Grain Quality and Biochemistry
Progress Report-5/87

Chickpea and Pigeonpea

Report of Work

January - December 1986

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

Foreword

This report on the work done during January - December 1986 has been prepared to share the information with scientists who have an interest in grain quality and biochemistry aspects of chickpea and pigeonpea improvement.

THIS IS NOT AN OFFICIAL PUBLICATION OF ICRISAT AND SHOULD NOT BE CITED.

Umaid Singh and

R. Jambunathan

Contents

Grain Quality and Biochemistry Staff and Collaborating Scientists

Biochemists

Dr. R. Jambunathan

Dr. Umaid Singh

Secretarial Staff

Mr. T.S. Noel Prashanth

Mr. K.D.V. Prasad

Research Associates

Mr. P.V. Rao

Mr. G.L. Waghray

Ms. R. Seetha

Laboratory Assistants

Mr. B. Hanmanth Rao

Mr. G. Venkateswarlu

Driver-cum-General Assistant

S.A. Khan

COLLABORATORS

Breeders	Agronomists	Germplasm Botanists	Entomologists
Dr. H.A. van Rheenen	Dr. C. Johansen	Dr. R.P.S. Pundir	Dr. W. Reed
Dr. Laxman Singh	Dr. O.P. Rupela	Dr. P. Remanandan	Dr. S.S. Lateef
Dr. C.L.L. Gowda			Dr. S. Sithanantham
Dr. Jagdish Kumar			
Dr. K.B. Saxena			

Chickpea

CHICKPEA

Project # : C-125 (85) IC

Title : Grain quality improvement in chickpea

Objectives :

1. Identify the major food forms of chickpea consumption and develop techniques to their quality.

2. Monitor grain quality of advanced breeding lines.

3. Study the effect of environment on grain quality.

C H I C K P E A

We concentrated our efforts in studying the following topics of chickpea grain and food quality during this year.

1. Cooking quality and consumer acceptance
2. Chemical composition of advanced breeding lines
3. Protein content as influenced by environments
4. Biological evaluation and protein digestibility
5. Amino acid composition of some wild species
6. Dehulling quality

1. Cooking quality and consumer acceptance

The identification of major food forms of chickpea consumption in the world has received our attention in recent years. To identify the major food preparations of chickpea, a questionnaire on utilization of chickpea was developed and published in the Chickpea Newsletter, June 1985 edition and we requested the readers to fill out and return it to us. Reader's response was not very encouraging and as a follow up action, this questionnaire was individually sent to many scientists in different countries. Then we received the responses from 138 scientists from 30 countries as shown in Table 1. Different proportions of chickpea consumption are summarised (Table 2). Dhal and food items prepared from besan (chickpea dhal flour) are the major forms of chickpea consumption in India. In some other Asian countries besan preparations are not very common. In other than Asian countries, it appears that chickpea is consumed in the form of whole seed. This underlines the need for studying the cooking quality of whole seed as well. In India, pakoda (oil fried), kadi (butter milk

boiled), roti (in combination with wheat flour) and dhokla (fermented) are the important food preparations of besan. The besan is also used in some sweet preparations. Roasted and germinated whole seeds are also consumed to a considerable extent in India. Chickpea soup and salad are also common preparations in some countries. These food preparations have been listed in Table 3.

We determined the cooking quality and organoleptic properties of some desi and kabuli cultivars grown in 1984/85 and 1985/86 seasons at ICRISAT subcenter Hisar. Results are summarised in Tables 4-6. We studied five genotypes each of desi (C 235, G 130, H 75-35, H 208, and ICCC 4) and kabuli (L 144, L 550, ICCC 25, ICCC 32, and ICCC 33) grown in 1985/86 season at ICRISAT subcenter Hisar for their cooking time and consumer acceptability parameters such as color, texture, flavor, taste and general acceptability. Consumer acceptance studies were conducted with the help of 10 panel members some of whom were associated with similar study in the previous years. Statistical analysis of the results of this study indicated no clear cut differences between desi and kabuli types (Table 7).

In addition, cooking time of whole-seed and dhal samples of 14 elite lines of chickpea was determined. The results of these lines and some other lines are summarised in Table 8. Cooking time of whole-seed of these genotypes varied from 54 min for ICCC 25 to 98 min for ICCC 42, whereas cooking time of dhal of these genotypes ranged between 25 min and 46 min with mean being 34.3 min. There was no significant correlation between the cooking time of whole seed and dhal of these 25 genotypes (Table 9). This indicated that cooking time of whole seed was affected by the nature of seed coat and it

could not be predicted on the basis of cooking time of dhal. To confirm this observation, analysis of more number of samples would be very useful. We observed that 100-grain mass (whole seed) was positively and significantly correlated with cooking time of whole-seed ($r = 0.40$, $P \leq 0.05$) and dhal ($r = 0.56$, $P \leq 0.01$). This shows that bold seeds would require longer time to cook. Protein content of these genotypes was not significantly correlated with the cooking time of either whole-seed or dhal (Table 9).

2. Chemical composition of advanced breeding lines

To study the nutrient profile of lines developed by ICRISAT, we analyzed the seeds of several genotypes (ICCV 1, ICCV 2, ICCV 5, ICCC 32, ICCC 37) including commonly grown cultivars (Annigeri and L 550) for their content of protein, starch, sugars, ash, fat, fiber, minerals and trace elements. As shown in Table 10, we observed significant differences in protein, starch, calcium and iron contents of dhal samples of these genotypes. ICCV 1 contained the highest amounts of protein as it also did during the 1984-85 season. Results of the analysis of whole-seed samples substantiated this observation. The nutrient profile of the genotypes developed by ICRISAT was comparable with that of the local cultivars, and for some constituents they were better as shown in Table 10. In addition, we analysed 14 elite lines (ICCC 14, 25, 33, 34, 36, 38-43, 46-48) for their chemical constituents as shown in Table 11. Noticeable differences in the levels of protein, starch and fat contents of these genotypes were obtained.

We examined the effect of growing season by analysing seed samples from eight genotypes grown during 1984-85 and 1985-86 at ICRISAT Center (Table 12). Whole-seed and dhal samples were analysed for their chemical composition including minerals and trace elements. Of the various constituents, the protein and starch were significantly influenced by the growing seasons. Mean protein content of 1985/86 season was significantly ($P \leq 0.05$) higher than 1984/85 season and reverse trend was true for starch content (Table 12). Detailed analyses on these genotypes have been reported in Appendices I-II. Further analysis indicated that the calcium content of the whole-seed was significantly ($P \leq 0.01$) higher than that of the dhal. On an average about 60% of the calcium in the grain was lost by the removal of the seed coat for dhal preparation and this confirmed our earlier findings.

3. **Protein content as influenced by environment**

The variability of the protein content in chickpea has become a matter of great concern to us. We conducted experiments to study the effects of field conditions (soil pH and EC), fertilizer, and location on protein content. The protein content of Annigeri whole-seed samples grown in different fields at ICRISAT Center varied from 13.9 to 23.8%, showing large variations due to field conditions. These results were examined in view of the variation in soil pH, EC and available phosphorus as shown in Table 13. However, the values for organic matter and available phosphorus did not show any relationships with protein content. Generally, at soil pH readings of 8 and above and EC readings of 0.2 and above, the protein content was reduced. Having observed a large variation due to field conditions in the

protein content of Annigeri, it was felt necessary to study the effect of such field conditions on its amino acid composition. Two seed samples of Annigeri showing lowest and highest protein levels when grown in different fields were analysed for amino acid composition (Table 14). Expectedly, the levels of lysine and sulphur amino acids were slightly higher in low protein sample than in the high protein sample indicating some effect on protein quality. We have planned an experiment to confirm these results during the next year. In collaboration with pulse agronomy, we studied the effect of fertilizer on protein. This trial was conducted at ICRISAT Center in 1985/86. As shown in Table 15, the application of nitrogen fertilizer alone or in combination with phosphorus significantly ($P = < 0.01$) increased the protein content.

Protein content of chickpea is considerably influenced by the location. To confirm our results, we examined the effect of location on protein content by analysing the seed samples of 16 genotypes each of ICCT - desi short (DS), ICCT - desi medium (DM), and ICCT - desi late (DL). ICCT-DS genotypes were grown with four replications each at Badnapur and Patancheru, ICCT-DM with three replications at Keojnar and Patancheru and ICCT-DL with three replications at Faridkot, Hisar and Kanpur. Protein contents of these genotypes from different locations are summarised in Table 16. As shown in Table 17, statistical analysis of these data revealed three important observations, a) differences between locations were significant, b) genotypes showed significant differences, and c) the interaction between locations and genotypes was significant, $P \leq 0.05$ in case of ICCT-DS ICCT-DL. However, no significant interaction between location

and genotype was observed in case of ICCT-DM (Table 17).

4. Biological evaluation and protein digestibility

Bioavailability of nutrients plays an important role in determining the nutritive value of diet. Among grain legumes, chickpea protein digestibiity has been reported to be better than other legumes. However, it has been demonstrated that digestibility of legume proteins increased after heat treatment and that might have been due to the destruction of some antinutritional factors. To study the effect of cooking on protein digestibility, biological evaluation of raw and cooked samples of Annigeri was carried out. Both whole seed and dhal samples were examined. We determined the biological value (BV), true protein digestibility (TPD) and net protein utilization of the raw and cooked samples using Wistar strain rats (Table 18). The protein digestibility did not increase significantly as a result of cooking in case of whole-seed. But it increased slightly in case of dhal. Net protein utilization of whole seed reduced slightly as a result of cooking and this may be attributed to the reduced biological value. This study indicated that as a result of cooking protein utilization might reduce in whole seed whereas no beneficial effect can be expected in the case of dhal. Observed results significantly indicate that in case of chickpea no beneficial effect of cooking is apparent to improve the protein digestibility and utilization.

5. Amino acid composition of some wild species

We have been continuing our efforts to analyse new collection of germplasm accessions for their amino acid contents to find out if any

high sulphur amino acid sources exist in our collection. During this period, we were able to analyse several accessions of wild species for amino acid composition as follows : Cicer bijugum 5, C. cuneatum 1, C. echinospermum, 1; C. judaicum, 4; C. pinnatifidum, 3; C. reticulatum, 6; and C. yamashitae, 2. Decorticated seed samples were analysed for amino acid composition by automatic amino acid analyser after protein hydrolysis with 6 N HCl. Amino acid composition and protein content of these species is shown in Tables 19-22. Protein content of defatted dhal samples of these species ranged between 26.4% for C. yamashitae and 33.7% for C. bijugum. In general, amino acid composition of the wild species was comparable with that of the cultivated species. No large variability was observed in the levels of essential amino acids, lysine, methionine and cystine. Methionine content of the wild species was slightly lower than the cultivated species and the reverse was true for cystine.

