83	3.02	1.268	1.253
1	26.1	26.0	2.91	3.18	1.115	1.223
4	26.5	24.7	2.87	2.49	1.083	1.007
3	25.5	23.1	2.65	2.62	1.039	1.137
1	24.9	26.3	2.77	2.97	1.112	1.129
1	23.8	28.3	2.54	3.61	1.067	1.279
1	25.4	31.9	2.76	2.30	1.087	0.721
3	26.4	27.5	3.04	3.12	1.152	1.135
2	23.9	25.8	2.62	3.34	1.096	1.298
2	30.4	28.5	3.72	3.42	1.224	1.183
2	24.0	24.7	2.35	2.46	0.979	0.992
2	24.8	24.9	2.25	2.72	0.911	1.090
1	31.1	27.2	3.40	3.65	1.093	1.342
Regression coefficient	.0835		.3394		.3584	

Table 13

PERCENT PROTEIN, METHIONINE CONTENT AND METHIONINE AS PERCENT PROTEIN FOR F_3 PLANTS AND THEIR F_4 PROGENY FOR THE CROSS BUSH BLUE LAKE 240 WITH PI. 229815

Number of plants included in F_4 mean.	Percent protein		Methionine content (mg/g. of seed)		Methionine as % protein	
	F_3	F_4	F_3	F_4	F_3	F_4
4	-	26.7	1.99	3.12	-	1.183
4	27.2	26.2	2.58	3.22	0.931	1.277
5	31.6	26.9	3.14	3.04	0.994	1.126
5	26.5	24.8	2.69	2.48	1.015	1.009
6	32.2	26.7	2.80	3.02	0.870	1.104
5	30.2	28.0	3.19	3.17	1.057	1.132
2	31.4	27.9	3.11	2.75	0.990	0.987
4	25.9	27.6	2.08	2.83	0.803	1.026
Regression coefficient	.1772		-.0010		.0290	

Table 14

CORRELATION COEFFICIENTS AND NUMBER OF COMPARISONS FOR DATA FROM THE POPULATIONS GENERATED BY THE CROSSING OF BUSH BLUE LAKE 240 WITH PI 207227, PI 302542 AND PI 229815.

Population	Yield vs. % protein N	Yield vs. % protein r	Yield vs. Methionine content N	Yield vs. Methionine content r
BBL 240				
PI 207227				
F_3	51	-.3741 **	51	-.1299
F_4	81	-.5704 **	81	-.3670 **
BBL 240				
PI 302542				
F_3	25	-.3308	25	-.1882
F_4	44	-.3170 *	44	-.1633
BBL 240				
PI 229815				
F_4	35	-.1688	35	-.0070

* Significant at the 5% level; ** Significant at the 1% level.

Table 15 Evaluation of four bean lines. Percentage composition of experimental diets. - Exp. CIAT 74-15

Ingredient	Experimental diets				
	Control	2 (#3)	3 (#5)	4 (#6)	5 (#7)
	%	%	%	%	%
Casein	10.9	-	-	-	-
Beans 1/	-	45.1	36.6	35.2	37.8
Corn starch	80.9	46.9	55.4	56.8	54.2
Minerals	4.0	4.0	4.0	4.0	4.0
Vitamins	2.0	2.0	2.0	2.0	2.0
Corn oil	2.0	2.0	2.0	2.0	2.0
Methionine	0.2	-	-	-	-
	100.0	100.0	100.0	100.0	100.0
% Protein diet	10.03	10.00	10.02	10.01	10.02

1/ Crude protein content of bean samples were: 22.18, 27.37, 28.43 and 26.50 for #3, 5, 6 and 7, respectively.

Table 16

RESULTS OF BIOLOGICAL EVALUATION OF FOUR BEAN LINES USING RATS 1/

Diet 2/	Experimental Variable	Total weight gain (g)	Feed Conversion	PER
1	Casein	96.0	3.2	3.2
	Bean lines			
2	PI 207227	35.0	6.8	1.5
3	PI 302542	35.9	6.5	1.5
4	BBL 240	43.4	6.0	1.6
5	PI 229815	32.5	7.3	1.4

1/ Experimental period: 28 days
Average of six rats per group

2/ Diets 1, 2, 3, 4 and 5 contained 9.8%, 10.0%, 10.5%, 10.5% and 10.0% crude protein respectively.