6. Dehulling quality

We evaluated nine genotypes for their dehulling quality using a Prairie Regional Laboratory (PRL) mill in cooperation with the Home Science College, Hyderabad. Dhal yield of these genotypes varied from 67.7 to 84.8% (Table 23). In general, dhal yield was higher for kabuli types than desi types and this might be due to their lower seed coat contents. However, we noticed that powder fraction was relatively higher in kabuli types indicating that kabuli genotypes might incur greater nutrient losses as a result of dehulling. Among desi types, dhal yield ranged between 67.7 and 83.5% indicating a large variation. Genotypes which recorded lower dhal yield contained

higher proportion of whole seed material which was not dehulled. This shows that such cultivars would require longer dehulling time resulting in lower dehulling efficiency. Additional studies in this direction would be useful.

The influence of dehulling on nutrient losses was examined. The objective of this study was two folds : 1) to know the distribution of different chemical constituents in the cotyledons and 2) to find out nutrient losses incurred during dehulling. 'Annigeri was dehulled for 2, 4, 8 and 12 min in Tangential Abrasive Dehulling Device (TADD). Dhal and powder fractions were collected and analyzed. For control, seed coat was removed manually and the dhal sample prepared was compared with other dhal fractions. Effect of duration of dehulling on the recovery of dhal and powder fractions is shown in Table 24. As the dehulling time increased, the grain weight decreased remarkably indicating that outer layers of the cotyledons are lost in the form of powder fraction which increased subsequently (Table 24).

The chemical constituents of dhal and powder fractions are shown in Table 25. Except starch, other constituents such as protein, sugar, fiber and ash (mineral contents) were relatively higher in the outer layers of the cotyledons. As these layers were removed, their levels showed a declining trend in dhal fraction. On the other hand starch content appeared to be concentrated in the inner parts of the cotyledons. Interestingly it is observed that powder fraction is a rich source of ash contents (minerals and trace elements). We plan to study the levels of different minerals and trace elements in the dhal and powder fractions. Also, these fractions will be studied for protease inhibitors, protein fractions and amino acid composition.

Table 1. Responses to the questionnaire on chickpea utilization received from different countries.

S.#	Country	
1.	Afghanistan	1
2.	Australia	5
3.	Austria	1
4.	Bangladesh	3
5.	Belize	1
6.	Botswana	1
7.	Bulgaria	1
8.	Canada	2
9.	Cyprus	1
10.	Ethiopia	2
11.	Greece	1
12.	India	80
13.	Israel	1
14.	Japan	1
15.	Mexico	1
16.	Morocco	2
17.	Nepal	1
18.	Netherland	1
19.	Pakistan	8
20.	Philippines	1
21.	South Africa	3
22.	Spain	2
23.	Sri Lanka	1
24.	Sudan	2
25.	Tanzania	1
26.	Tunisia	1
27.	Turkey	1
28.	United Kingdom	3
29.	United States	8
30.	Zambia	1
	Total	138

Table 2. Relative proportions of chickpea consumption in the world[a]

Component	India	Asia (Excluding India)	Other countries
Wholeseed	26.0	23.3	86.3
Dhal (Decorticated)	34.1	56.7	5.7
Besan (Dhal flour)	42.6	19.2	5.8

[a] Number of respondents, India 76, Asia 8, and other countries 18.

Table 3. Some important food preparations of chickpea around the world.

Food preparation	Component	Method
1. Dhal	Decorticated dry split cotyledons	Boiled in water to a soft consistency and fried with spices and consumed with cereals
2. Chhole	Whole seed	Prepared and consumed as above.
3. Pakoda	Besan (dhal flour)	Oil fried and consumed as snack items.
4. Kadi	Besan	Butter milk boiled and used as vegetable.
5. Unleavened bread	Besan	Dry split seeds are mixed with wheat flour and chapati repared.
6. Kiyit Injera (Local bread in Ethiopia)	Whole seed	As above
7. Roasted	Whole seed	Parched grains-heated at 245-250°C for 2 min.
8. Homos Bi-Tehineh	Whole seed	Soaked, boiled and mixed with other gradients.
9. Tempeh	Decorticated split seed	Fermented product.
10. Lablebi	Whole seed	Boiled in water with salt and pepper.
11. Dhokla	Besan	Fermented with urd-bean flour.
12. Salad	Whole seed	Boiled in water and served with other vegetables.

Table 4. Cooking quality and organoleptic properties of dhal of desi cultivars grown in 1984/85 and (1985/86) seasons at Hisar.

Cultivar	Cooking quality			Organoleptic properties[a]				
	100-Seed mass (g)	Cooking time (min)	Water absorption (g/g)	Color	Texture	Flavor	Taste	General acceptability
ICCC 4	13.4 (12.8)	32 (32)	1.04 (1.04)	3.1 (3.7)	3.1 (3.6)	3.1 (3.2)	3.0 (3.1)	3.1 (3.4)
C 235	(10.8)	(31)	(1.08)	(2.6)	(2.6)	(2.9)	(3.0)	(2.7)
G 130	12.2 (12.2)	35 (35)	0.98 (1.02)	3.3 (3.2)	3.1 (3.3)	3.1 (2.8)	2.9 (3.0)	3.0 (3.3)
H 75 35	17.0 (17.4)	34 (35)	1.03 (1.04)	3.7 (1.9)	3.7 (2.4)	3.6 (2.2)	3.4 (2.3)	3.4 (2.1)
H 208	11.6 (12.1)	33 (31)	1.01 (1.06)	3.3 (2.9)	3.4 (2.6)	3.4 (2.9)	3.0 2.4)	2.9 (2.6)
SE ±	0.31 (0.19)	0.46 (0.27)	0.02 (0.06)	0.28 (0.25)	0.27 (0.28)	0.28 (0.30)	0.25 (0.30)	0.24 (0.28)

[a] Rating scale : Excellent, 4; good, 3; fair, 2; poor, 1, based on evaluation of 10 panelists.

Table 5. Cooking quality and organoleptic properties of whole seed of desi cultivars grown in 1985/86 at Hisar.

Cultivar	Cooking quality			Organoleptic properties[a]				
	100-Seed wt. (g)	Cooking time (min)	Water absorption (g/g)	Color	Texture	Flavor	Taste	General acceptability
G 130	12.2	68	1.07	3.4	3.6	3.5	3.4	3.0
H 75 35	17.4	74	1.03	1.7	1.8	1.8	1.9	2.0
H 208	12.1	66	1.10	2.0	1.9	2.1	2.2	1.8
C 235	12.2	74	1.05	3.1	3.2	2.7	3.2	3.1
ICCC 4	12.8	74	1.09	2.8	2.9	2.3	3.1	2.8
SE ±	0.24	0.98	0.02	0.26	0.21	0.29	0.28	0.25

[a] Rating scale : Excellent, 4; good, 3; fair, 2; poor, 1, based on evaluation of 10 panelists.

Table 6. Cooking quality and organoleptic properties of whole seed of kabuli cultivars grown in 1984/85 and (1985/86) seasons at Hisar.

Cultivar	Cooking quality			Organoleptic properties[a]				
	100-Seed wt. (g)	Cooking time	Water absorption	Color	Texture	Flavor	Taste	General acceptability
L 144	28.9 (24.9)	80 (78)	1.07 (1.20)	3.9 (3.6)	3.1 (3.0)	3.6 (3.2)	3.8 (3.2)	3.9 (3.3)
ICC 25	(17.1)	(64)	(1.02)	(3.3)	(3.0)	(3.4)	(3.0)	(3.2)
L 550	18.2 (18.5)	74 (72)	1.04 (1.04)	3.7 (2.5)	3.1 (1.8)	3.4 (2.1)	3.1 (2.3)	3.4 (1.7)
ICCC 32	16.2 (17.9)	66 (66)	1.07 (1.12)	2.7 (2.2)	3.1 (2.2)	2.9 (2.1)	2.9 (2.1)	2.7 (2.2)
ICCC 33	16.4 (16.8)	62 (64)	1.15 (1.15)	3.0 (1.6)	3.1 (1.8)	2.8 (1.7)	2.7 (1.5)	3.0 (1.7)
ICCC 34	18.4 (20.9)	60 (66)	1.20 (1.15)	3.7 (3.0)	3.4 (2.8)	3.6 (3.2)	3.5 (3.4)	3.8 (3.5)
SE ±	0.21 (0.18)	1.12 (0.75)	0.03 (0.02)	0.16 (0.14)	0.20 (0.18)	0.21 (0.22)	0.16 (0.21)	0.24 (0.17)

[a] Rating scale : Excellent, 4; good, 3; fair, 2; poor, 1, based on evaluation of 10 panelists.

Table 7. Consumer acceptance studies in whole seed of desi and kabuli cultivars grown in 1984-85 season at ICRISAT sub center Hisar[a]

	Cooking time (min)	Color	Texture	Flavor	Taste	General acceptability
Desi	70.8	2.6	2.7	2.5	2.8	2.5
Kabuli	69.2	2.7	2.3	2.5	2.4	2.4
SE	± 2.66	± 0.34	± 0.32	± 0.32	± 0.30	± 0.31

[a] Rating scale : Excellent, 4; good, 3; fair, 2; poor, 1, based on evaluation of 10 panelists.

Table 8. Evaluation of cooking quality of whole seed and dhal samples of some genotypes.

Cultivar	100-Seed mass g)	Whole seed		Dhal	
		Protein (%)	Cooking time (min)	Protein (%)	Cooking time (min)
C 235 D	12.2	21.1	74	24.3	32
G 130 D	12.2	21.2	68	25.0	35
H 75-35 D	17.4	20.7	74	24.7	34
H 208 D	12.1	19.1	66	22.8	33
H 850 D	27.7	19.5	78	21.0	40
L 144 K	24.9	20.4	78	21.5	45
L 550 K	18.5	18.9	72	19.9	34
ICCC 32 K	17.9	20.8	66	21.7	36
ICCC 4 D	16.6	22.5	78	27.6	34
ICCC 25 K	18.3	23.3	54	25.6	29
ICCC 33 K	19.7	23.2	64	24.8	33
ICCC 34 K	27.8	21.7	74	23.5	37
ICCC 36 D	15.4	21.9	76	27.9	28
ICCC 38 D	15.5	23.1	68	27.6	27
ICCC 39 D	14.1	22.0	72	27.6	25
ICCC 40 D	22.0	17.9	80	20.7	28
ICCC 41 D	15.7	18.8	71	22.2	28
ICCC 42 D	29.2	21.8	98	25.1	46
ICCC 43 D	17.4	23.6	82	27.3	27
ICCC 46 D	14.3	22.3	88	27.3	30
ICCC 47 D	19.9	23.3	84	26.8	27
ICCC 48 D	21.9	20.9	88	23.1	26
SE	± 0.34	± 0.26	± 1.79	± 0.34	± 0.65

D : desi. K : kabuli.

Table 9. Correlation matrix of various cooking quality characteristics.

Constituent	1	2	3	4	5
1. 100 Seed wt.	1.000	-	-	-	-
2. Cooking time (whole seed)	0.404*	1.000	-	-	-
3. Cooking time (dhal)	0.558**	0.085	1.000	-	-
4. Protein (whole seed)	-0.137	0.068	-0.299	1.000	-
5. Protein (dhal)	-0.343	0.198	-0.496	0.839**	1.000

*, ** Significant at 5% and 1% level, respectively. Results are based on the analysis of genotypes reported in Table 8.

Table 10. Chemical composition of dhal samples of genotypes developed by ICRISAT, ICRISAT Center, 1985/86[a]

Genotype	Protein (%) (N x 6.25)	Starch (%)	Soluble sugars (%)	Fat (%)	Fiber (%)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
ICCV 1	29.0	50.0	5.5	5.7	1.0	73.2	8.8	5.8
ICCV 2	22.6	57.9	5.3	5.8	1.2	93.4	6.3	4.0
ICCV 5	20.7	56.3	5.6	6.8	1.1	58.4	6.3	4.6
ICCC 32	21.9	54.1	5.3	4.3	1.4	74.9	7.6	6.0
ICCC 37	22.9	54.6	5.7	6.1	1.2	52.9	6.4	4.2
Annigeri	23.3	54.0	5.8	6.7	1.1	50.5	6.1	4.0
L 550	22.7	54.2	5.7	5.3	1.2	73.2	6.5	4.7
SE	± 0.25	± 0.82	± 0.12	± 0.13	± 0.07	± 5.59	± 0.29	± 0.07

[a] Expressed on moisture free basis

Table 11. Chemical composition of some advanced breeding lines.

Genotype	Group	100 seed mass (g)	Protein	Starch	Sugars	Fat	Crude fiber	Ash
			(%)					
ICCC 25	Kabuli	18.3	25.4	51.2	4.6	5.6	1.2	3.1
ICCC 33	Kabuli	19.7	25.0	53.0	5.1	4.3	1.1	3.1
ICCC 34	Kabuli	29.8	23.1	53.3	4.6	6.0	1.2	2.9
ICCC 14	Desi	18.7	27.3	50.8	5.0	4.4	1.1	3.2
ICCC 36	Desi	15.4	26.8	48.4	4.4	4.7	1.0	3.0
ICCC 38	Desi	15.5	28.2	51.5	4.7	5.8	1.0	3.1
ICCC 39	Desi	14.1	27.2	51.1	2.05	5.7	0.9	3.4
ICCC 40	Desi	22.0	20.6	56.7	5.55	7.7	1.2	2.2
ICCC 41	Desi	15.7	22.8	53.5	5.13	5.9	0.9	2.2
ICCC 42	Desi	29.2	25.3	52.0	4.3	8.0	1.2	1.6
ICCC 43	Desi	17.4	27.8	49.5	4.8	6.3	1.1	2.8
ICCC 46	Desi	14.3	27.8	51.7	4.6	5.8	1.0	2.8
ICCC 47	Desi	19.9	27.4	50.6	4.6	6.6	1.2	2.7
ICCC 48	Desi	21.9	23.6	54.0	4.9	6.9	1.0	2.5
SE	-	±0.19	±0.51	±0.64	±0.09	±0.05	±0.02	±0.03

Table 12. Chemical composition as influenced by growing seasons, ICRISAT Center[a]

Year	Protein (Nx6.25)	Starch	Soluble sugars	Fat	Crude fiber	Ash	Calcium	Iron	Zinc
	(g/100g)						(mg/100g)		
Whole seed									
1984-85	21.1	55.2	6.1	6.9	6.5	3.4	165.7	8.7	1.8
1985-86	24.1	50.0	5.9	6.4	5.8	3.3	173.1	7.9	1.1
SE	± 0.70	± 1.15	±0.15	±0.24	±0.93	±0.10	± 10.68	±0.35	±0.10
Dhal									
1984-85	23.2	60.7	6.6	7.2	1.3	3.3	57.9	7.6	0.77
1985-86	25.7	57.2	5.9	6.4	1.2	3.5	70.2	7.1	0.99
SE	± 0.89	± 1.03	±0.09	±0.35	±0.05	±0.17	± 4.88	±0.41	±0.08

[a]Expressed on moisture free basis, mean values of eight genotypes. For details see Appendix I and II.

Table 13. Protein content of cv. Annigeri and soil parameters of the fields where it was grown in 1985/86.

Field	Number of samples	Protein (%) Range	Protein (%) Mean	pH	EC m.mhs/cm	Organic matter (%)	Available P (ppm)
BM 13A(1)	20	18.7-23.1	20.2	8.51	<0.15	0.37	0.50
BP 3A	16	16.3-19.7	17.8	8.86	0.21	0.39	2.30
BP 3B	20	16.7-19.7	17.9	8.65	0.27	0.41	4.30
BR 3(1)	50	21.9-23.8	22.9	7.85	0.16	0.49	0.50
BM 13A(1)	20	17.2-22.8	18.3	8.51	<0.15	0.37	0.50
BUS 2B	39	13.9-21.0	15.6	8.08	0.20	0.57	2.50

Table 14. Amino acid composition of whole seed (g/100g protein) of low and high protein samples of Annigeri grown in different fields (BUS 2B and BR3, respectively), at ICRISAT Center in 1985/86 season.

Amino acid	High protein	Low protein
Lysine	5.98	6.97
Histidine	2.90	3.12
Arginine	10.26	7.79
Aspartic acid	10.38	11.70
Threonine	3.26	4.26
Serine	4.72	5.16
Glutamic acid	15.35	16.77
Proline	4.28	4.89
Glycine	3.53	4.27
Alanine	3.86	4.66
Cystine	1.20	1.53
Valine	4.10	4.92
Methionine	1.46	1.82
Isoleucine	4.24	5.01
Leucine	6.83	8.25
Tyrosine	2.91	3.78
Phenylalanine	5.67	6.29
Total	91.82	101.17
Protein (%)[a]	24.3	14.9

[a] Moisture free (N x 6.25).

Table 15. Effect of nitrogen and phosphorus application on protein content in chickpea grown at ICRISAT Center[a].

N (kg/ha)	P_2O_5			
	0	30	90	120
0	16.9	17.4	17.6	17.1
120	19.3	19.9	19.4	19.1
SE	± 0.33	± 0.65	± 0.35	± 0.39

[a] Whole-seed protein per cent (N x 6.25).

Table 16. Protein content of [illegible] 1985/86 season.

S.No.	ICCT-DS Line #	Badnapur	Parbhani	[illegible] Line #	[illegible]	[illegible]	ICCT-DL Line #	Parbhani	Pusar	Palspur
		Protein (%)			Protein (%)			Protein (%)		
1	ICC 4918	18.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24.4	[illegible]
2	ICC [illegible]03	20.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.8	[illegible]
3	ICC 11141	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 85465	[illegible]	23.1	[illegible]
4	ICCL [illegible]7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 84421	20.6	23.5	19.5
5	ICCL 83135	24.9	[illegible]	ICC 1881	[illegible]	[illegible]	[illegible] 85048	19.3	23.9	17.7
6	ICCL 8211[illegible]	25.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 84460	19.8	24.2	18.7
7	ICCL 81[illegible]15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 12819	20.1	22.6	17.5
8	ICCL 8[illegible]08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 84446	17.9	20.8	18.6
9	ICCL [illegible]30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 1849	17.9	23.1	17.8
10	ICCL 8[illegible]24	22.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 84444	19.9	23.1	19.7
11	ICCL 84[illegible]15	21.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 10136	17.3	24.1	20.2
12	ICCL 84[illegible]17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 85447	17.9	23.6	19.0
13	ICCL 84219	22.8	[illegible]	ICCL 84[illegible]	[illegible]	[illegible]	ICCL 85449	17.2	22.4	18.0
14	ICCL 84224	23.3	26.9	ICCL 84[illegible]	[illegible]	[illegible]	ICC 14303	19.3	25.5	20.7
15	ICCL 83228	18.9	[illegible]	ICCL 84[illegible]	[illegible]	[illegible]	ICCL 84443	19.8	24.4	20.7
16	Local check	21.7	[illegible]	Local check	[illegible]	[illegible]	ICCL 4948	19.1	23.8	18.8
	Mean	20.4	[illegible]	Mean	[illegible]	[illegible]	Mean	18.8	23.3	18.9

Table 17. Analysis of variance on protein content of cultivars grown at different locations.

Source of variation	ICCT-DS				ICCT-DM				ICCT-DL			
	df	SS	MS	VR	df	SS	MS	VR	df	SS	MS	VR
Replication	3	8.5	2.8	-	2	53.8	26.9	-	2	8.8	4.4	-
Genotype	15	155.9	10.4	15.2**	15	62.9	4.1	3.9**	2	647.6	323.6	237.7**
Location	1	501.9	501.9	734.1**	1	571.3	571.3	533.4**	15	83.5	5.6	4.0**
Gen x Loc	15	64.5	4.2	6.3**		19.5	1.3	1.2	30	72.1	2.4	1.7*

*,** significant at 5% and 1% level respectively

Table 18. Effect of cooking on biological value, protein digestibility and net protein utilization in chickpea

Treatment	Food consumed per rat (g)	Biological value (%)	True protein digestibility (%)	Net protein utilization (%)
Whole-seed				
Raw	45.8	78.9	80.8	63.7
Cooked	46.8	73.2	81.9	60.0
SE	± 1.53	± 2.78	± 0.90	± 2.52
Dhal				
Raw	47.9	79.3	87.6	69.5
Cooked	49.0	80.7	86.9	70.1
SE	± 0.62	± 1.34	± 1.22	± 1.16

Table 19. Amino acid composition (g/100g protein) of dhal samples of some accessions of wild species.

Amino acid	C. arietinum[a]	C. Bijuncum	C. Bijuncum	C. Bijuncum	C. Bijuncum	C. Cuneatum
Lysine	6.43	6.33	6.09	6.10	6.25	6.47
Histidine	2.77	2.98	2.77	2.86	2.86	2.98
Arginine	9.38	9.61	10.50	10.48	10.65	7.71
Aspartic acid	10.40	10.09	10.48	10.34	10.57	10.48
Threonine	3.03	3.22	3.10	3.18	3.22	3.61
Serine	4.40	4.06	4.28	4.18	4.39	4.53
Glutamic acid	15.74	14.14	14.90	14.60	15.03	15.36
Proline	3.78	3.78	3.88	3.72	3.95	4.11
Glycine	3.72	3.44	3.45	3.26	3.51	3.74
Alanine	3.72	3.57	3.64	3.62	3.70	4.01
Cystine	1.12	1.63	1.44	1.49	1.43	1.16
Valine	4.23	3.81	3.85	3.91	3.86	4.19
Methionine	1.79	1.36	1.11	1.26	1.22	1.29
Isoleucine	4.02	4.12	4.14	4.40	4.30	4.41
Leucine	7.02	6.42	6.70	6.55	6.71	6.95
Tyrosine	2.89	3.04	2.88	2.94	2.86	3.04
Phenylalanine	5.21	5.35	5.48	5.93	5.65	5.60
Total	89.68	86.95	88.69	88.82	90.19	89.75
Protein (%)[b]	25.15	31.93	33.72	32.68	32.43	30.32

[a] C 130 used as a laboratory check for comparison, values taken from last year analysis

[b] Moisture free (Nx6.25)

Table 20. Amino acid composition (g/100g protein) of dhal samples of some accessions of wild species.