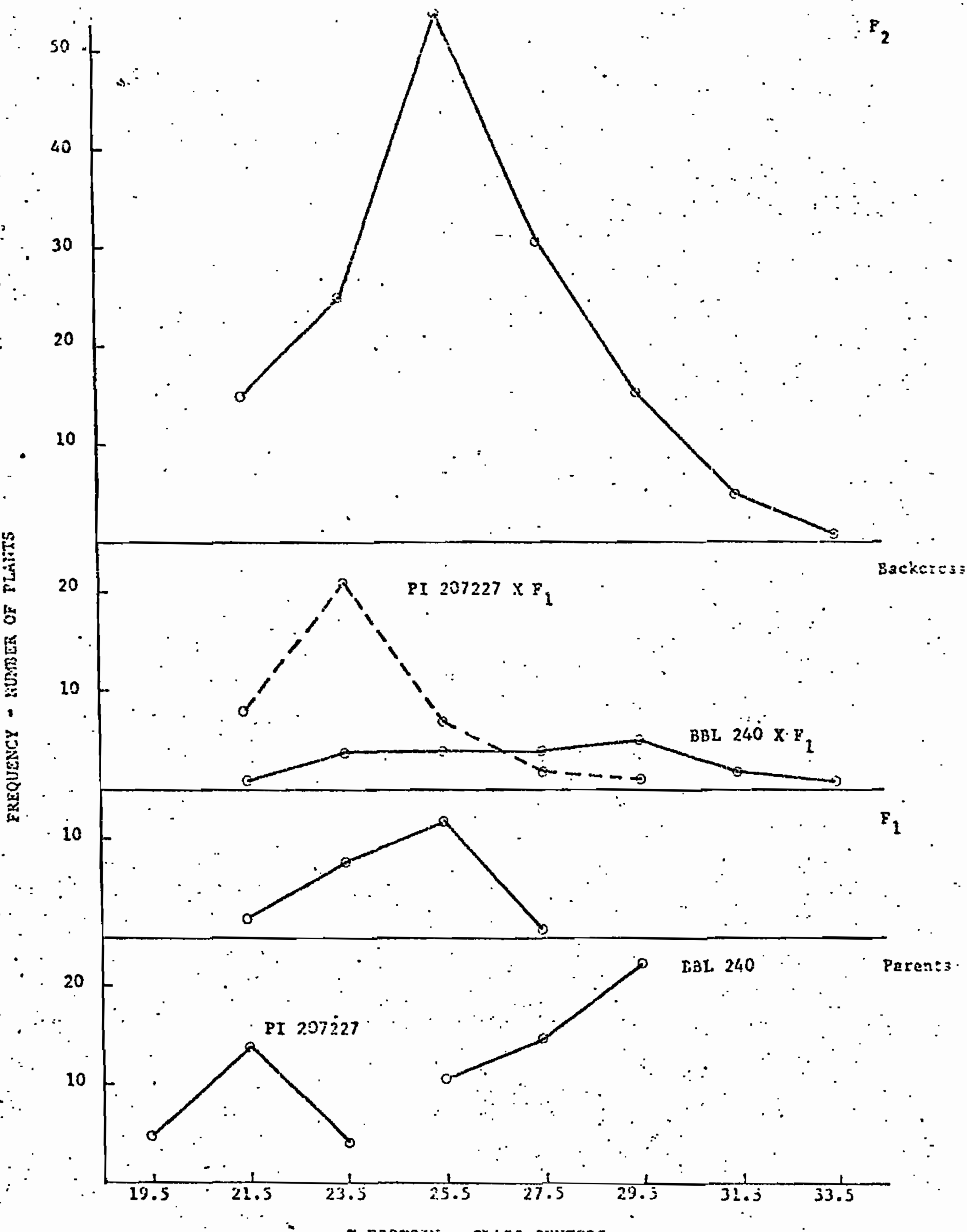

FIG. 1 Frequency distribution of percent crude protein in Bush Blue Lake 240, PI 207227 and their F_1, F_2 and backcross progeny.