Amino acid	C. Echinospermum		C. Judaic		
Lysine	6.05	6.15	6.37	6.52	6.45
Histidine	2.88	2.87	2.92	2.98	2.87
Arginine	9.75	8.75	9.65	8.91	8.41
Aspartic acid	10.26	10.58	11.37	10.52	11.40
Threonine	3.25	2.96	3.26	3.28	3.41
Serine	4.36	4.20	4.51	4.30	4.55
Glutamic acid	14.72	15.55	16.44	15.61	16.45
Proline	3.90	3.87	4.14	3.71	3.90
Glycine	3.54	3.45	3.72	3.63	3.77
Alanine	3.78	3.64	3.95	3.59	4.00
Cystine	1.21	1.27	1.11	1.27	1.09
Valine	3.95	3.91	4.22	3.94	4.20
Methionine	1.16	1.12	1.25	1.11	1.33
Isoleucine	4.17	4.19	4.53	4.59	4.53
Leucine	6.60	6.68	7.13	7.04	7.20
Tyrosine	2.95	2.88	3.14	3.16	3.34
Phenylalanine	5.30	5.57	6.02	6.02	6.17
Total	87.83	87.58	93.73	90.18	93.07
Protein (%)[a]	29.43	30.22	30.60	30.11	28.62

[a] Moisture free (N x 6.25)

Table 21. Amino acid composition (g/100g protein) of dhal samples of accessions of wild species.

Amino acid	C. Pinnatifidum	C. Pinnatifidum	C. Pinnatifidum	C. Reticulatum	C. Reticulatum
Lysine	6.18	5.08	5.94	6.40	6.08
Histidine	2.85	2.25	2.99	3.06	3.00
Arginine	9.32	7.63	10.15	9.66	10.30
Aspartic acid	9.93	7.42	9.91	10.48	10.25
Threonine	3.28	2.10	3.05	3.34	3.20
Serine	4.35	1.90	4.33	4.65	4.31
Glutamic acid	14.67	14.45	14.98	15.19	14.78
Proline	3.74	3.52	3.62	4.01	3.62
Glycine	3.56	3.17	3.35	3.49	3.63
Alanine	3.83	4.02	3.58	3.88	3.75
Cystine	1.00	0.58	1.07	1.44	1.11
Valine	4.01	3.90	3.71	4.00	3.94
Methionine	1.34	1.08	1.26	1.43	1.39
Isoleucine	4.09	3.83	3.92	4.23	4.09
Leucine	6.57	6.23	6.47	6.90	6.59
Tyrosine	3.08	2.47	2.96	3.02	2.92
Phenylalanine	5.29	4.81	5.48	3.56	5.31
Total	87.09	74.44	86.77	90.44	88.27
Protein (%)[a]	28.26	28.39	32.43	30.57	30.86

[a] Moisture free (N x 6.25)

Table 22. Amino acid composition (g/100g protein) of dhal samples of some accessions wild species.

Amino acid	C. Reticulatum	C. Reticulatum	C. Reticulatum	C. Reticulatum	C. Yanashitae	C. Yanashitae
Lysine	6.15	6.15	5.79	5.81	6.68	6.63
Histidine	2.86	2.88	2.80	2.88	2.90	2.80
Arginine	9.48	9.62	9.75	10.70	9.17	9.26
Aspartic acid	10.33	10.40	10.43	9.91	10.73	10.88
Threonine	3.39	3.17	3.21	2.99	3.41	3.62
Serine	4.28	4.31	4.53	4.27	4.60	4.82
Glutamic acid	15.20	14.75	14.89	14.11	16.29	16.33
Proline	4.11	3.82	3.96	3.70	3.93	4.26
Glycine	3.57	3.48	3.41	3.30	3.75	3.85
Alanine	3.91	3.79	3.70	3.63	4.13	4.23
Cystine	1.21	1.30	1.22	1.05	1.11	1.24
Valine	3.95	4.01	4.01	3.87	4.06	4.58
Methionine	1.43	1.45	1.27	1.27	1.49	1.32
Isoleucine	4.15	4.25	4.01	3.87	4.60	4.58
Leucine	6.73	6.81	6.49	6.10	7.30	7.25
Tyrosine	3.08	2.99	2.82	2.71	3.08	3.14
Phenylalanine	5.40	5.49	5.42	5.15	5.85	5.83
Total	89.23	88.67	87.47	851.6	93.27	94.30
Protein (%)[a]	28.15	28.43	31.74	33.88	26.42	26.66

[a] Moisture free (N x 6.25)

Table 23. Dehulling quality of chickpea genotypes[a]

Genotype	100 grain mass (g)	Fraction yield (%)					
		Whole seed	Dhal	Brokens	Powder	Husk	Total
ICCV 1	15.0	6.9	67.7	1.8	4.8	11.2	92.4
ICCV 2	23.8	1.4	84.8	1.0	6.2	4.5	97.9
ICCC 32	17.5	1.1	84.3	1.5	6.8	3.6	97.3
ICCC 37	18.2	7.6	72.1	4.7	5.3	7.3	97.0
K 850	29.4	2.4	83.5	2.1	4.0	9.4	98.4
P 1329	18.7	2.6	80.5	2.5	1.7	10.2	97.5
Annigeri	21.6	12.5	72.9	1.1	3.6	9.7	99.8
H 208	11.3	7.6	70.2	5.0	3.9	9.9	96.6
L 550	19.7	1.0	84.7	0.8	7.1	3.3	96.9
SE	± 0.33	± 1.86	± 2.59	±0.23	±0.21	± 0.46	± 2.13

[a] Dehulled using Prairie Research Laboratory (PRL) mill

Table 24. Effect of dehulling on dhal yield chickpea (cv. Annigeri)[a]

Dehulling time (min)	100-grain mass (g)	Recovery (%)		
		Dhal	Powder	Total
0	18.5	100.0	-	100.0
2	17.2	92.5	5.2	97.7
4	16.3	84.6	12.7	97.3
8	13.0	70.4	26.2	96.4
12	10.8	56.3	39.2	94.5
SE	± 0.34	± 1.28	± 2.03	± 0.54

[a] Using Tangential Abrasive Dehulling Device (TADD).

Table 25. Chemical constituents (g/100 g sample) of dhal and powder fraction[a]

Dehulling time (min)	Dhal					Powder				
	Protein	Sugar	Starch	Fiber	Ash	Protein	Sugar	Starch	Fiber	Ash
0	18.6	6.8	56.2	1.2	2.8	-	-	-	-	-
2	18.0	6.5	57.8	1.1	2.6	23.6	12.1	48.0	1.7	4.1
4	17.5	6.3	57.8	1.0	2.7	21.8	10.5	50.3	1.4	3.6
8	17.5	6.0	58.0	0.9	2.5	19.8	9.5	52.0	1.2	3.4
12	16.4	6.1	60.8	1.0	2.6	18.9	8.6	55.4	1.0	3.3
SE	± 0.18	±0.21	±0.31	±0.08	±0.14	±0.21	±0.13	± 0.51	±0.09	±0.12

[a] Fractions obtained by using Tangential Abrasive Dehulling Device (TADD).

APPENDIX I

Chemical composition of whole seed of some advanced breeding lines and [illegible]

Genotype	Group	Protein (%)	Starch (%)	Soluble sugars (%)	Oil (%)	Ash (%)	Crude fiber (%)
1984/85							
ICCV 1 (ICCC 4)	Desi	23.3	45.3	5.4	5.6	3.5	8.5
ICCC 37	Desi	18.7	50.3	5.9	6.4	2.9	8.5
K 850	Desi	20.0	50.7	5.2	6.4	3.1	7.6
P 1329	Desi	19.7	51.6	5.7	7.0	3.1	7.8
Annigeri	Desi	15.9	53.7	5.8	7.6	3.1	8.2
L 550	Kabuli	20.3	56.3	6.1	6.5	3.3	2.5
ICCV2 (ICCL 82001)	Kabuli	20.6	53.9	6.4	6.7	3.5	3.8
ICCV6 (ICCC 32)	Kabuli	21.1	55.5	6.1	5.8	3.4	2.7
SE ±		0.08	0.46	0.10	0.12	0.30	0.22
1985/86							
ICCV 1 (ICCC4)	Desi	25.2	47.8	5.6	5.4	3.1	8.1
ICCC 37	Desi	20.6	45.8	5.7	6.3	3.2	6.8
K 850	Desi	24.4	46.2	5.0	7.0	2.7	6.3
P 1329	Desi	24.8	45.7	5.3	6.7	2.6	7.1
Annigeri	Desi	21.2	47.3	5.6	6.2	3.1	7.2
L 550	Kabuli	22.0	47.5	6.3	5.8	3.4	2.5
ICCV2 (ICCL 82001)	Kabuli	23.0	53.5	5.5	5.9	3.4	3.3
ICCV6 (ICCC 32)	Kabuli	22.1	48.5	6.1	5.0	3.4	2.8
SE ±		0.17	0.83	0.08	0.23	0.06	0.22

APPENDIX II

Mineral and trace element composition of whole seed of some advanced breeding lines and cultivars of chickpea in 1984/85 and 1985/86 at ICRISAT Centre

Genotype	Group	K	Na	Ca	Mg	Zn	Cu	Fe	Mn
		mg(100g)$^{-1}$							
1984/85									
ICCV 1 (ICCC 4)	Desi	1087.5	43.5	220.9	138.1	4.8	1.9	8.8	2.0
ICCC 37	Desi	1018.8	27.6	164.7	124.2	3.8	1.4	7.1	2.6
K 850	Desi	1012.4	31.5	139.0	124.8	3.6	1.0	7.4	2.5
P 1329	Desi	1071.2	35.4	136.5	125.0	2.9	1.6	7.5	2.0
Annigeri	Desi	1108.9	47.0	152.3	128.0	3.7	2.0	7.9	1.7
L 550	Kabuli	1088.1	92.6	128.9	119.4	4.2	1.7	8.9	1.6
ICCV2 (ICCL 82001)	Kabuli	1159.4	34.3	150.3	137.1	4.1	1.7	8.1	3.5
ICCV6 (ICCC32)	Kabuli	1143.5	61.2	163.7	133.7	3.8	1.4	10.0	2.0
SE ±		21.1	4.05	2.71	3.30	0.13	0.10	0.37	0.07
1985/86									
ICCV 1 (ICCC4)	Desi	909.1	25.5	180.0	126.5	4.5	1.0	7.6	2.0
ICCC 37	Desi	1035.0	63.1	170.1	117.3	3.6	0.9	8.2	2.1
K 850	Desi	1021.7	50.2	223.2	134.4	3.0	0.6	6.6	2.0
P 1329	Desi	1038.2	23.2	136.1	129.7	3.7	0.7	7.5	2.2
Annigeri	Desi	1116.1	39.8	147.5	112.4	3.4	0.8	6.1	1.8
L 550	Kabuli	1114.2	51.3	143.3	127.0	3.3	1.3	7.6	2.3
ICCV2 (ICCL 82001)	Kabuli	1212.2	41.5	136.2	134.2	3.8	1.3	7.7	2.9
ICCV6 (ICCC 32)	Kabuli	1187.5	81.1	173.6	140.3	4.9	1.5	8.9	3.0
SE ±		20.43	4.48	12.0	2.89	0.11	0.08	0.66	0.08

APPENDIX III

Chemical composition of dhal of some advanced breeding lines and cultivars of chickpea grown in 1984/85 and 1985/86 at ICRISAT Center

Genotype	Group	Protein (%)	Starch (%)	Soluble sugars (%)	Oil (%)	Ash (%)	Crude fiber (%)
1984/85							
ICCV 1 (ICCC 4)	Desi	27.0	51.4	6.0	6.2	3.4	1.2
ICCC 37	Desi	21.5	58.2	6.2	7.1	3.1	1.1
K 850	Desi	22.7	56.8	6.0	6.9	3.0	1.2
P 1329	Desi	21.8	58.3	6.4	7.9	2.9	1.2
Annigeri	Desi	18.5	59.5	6.7	7.9	3.3	1.3
L 550	Kabuli	20.9	59.7	6.2	6.6	3.1	1.4
ICCV2 (ICCL 82001)	Kabuli	21.9	57.4	6.2	6.7	3.4	1.3
ICCV6 (ICCC 32)	Kabuli	21.8	59.2	6.4	5.1	3.1	1.5
SE ±		0.13	0.46	0.19	0.21	0.04	0.05
1985/86							
ICCV 1 (ICCC4)	Desi	29.0	50.1	5.6	5.7	3.4	1.0
ICCC 37	Desi	23.0	54.6	5.9	6.1	3.6	1.2
K 850	Desi	25.6	57.2	5.3	7.2	2.4	1.1
P 1329	Desi	26.8	53.8	5.7	7.3	2.5	1.1
Annigeri	Desi	23.3	54.0	5.8	6.7	3.2	1.1
L 550	Kabuli	22.7	54.2	5.7	5.3	3.9	1.2
ICCV2 (ICCL 82001)	Kabuli	22.8	57.9	5.3	5.8	3.7	1.2
ICCV6 (ICCC 32)	Kabuli	21.4	54.1	5.3	4.3	4.0	1.4
SE ±		0.25	0.89	0.10	0.11	0.10	0.06

APPENDIX IV

Mineral and trace element composition of dhal of some advanced breeding lines and cultivars of chickpea in 1984/85 and 1985/86 at ICRISAT Centre

Genotype	Group	K	Na	Ca	Mg	Zn	Cu	Fe	Mn
		mg(100)$^{-1}$							
1984/85									
ICCV 1 (ICCC 4)	Desi	1139.0	41.4	69.5	128.5	5.0	1.2	7.0	1.3
ICCC 37	Desi	955.9	24.3	42.1	100.0	3.7	0.6	6.8	1.3
K 850	Desi	1142.5	28.2	47.6	106.6	3.9	0.7	6.9	1.5
P 1329	Desi	1086.2	40.8	49.4	108.7	3.4	0.6	6.8	1.1
Annigeri	Desi	1166.0	53.0	56.6	116.8	3.8	0.7	6.4	1.1
L 550	Kabuli	1068.7	89.6	68.1	103.1	4.0	0.9	7.5	1.3
ICCV2 (ICCL 82001)	Kabuli	1114.8	35.3	60.5	122.5	3.7	0.6	5.8	1.7
ICCV6 (ICCC32)	Kabuli	1163.4	47.9	46.0	113.1	3.6	0.6	9.7	1.4
SE ±		47.7	3.98	5.30	5.0	0.05	0.10	0.56	0.21
1985/86									
ICCV 1 (ICCC4)	Desi	1078.3	65.2	73.2	125.7	5.8	1.2	8.8	1.1
ICCC 37	Desi	1030.2	41.6	52.9	107.7	4.2	1.0	6.4	1.2
K 850	Desi	1071.1	58.6	56.8	110.3	3.1	0.7	5.8	1.2
P 1329	Desi	1071.5	41.7	54.7	117.9	4.6	0.8	6.7	1.1
Annigeri	Desi	1015.1	51.3	50.5	115.1	4.0	0.8	6.1	1.2
L 550	Kabuli	1158.8	53.9	73.2	125.7	4.7	1.1	6.6	1.5
ICCV2 (ICCL 82001)	Kabuli	1157.2	50.1	93.9	124.0	4.0	1.0	6.3	2.0
ICCV6 (ICCC 32)	Kabuli	1095.5	80.0	74.9	110.7	6.0	1.1	7.6	1.8
SE ±		58.1	4.38	5.42	7.46	0.06	0.05	0.29	0.05

Pigeonpea

[redacted]

Project # : P-111 (85) IC

Title : Study some of the factors affecting the grain quality of pigeonpea.

Objectives:

1. Evaluate the cooking quality of pigeonpea cultivars.

2. Examine the levels of antinutritional factors.

3. Study the digestibility of proteins and carbohydrates in uncooked and cooked samples.

4. Determine the amino acid composition of selected cultivars.

PIGEONPEA

The following aspects of grain and food quality of pigeonpea were studied during this period. In addition, analysis of vegetable and podfly resistance and susceptible lines was undertaken.

1. Cooking quality and consumer acceptance
2. Chemical composition of advanced breeding lines
3. Protein content and amino acids
4. Effect of cooking on protein digestibility
5. Vegetable pigeonpeas
6. Dehulling quality
7. Chemical analysis of podfly resistance and susceptible lines

Some experiments were conducted to study these aspects. The results of such experiments are summarised and discussed in this report.

1. Cooking quality and consumer preference

In some African and Asian countries, cooking quality of pigeonpea is generally compared with other grain legumes, particularly in Africa it is compared with cowpea. We compared the cooking time of pigeonpea with other grain legumes as shown in Table 1. When the cooking times of whole-seed and dhal of different legumes were compared, we observed that reduction in cooking time after decortication was more in pigeonpea (Table 1). Soybean required the longest cooking time and mung bean the shortest for both whole-seed and dhal samples. In general the required time to cook was more for pigeonpea whole-seed

than cowpea (Table 2). These differences in cooking time of whole seed disappeared after soaking in both water and baking soda ($NaHCO_3$, 1% solution) indicating that soaking is more beneficial in case of pigeonpea. Although we do not know the precise reasons for a much greater reduction in cooking time in pigeonpea as compared to cowpea, the nature of seed coat and some physicochemical properties of the cotyledons might contribute to such differences.

Cooking quality of dhal of some advanced breeding lines of pigeonpea was carried out. Cooking time, water absorption and solid dispersability were determined (Table 3). Cooking time of these genotypes ranged between 32 min for ICPL 354 and 22 min for Bahar and Gwalior 5 min. These differences were also substantiated by water absorption and solids dispersion characteristics which are also considered important for evaluation of cooking quality. We determined the cooking time, water absorption and solids dispersion of six genotypes of early maturity, ICPL 81, ICPL 87, ICPL 151, ICL 186, ICPL 8324, and UPAS 120 and five of medium maturity, ICPL 270, ICPL 304, ICPL 333, ICPL 84060 and C 11. Cooking time of these genotypes including the check ranged between 16 and 22 minutes indicating significant ($P < 0.05$) differences among the genotypes (Table 4). Similarly protein content of these genotypes also differed significantly ($P < 0.01$). However, we did not observe clear cut differences between early and medium groups with respect to these characteristics.

For use as a mature grain, multiple harvesting of early pigeonpeas is becoming a common practice with the farmers. We determined the effect of multiple harvesting on cooking quality of

ICRISAT genotypes, ICPL 81, ICPL 87, and ICPL 151 grown during 1985-86 season at ICRISAT Center. Samples were harvested at an interval of about 60 days and dhal samples were analyzed for protein content, cooking time, water absorption and solids dispersion as shown in Table 5. No significant differences were apparent in cooking time of sample of two harvests and our results on water absorption and solids dispersion also substantiated this observation. On the other hand, protein content of two harvests differed significantly ($P < 0.01$) showing higher values for the second harvest. This might have been due to higher mobilization of nitrogen during the period of second harvest.

Germinated and fermented preparations of pigeonpea, if developed may enhance utilization of pigeonpea in some Asian and African countries. In our laboratory, preliminary efforts have been made in this direction. We prepared two products of germinated pigeonpea (seed coat removed after germination) in combination with rice flour named as uttapa (oil-cooked) and porridge (water-cooked) and one fermented product (dhokla) of pigeonpea dhal flour in combination with rice and urd bean (black gram) dhal flours. Interestingly, sensory analysts found all these products acceptable from consumption point of view. We also observed that both germination and fermentation process were able to remove off-flavor from pigeonpea. There is a need to develop more soybean like products of pigeonpea if this crop is to become popular in some Asian countries. We plan to make some efforts in this direction in the future.

2. Chemical composition of advanced breeding lines

It has been our endeavour to monitor the grain quality of the newly developed and advanced lines and genotypes of pigeonpea. Dhal samples of some genotypes were analysed for protein, starch, sugars, fat, crude fiber and ash contents (Table 6). Protein content of these genotypes ranged between 20.1% for ICPL 151 and 24.3% for UPAS 120. ICPL 87 showed 23.4% protein. Similar variation was observed in starch content of these genotypes.

3. Protein content and amino acids

We analyzed the protein content of 1573 dhal and 752 whole-seed samples received from ICRISAT pigeonpea breeders. It ranged from 18.8 to 34.5% for dhal samples and from 16.3 to 22.8% for whole-seed samples. The analyses of dhal samples confirmed our earlier results that some of the lines developed by ICRISAT breeding program have particularly high protein contents. In addition, we determined the protein content of 865 whole-seed samples from our Genetic Resources Unit; which ranged from 17.2 to 24.8%.

We investigated the variability in amounts of sulfur-amino acids in pigeonpea. These are at inadequate levels in genotypes so far tested and we hope to identify genotypes with adequate levels. We estimated methionine in 105 defatted dhal samples of a progeny raised from gamma-irradiated material. The methionine content of these samples ranged from 0.82 to 1.38 g $(100\ g)^{-1}$ protein and their protein content varied from 21.4 to 30.4%. Our pigeonpea breeders grew 22 accessions of Atylosia scarabaeoides in the postrainy season 1985/86 at ICRISAT Center and we analyzed defatted dhal samples of these for their methionine + cystine content. Values ranged between 2.37 and

3.03 g(100 g)$^{-1}$ protein with the mean being 2.50 g (100 g)$^{-1}$ protein. This indicated only a small variation in the sulfur-amino acid contents of these accessions.

4. Biological evaluation and protein digestibility

Among the grain legumes, the digesibility of pigeonpea protein is reported to be low even after heat treatment. We examined the effect of cooking on protein digestibility of whole-seed and dhal. We used raw and cooked (15 lb pressure for 15 min) samples of C 11 for biological evaluations by conducting rat feeding trials. Five male rats each weighing about 60 to 68 g were fed the diet for five days in metabolic cages. 10 g diet was fed daily. Urine and faeces were collected after the experimental period of 5 days and analysed for nitrogen content. Diet consumed and body weight gained by the rats were also calculated.

Some differences although statistically nonsignificant were observed in the amounts of food consumed by the rats. The amount of food consumed was more in the case of raw than in cooked whole-seed but the reverse was true for dhal sample. The amount of food consumed was associated with the body weight gain which increased significantly in dhal sample as a result of cooking (Table 7). Cooking significantly ($P < 0.01$) increased the protein digestibility in both whole-seed and dhal, and the effect was more pronounced in dhal sample (Table 7). Biological value of whole-seed decreased significantly ($P < 0.01$) on cooking while such an effect was not apparent in dhal sample. Lower biological value of whole-seed cooked sample showed that less nitrogen was absorbed by the body after heat treatment. Although the biological value of whole-seed decreased slightly, a

significant ($P < 0.01$) increase in protein digestibility of dhal brought about remarkable improvement in its net protein utilization as a result of cooking. This study sufficiently showed that beneficial effect of cooking in terms of protein utilization may be possible in dhal and not in whole-seed.

5. Vegetable pigeonpeas

The development of vegetable pigeonpeas has received considerable attention in the recent past. Although it is not clear what quality factors are important in selecting pigeonpea for vegetable purpose, we continued to analyse the breeding lines for protein, soluble sugars and fiber contents, the constituents which we have identified as important from the utilization point of view. Green seed samples of 45 genotypes were analysed for these constituents. Developing pods at 30 to 35 days after flowering were collected and shelled in the laboratory. After noting the grain fresh weight, samples were freeze-dried and analysed. Fifteen genotypes each belonging to early, medium and late maturity groups were analysed (Appendix 1). No large difference in the levels of these constituents were observed. Also, the genotypes belonging to different maturity groups did not reveal clear cut differences.

6. Dehulling quality

We continued our dehulling studies and during this year our major emphasis was to study the nutrient losses due to methods of processing. To examine this aspect, the effect of duration of dehulling on dhal yield was studied (Table 9). As the dehulling time increased in TADD the powder fraction increased and subsequently dhal yield decreased. This happens due to the abrasive action of the mill

which successively remove the outer portions of the cotyledons. In a typical commercial dhal mill, dehulling of pigeonpea is carried out using a similar mechanism of a roller machine.

The results of chemical analysis including minerals and trace elements of dhal and powder fractions obtained by dehulling for different times are shown in Tables 10-11. Protein, soluble sugars, fiber and ash contents of powder fraction were higher than the dhal fraction and the reverse was true for starch content (Table 10). These differences were more pronounced when dehulling was performed for 2 min. But dehuling for a longer period reduced such differences. This indicated that outer portins of cotyledons are richer sources of protein, fiber, sugar, and ash and poorer sources of starch which appeared to be concentrated in the inner portion of the cotyledons. Further, it may be noted that these constitutions are not uniformly distributed in the cotyledons of pigeonpea.

Mineral and trace elements analysis of these fractions also indicated some changes (Table 11). Of the various constituents, we observed significant losses in calcium ($P < 0.01$) and iron ($P < 0.01$) contents even in case of dehulling for 2 minutes. This indicated that these constituents are concentrated in outer layers of cotyledons which are successively removed as a result of dehulling. Amino acid composition, protein fractions, and trypsin inhibitors play a very important role in determining the protein quality of grain legumes. Effects of dehulling of pigeonpea on these constituents are shown in Tables 12-13. Results of amino acid analysis of dhal and powder fractions indicated no large differences (Table 12-13). The concentration of major amino acids, glutamic acid, aspartic acid,

leucine and phenylalanine did not vary between the dhal and powder fractions. This indicated that these amino acids are uniformly distributed in the cotyledons. These fractions were also examined for trypsin inhibitor activity (Table 14). Trypsin inhibitor units (TIU) were slightly higher in powder fraction than in dhal and the trend was reversed when the results were expressed as TIU/mg proteins (Table 15). This might have been due to higher protein content of the powder fraction. Observed results reveal that trypsin inhibitor activity may not be removed considerably due to processing method. The distribution of albumin, globulin, glutelin and prolamin protein fractions in dhal component dehulled for different intervals is shown in Table 15. The levels of various protein fractions did not change significantly ($P < 0.05$) as a result of dehulling.

7. Chemical analysis of podfly resistance and susceptible lines

Two genotypes with four replications each of low podfly (LPF) and high podfly (HPF) groups were analysed for protein and sugar contents, the constituents considered important in terms of pod fly attack based on our previous results. Flowers, podwall, immature and mature seeds of these genotypes were analysed and statistical analyses of the data are presented in Table 16. Differences among genotypes were significant excepting protein and sugar contents of mature seed. However, the differences between LPF and HPF were significant with respect to sugar content of flower and mature seed samples which was higher in LPF genotypes. Podwall samples of these genotypes were also analysed for amino acid composition (Table 17). Aspartic acid and glutamic acid were higher in LPF genotypes as compared to HPF indicating their possible role in podfly attack in pigeonpea. However, additional studies in this direction will be useful.

Table 1. Comparison of cooking time of whole seed and dhal of legumes.

Legume	Cooking time (min)		Per cent reduction in cooking time of dhal
	Whole seed	Dhal	
Pigeonpea (C 11)	44	20	54.5
Chickpea (G 130)	54	28	48.1
Cowpea[a]	30	15	50.0
Soybean[a]	64	43	32.8
Mungbean[a]	17	10	41.2
SE	± 2.13	± 1.75	± 0.83

[a] Market sample

Table 2. Comparison of cooking time of whole seed of pigeonpea and cowpea.

Genotype	100 grain mass (g)	Cooking time (min)					Reduction in cooking time[b] (%)	
		Control	Soaking treatment[a]					
			Water		Baking soda (1%)		Water	Baking soda (1%)
T 21	7.0	46	15	(1.13)	13	(1.17)	67.4	71.7
ICPL 87	9.3	48	12	(1.10)	10	(1.14)	75.0	79.2
ICPL 151	9.7	54	14	(1.10)	13	(1.16)	74.8	72.2
ICPL 85063	8.6	50	12	(1.19)	10	(1.22)	76.0	80.0
ICPL 85057	9.0	44	12	(1.15)	10	(1.17)	72.7	77.7
ICPL 85058	9.5	52	15	(1.09)	12	(1.10)	71.2	76.9
ICPL 85021	10.0	48	15	(1.25)	12	(1.26)	68.8	75.0
ICPL 85033	11.1	42	12	(1.10)	10	(1.09)	71.4	76.2
ICPL 85037	10.0	48	15	(1.26)	12	(1.29)	68.8	75.0
ICPL 85012	10.1	58	19	(1.06)	16	(1.10)	67.2	72.4
ICPL 85015	8.6	60	19	(1.18)	16	(1.10)	66.7	73.3
ICPL 86007	11.1	46	15	(1.10)	12	(1.15)	67.4	73.9
ICPL 86010	10.5	58	14	(1.12)	13	(1.03)	72.2	75.9
NYLON	13.1	78	20	(1.09)	18	(1.14)	73.0	75.7
RHADPHKUY1	14.5	80	18	(1.01)	15	(1.08)	70.0	75.0
ICPL 270	11.8	46	12	(1.10)	10	(1.13)	73.9	78.3
ICPL 304	10.3	42	15	(1.04)	12	(1.10)	75.8	80.6
ICPL 366	10.6	58	15	(1.04)	10	(1.05)	74.1	82.8
ICPL 131 (C-11)	9.2	52	14	(1.07)	12	(1.05)	71.2	76.9
ICPL 138 (BDN 1)	9.3	54	15	(1.17)	10	(1.14)	72.2	81.5
Cowpea								
RUSSIAN	17.1	38	20	(1.09)	18	(1.10)	47.4	52.6
LOCAL 1	22.7	36	18	(1.03)	15	(1.05)	50.0	58.3
LOCAL 2	11.0	34	15	(1.05)	12	(1.10)	55.9	64.7
SE	± 1.31	± 1.91	± 0.67	(0.03)	± 0.88	(0.02)	± 1.48	± 1.53

[a] Soaked for 16 hr at room temperature and values within parenthesis indicate water absorption (g/g sample)

Table 3. Evaluation of cooking quality of dhal samples of some genotypes of pigeonpea grown at ICRISAT in 1985/86 season

Cultivar	Protein (%)	Cooking time (min)	Water[a] absorption g/g	Solid disperaion[a] (%)
ICPL 354	21.7	32	1.18	20.2
ICPL 358	22.2	28	1.26	22.5
ICPL 360	22.1	25	1.26	28.0
ICPL 365	22.3	25	1.26	26.4
ICPL 366	18.7	27	1.20	21.4
ICPL 369	22.1	25	1.23	26.5
ICPL 371	22.0	26	1.25	23.6
ICPL 8398	23.6	28	1.75	38.6
ICPL 83103	21.4	24	1.19	23.2
ICPL 83104	22.4	23	1.15	31.5
ICPL 83105	20.8	25	1.22	29.6
ICPL 83106	23.9	24	1.21	28.1
ICPL 83120	22.4	26	1.41	21.9
ICPL 83143	22.9	25	1.18	27.8
ICPL 84072	21.7	29	1.18	22.4
NP(WR) 15	23.3	28	1.71	29.9
GWALIOR 5	24.7	22	1.77	26.6
T 7	23.5	24	1.63	25.6
BAHAR	21.6	22	1.74	28.5
SE	± 0.24	± 0.32	± 0.025	± 0.58

[a] Samples were cooked for 20 minutes

Table 4. Evaluation of cooking quality of dhal samples some early and medium maturation of genotypes.

Genotype	Protein (%)	Cooking time (min)	Water absorption (g/g)	Solids dispersion[a] (%)
Early				
ICPL 81	20.0	16	1.22	27.4
ICPL 87	20.2	17	1.19	32.3
ICPL 151	17.9	17	1.09	24.6
ICPL 186	23.2	22	1.06	23.3
ICPL 8324	19.5	19	1.22	33.0
UPAS 120	21.3	17	1.07	28.9
Medium				
ICPL 270	20.7	17	1.27	38.9
ICPL 304	20.1	17	1.06	25.4
ICPL 333	20.1	16	1.29	37.9
ICPL 84060	21.0	16	1.05	28.0
C 11	20.4	17	1.04	25.5
SE	± 0.21	± 0.8	± 0.043	± 8.8

[a] Sample cooked for 15 min before estimation

Table 5. Effect of harvesting on protein and cooking quality of dhal samples pigeonpea genotypes grown at ICRISAT Center in 1985/86.

Genotypes	Harvest	Protein (%)	Cooking time (min)	Water absorption (g/g)	Solids dispersion (%)
ICPL 81	1	18.7	18	1.24	27.4
	2	20.0	16	1.13	34.5
ICPL 87	1	21.2	16	1.12	32.5
	2	21.4	16	1.22	34.2
ICPl 151	1	20.2	21	1.10	23.4*
	2	20.8	24	1.11	26.0
SE		± 0.12	± 0.59	± 0.036	± 0.66

Table 6. Chemical composition dhal samples of genotypes developed at ICRISAT[a].

Cultivar	Protein (%)	Starch (%)	Sugars (%)	Fat (%)	Crude Fiber (%)	Ash (%)
ICPL 81	22.6	53.8	7.12	2.78	1.29	4.70
ICPL 87	23.4	54.5	7.02	2.32	1.29	3.88
ICPL 151	20.1	57.7	7.08	3.02	1.24	3.99
ICPL 304	22.7	54.9	6.74	2.68	1.28	4.49
ICPL 270	23.3	54.6	6.78	2.69	1.41	4.47
UPAS 120	24.3	52.6	7.72	2.56	1.40	4.70
C 11	22.3	57.1	6.62	2.55	1.06	4.35
SE	± 0.15	± 0.44	± 0.09	± 0.12	± 0.05	± 0.05

[a] Grown at ICRISAT Center in 1985/86.

Table 7. Effect of cooking on biological value, protein digestibility and net protein utilization in pigeonpea (cv. C 11).

Treatment	Food consumed per rat (g)	Weight gain per rat (g)	Biological value (%)	True protein digestibility (%)	Net protein utilization (%)
Whole seed					
Raw	44.2	4.4	70.7	61.1	43.1
Cooked	41.0	3.4	64.7	77.8	50.3
SE	± 3.32	± 0.32	± 2.05	± 1.13	± 1.80
Dhal					
Raw	41.9	1.9	77.7	71.0	55.2
Cooked	44.7	5.6	69.6	83.0	57.8
SE	± 1.87	± 0.64	± 1.37	± 1.60	± 1.63

Table 8. Effect of storage on cooking quality of vegetable pigeonpea cv. Nylon stored at different temperatures[a]

Storage time	Room temp. (25°C)				Cold room temp. (5°C)			
	Moisture (%)	Cooking time (min)	Texture peak area[c]		Moisture (%)	Cooking time (min)	Texture peak area	
			Raw[b]	Boiled[b]			Raw[b]	Boiled[b]
0	63.7	13	9.88	3.75	63.7	-	-	-
1 day	61.6	15	12.28	4.66	61.6	13	10.85	4.05
2 day	61.0	15	12.85	4.66	61.1	13	11.65	4.19
3 day	59.7	16	16.05	5.05	60.9	13	12.52	4.43
4 day	59.6	18	-	7.36	60.7	15	13.68	4.71
SE	± 0.56	± 0.24	± 0.84	± 0.43	± 1.06	± 0.3	± 0.34	± 0.18

[a] Pods were harvested at vegetable stage and stored in the laboratory.

[b] 30 g grains were taken and texture measured using an extrusion cell.

for boiled sample, boiling time was 30 min

Table 9. Effect of dehulling using the Tangential Abrasive Dehulling Device (TADD) on dhal yield (cv. C 11).

Dehulling time (min)	100 grain mass (g)	Recovery (%)		
		Dhal	Powder	Total
0[a]	8.4	100.0	-	100.0
2	7.9	93.3	5.4	98.7
4	7.4	87.3	10.9	98.2
8	6.3	74.7	20.6	95.3
12	5.0	63.1	33.4	96.5
SE	± 0.42	± 1.30	± 0.65	± 0.54

[a]This treatment was dehulled by hand and not subjected to abrasion in the TADD.

Table 10. Chemical constituents of dhal and powder fractions.

Dehulling time (min)	Dhal (%)					Powder (%)				
	Protein	Sugar	Starch	Fiber	Ash	Protein	Sugar	Starch	Fiber	Ash
0[a]	21.4	6.8	56.3	1.0	4.1	-	-	-	-	-
2	20.8	6.5	57.6	1.1	4.0	31.2	9.6	41.9	1.9	5.3
4	20.3	6.3	58.1	1.0	3.8	29.7	9.3	46.8	1.8	5.2
8	19.6	6.5	60.2	1.1	3.8	27.1	8.2	51.7	1.4	4.7
12	19.6	6.2	60.4	1.0	3.8	24.9	7.8	53.8	1.3	4.5
SE	± 0.17	±0.11	±0.24	±0.	±0.18	±0.15	±0.17	±0.42	±0.13	±0.21

[a]This treatment was dehulled by hand and not subjected to abrasion in the TADD

Table 11. Effect of duration of dehulling on mineral and trace elements of dhal and powder fractions.

Dehulling time (min)	Calcium	Magnesium	Zinc	Copper	Iron	Manganese
	(mg/100 g)					
Dhal						
0[a]	58.2	117.5	2.9	1.4	5.1	1.6
2	46.5	108.7	2.9	1.3	3.7	1.6
4	46.0	108.5	2.6	1.3	3.6	1.4
8	41.0	110.1	2.6	1.2	3.2	1.4
12	40.8	108.2	2.6	1.1	2.5	1.2
SE	± 2.34	± 3.19	±0.12	±0.11	±0.19	±0.13
Powder						
2	149.7	151.6	5.0	3.0	15.4	3.4
4	107.5	137.8	3.9	2.2	11.0	2.9
8	86.3	112.1	3.6	2.2	8.4	2.9
12	82.6	109.8	3.5	2.1	7.8	2.2
SE	± 2.08	± 2.78	±0.14	±0.15	± 1.53	±0.19

[a]This treatment was dehulled by hand and not subjected to abrasion in the TADD.

Table 12. Amino acid composition (g/100 g protein) of dhal of C 11 obtained by dehulling for different intervals

Amino acid	Dehulling time (min)				
	0 min (Control)	2 min	4 min	8 min	12 min
Lysine	6.98	6.88	7.00	6.86	6.76
Histidine	3.91	3.87	3.96	3.86	3.72
Ariginine	6.64	7.21	6.54	6.49	6.15
Aspartic acid	9.91	9.81	9.80	10.04	10.45
Threonine	3.72	3.63	3.80	3.82	3.41
Serine	4.74	4.66	4.82	4.33	3.56
Glutamic acid	21.20	20.56	20.81	21.18	21.34
Proline	4.12	3.90	4.17	4.02	3.78
Glycine	3.65	3.68	3.84	3.74	3.52
Alanine	4.07	4.09	3.92	4.13	4.18
Cystine	0.98	0.88	1.08	0.96	0.90
Valine	3.78	3.81	3.87	4.21	4.01
Methionine	1.48	1.38	1.39	1.34	1.23
Isoleucine	3.65	3.69	3.71	3.62	3.64
Leucine	7.10	7.16	7.24	7.29	7.00
Tyrosine	3.04	2.97	3.04	3.14	2.83
Phenyalanine	8.66	8.59	8.77	8.42	8.10
Total	97.63	96.77	97.76	97.45	94.37
Norleucine Recovery (%)	98	97	96	98	101
Protein % in sample (defatted moisture free)	21.4	20.8	20.3	19.6	19.6

Table 13. Amino acid composition (g/100 g protein) of power fraction of C 11 obtained by dehulling for different intervals

Amino acid	Dehulling time (min)			
	2 min	4 min	8 min	12 min
Lysine	6.38	6.46	6.49	6.46
Histidine	3.66	3.69	3.69	3.77
Arginine	6.55	6.51	6.40	6.45
Aspartic acid	9.75	9.85	9.74	10.05
Threonine	3.89	3.85	3.86	3.80
Serine	4.57	4.62	4.68	4.54
Glutamic acid	19.88	20.42	20.24	20.72
Proline	3.57	3.72	3.65	3.73
Glycine	3.62	3.58	3.59	3.54
Alanine	3.89	3.81	3.87	3.75
Cystine	1.26	1.20	1.25	1.16
Valine	3.87	3.87	3.94	3.89
Methionine	1.40	1.43	1.45	1.45
Isoleucine	3.62	3.59	3.62	3.64
Leucine	7.00	6.62	6.69	6.87
Tyrosine	2.92	2.87	2.91	3.02
Phenylalanine	8.55	8.72	8.81	8.87
Total	94.38	94.81	94.88	95.71
Norleucine Recovery (%)	99	98	99	100
Protein % in sample (defatted moisture free)	31.2	29.7	27.1	24.9

Table 18 Effect of duration of dehulling on trypsin inhibitor activity of dhal and powder fraction of C 11.

Dehulling time (min)	Trypsin inhibitor units (TIU)			
	TIU/mg sample		TIU/mg protein	
	Dhal	Powder	Dhal	Powder
0[a]	14.6	-	68.0	-
2	12.5	16.7	60.1	53.4
4	13.5	14.7	66.3	49.1
8	13.0	15.3	66.4	56.3
12	12.5	14.7	67.0	58.8
SE	± 0.34	± 0.15	± 0.48	± 0.52

[a]This treatment was dehulled by hand and not subjected to abrasion in the TADD.

Table 15. Effect of duration of dehulling on seed protein fractions of dhal

Dehulling time (min)	Albumin	Globulin	Glutelin	Prolamin	Recovery (%)
	(g/100 g total protein)				
0[a]	9.5	65.4	18.5	3.5	96.9
2	8.4	67.2	20.3	3.4	99.3
4	8.8	66.5	19.0	2.9	97.2
8	8.2	66.4	18.2	3.2	96.0
12	7.8	66.3	18.2	3.6	95.9
SE	±0.36	± 1.30	± 0.75	±0.40	-

[a]This treatment was dehulled by hand and not subjected to abrasion in the TADD.

Table 16. Protein and soluble sugars of flowers, podwalls and seeds of pigeonpea lines showing variable response to podfly attack ICRISAT Center, Kharif 1985/86.

Cultivar	Protein				Soluble sugars			
	Flowers	Pod-wall	Green seed	Mature seed	Flowers	Pod-wall	Green seed	Mature seed
ICP 7941 LPF	4.35	12.83	28.45	19.03	6.06	8.35	10.05	6.72
ICP 81025 LPF	3.65	12.97	26.63	19.62	7.31	10.81	14.16	6.77
ICP 7337 HPF	3.77	14.08	27.17	19.68	5.78	10.41	13.32	6.42
ICP 8509 HPF	4.12	12.67	28.87	20.30	6.44	10.28	12.63	6.30
SE (m) ±	0.149	0.211	0.287	0.442	0.142	0.286	0.506	0.148
CV (%)	9.2	3.9	2.2	5.5	5.4	7.0	9.9	5.5
Significance	S	S	S	NS	S	S	S	NS
OVERALL COMPARISON BETWEEN LESS AND MORE SUSCEPTIBLE								
Low podfly	4.0	12.90	27.64	19.33	6.68	9.58	12.10	6.74
High podfly	3.9	13.38	28.02	19.99	6.11	10.34	12.98	6.36
SE (m)	0.13	0.208	0.314	0.434	0.181	0.322	0.543	0.109
CV (%)	11.0	5.5	4.0	7.6	9.4	11.2	15.0	5.7
Significance	NS	NS	NS	NS	S	NS	NS	S

LPF : Less susceptible to podfly

HPF : Highly susceptible to podfly

NS : Not significant

S : Significant

Table 17. Amino acid composition (g/100 g protein) of tender pod wall of genotypes showing variable response to podfly attack.

Amino acid	ICP 7941 (LPF)	ICP 8102 (LPF)	ICP 7337 (HPF)	ICP 8595 (HPF)
Lysine	5.32	4.38	4.40	4.37
Histidine	3.67	3.22	2.95	3.30
Ariginine	3.95	3.66	3.63	4.07
Aspartic acid	13.34	13.46	16.36	15.86
Threonine	3.71	3.04	2.96	2.86
Serine	4.11	3.53	3.33	3.17
Glutamic acid	9.99	8.60	8.22	7.89
Proline	4.10	3.82	3.72	3.71
Glycine	4.16	3.45	3.21	3.10
Alanine	4.43	3.90	3.72	3.66
Cystine	0.39	0.34	0.35	0.27
Valine	4.49	3.77	3.75	3.51
Methionine	1.57	1.40	1.15	1.07
Isoleucine	3.99	3.20	3.05	3.04
Leucine	6.59	5.49	5.19	5.12
Tyrosine	3.49	2.84	2.68	2.47
Phenyalanine	4.35	3.69	3.32	3.48
Total	81.65	71.79	71.99	70.68
Protein[a] (%)	11.6	12.9	14.6	11.3

[a] Defatted and moisture free basis (N x 6.25)

LPF = Less susceptible to podfly, HPL = High susceptible to podfly

APPENDIX I

Protein and methionine contents of a progeny raised from radiated material.

Sl. No.	Identidi-cation number	Protein (%)	Methionine	
			g/100 g sample	g/100 g protein
1	76175 - 1	25.9	0.255	0.98
2	4007 - 5	25.3	0.255	1.06
3	6	25.3	0.289	1.14
4	4010 - 2	23.7	0.277	1.17
5	4	26.4	0.245	0.93
6	6	27.9	0.250	0.90
7	4012 - 2	26.7	0.255	0.95
8	5	28.8	0.263	0.91
9	9	26.3	0.257	0.98
10	4015 - 1	29.4	0.287	0.98
11	3	29.1	0.257	0.88
12	8	26.1	0.270	1.04
13	4017 - 2	27.8	0.292	1.05
14	5	29.0	0.250	0.86
15	9	25.5	0.353	1.38
16	4021 - 1	27.7	0.249	0.90
17	2	25.6	0.272	1.06
18	4	27.1	0.316	1.17
19	4022 - 5	24.4	0.255	1.04
20	ICPL 131	21.4	0.257	1.20
21	4022 - 6	26.8	0.292	1.09
22	8	26.1	0.292	1.12
23	4023 - 1	27.1	0.326	1.20
24	2	26.0	0.263	1.01
25	5	25.9	0.320	1.23
26	4025 - 1	26.3	0.287	1.09
27	3	26.3	0.287	1.09
28	10	26.5	0.283	1.07
29	4026 - 4	25.3	0.277	1.09
30	6	25.8	0.227	0.88
31	8	25.0	0.234	0.94
32	4028 - 1	26.2	0.277	1.06
33	3	26.1	0.228	0.88
34	4	27.4	0.237	0.87
35	4032 - 1	30.4	0.370	1.22
36	5	27.6	0.315	1.00
37	9	24.8	0.280	1.13
38	4033 - 1	29.4	0.267	0.91
39	3	27.6	0.315	1.14
40	ICPL 131	22.3	0.213	0.96
41	4033 - 5	29.3	0.240	0.82

Sl. No.	Identidi-cation number	Protein (%)	Methionine	
			g/100 g sample	g/100 g protein
42	4038 - 2	29.1	0.242	0.83
43	4	25.7	0.240	0.93
44	5	23.4	0.265	0.83
45	4041 - 2	27.1	0.226	0.83
46	3	27.7	0.279	1.01
47	5	28.3	0.275	0.97
48	4046 - 4	26.8	0.270	1.01
49	6	24.0	0.267	1.11
50	9	21.6	0.288	1.33
51	4049 - 2	25.4	0.267	1.05
52	3	28.8	0.279	0.97
53	5	24.9	0.250	1.00
54	4051 - 4	28.5	0.257	0.90
55	5	25.6	0.243	0.90
56	6	22.1	0.255	1.15
57	4055 - 2	25.7	0.255	0.99
58	4	25.8	0.237	0.92
59	10	27.6	0.267	0.97
60	ICPL 131	21.8	0.225	1.03
61	4061 - 2	28.5	0.243	0.85
62	8	23.3	0.217	0.93
63	10	24.8	0.220	0.89
64	4063 - 3	27.3	0.230	0.84
65	4	26.0	0.271	1.04
66	9	26.7	0.289	1.08
67	4068 - 1	26.2	0.266	1.02
68	2	27.8	0.223	0.80
69	3	27.2	0.229	0.84
70	4071 - 3	25.5	0.283	1.11
71	4	26.1	0.256	0.98
72	7	25.6	0.232	0.91
73	4073 - 2	26.6	0.239	0.90
74	6	25.7	0.252	0.98
75	7	26.6	0.277	1.04
76	4075 - 1	27.4	0.321	1.17
77	2	24.6	0.266	1.08
78	4	25.3	0.269	1.06
79	4082 - 2	23.2	0.282	1.22
80	ICPL 131	21.2	0.259	1.22
81	4082 - 3	23.2	0.264	1.14
82	5	24.8	0.280	1.12
83	4085 - 3	24.1	0.267	1.11
84	6	26.1	0.255	0.98
85	7	22.8	0.230	0.90
86	4089 - 7	24.6	0.273	1.11
87	8	25.4	0.212	0.83
88	9	24.7	0.186	0.85

Sl. No.	Identidi-cation number	Protein (%)	Methionine	
			g/100 g sample	g/100 g protein
89	4092 - 3	22.9	0.268	1.17
90	6	23.4	0.192	0.82
91	8	25.2	0.237	0.94
92	4095 - 3	23.9	0.193	0.82
93	5	24.9	0.203	0.82
94	8	25.5	0.265	1.04
95	4099 - 3	26.2	0.317	1.21
96	4	26.2	0.291	1.11
97	7	26.7	0.291	1.08
98	4103 - 3	27.1	0.289	1.07
99	4	24.8	0.280	1.13
100	ICPL 131	20.8	0.230	1.11
101	4103 - 5	26.6	0.237	0.89
102	4106 - 6	27.3	0.280	1.02
103	8	27.3	0.232	0.85
104	9	26.6	0.240	0.90
105	ICPL 131	21.2	0.193	0.91

II

Pigeonpea : Results of analysis of green and mature seeds of vegetable pigeonpeas grown in 1986/87 at ICRISAT Center.

Entry #	Protein %		Sugars %		Crude Fiber %	
	Green	Mature	Green	Mature	Green	Mature
7201	22.0	18.2	4.35	5.82	6.89	6.20
7202	21.3	19.1	4.39	5.76	6.76	7.05
7207	21.8	18.6	2.64	5.66	6.33	6.60
7210	21.9	19.3	3.65	5.22	8.17	6.20
7211	23.1	19.9	4.54	6.24	6.04	7.01
7408	21.7	19.1	6.60	6.24	7.69	5.74
7409	20.5	17.9	6.37	6.37	8.99	6.94
7410	21.4	19.3	5.01	6.08	8.63	6.22
7412	21.8	19.3	5.86	5.82	9.06	7.84
7413	21.6	18.4	5.59	6.04	8.66	5.90
7503	21.3	18.5	8.19	5.60	7.02	6.16
7505	22.2	20.9	6.64	6.63	8.89	6.35
7506	23.2	18.8	8.08	6.65	7.57	6.95
7514	23.3	20.6	7.53	6.57	7.85	6.98
7515	22.3	20.1	8.12	5.93	8.10	5.87
8301	22.5	20.2	6.90	5.77	7.75	5.45
8302	21.8	20.6	7.53	5.22	6.79	5.48
8203	21.6	19.8	6.10	5.83	7.36	5.22
8304	22.6	19.5	6.98	5.64	7.85	5.88
8308	21.7	19.9	7.45	5.49	7.77	6.57
8309	22.2	20.5	6.14	5.75	7.46	5.96
8310	22.5	20.5	7.53	5.38	7.64	5.74

Entry #	Protein %		Sugars %		Crude Fiber %	
	Green	Mature	Green	Mature	Green	Mature
8311	21.5	20.0	7.53	5.54	7.82	6.14
8314	21.9	20.5	6.65	5.44	7.59	5.83
8316	22.1	19.0	5.08	5.26	7.43	5.61
8701	21.7	19.8	11.72	5.34	7.63	5.59
8702	22.2	20.6	9.32	5.42	7.61	5.72
8703	22.7	20.5	9.04	5.73	6.37	6.02
8704	23.1	22.2	8.73	6.33	6.50	6.19
8705	22.1	22.1	8.18	6.00	6.84	5.84
8708	22.3	20.3	9.00	6.04	6.22	5.72
8711	22.2	21.3	9.18	5.90	7.75	5.58
8712	21.5	21.1	8.23	6.14	6.84	5.29
8714	21.4	20.9	10.63	5.76	7.03	5.70
8716	22.4	20.5	11.62	6.08	7.67	4.93
8801	21.9	22.1	4.87	5.46	7.90	5.41
8802	22.2	19.9	4.86	5.82	7.40	5.70
8803	22.6	20.1	5.71	5.44	8.10	5.87
8804	22.2	20.5	6.97	5.32	7.23	5.95
8805	20.6	21.0	5.20	5.48	7.61	5.85
8806	22.8	20.6	4.43	5.20	7.71	6.39
8807	22.7	20.0	5.44	5.10	7.56	5.94
8809	21.2	18.8	5.69	5.40	7.91	4.81
8810	22.4	20.2	5.93	5.46	7.07	5.40
8812	22.3	20.9	5.88	5.44	6.95	5.68