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Evolution of rice and pulse varieties with improved quality through induced mutations, (part of a coordinated programme on the use of nuclear techniques for seed protein improvement)

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FINAL REPORT

(a) i. Contract No. BAN 1312/GS.

ii. Title of Project: Evolution of rice and pulse varieties with improved quality through induced mutations, (Part of a coordinated programme on the use of nuclear techniques for seed protein improvement).

iii. Institute where research is being carried out :

Institute of Nuclear Agriculture,
P.O. Box No. 4, Mymensingh, Bangladesh.

iv. Principal Scientific Investigator :

M. A. Q. Shaikh (1312/GS, R_1 & R_2)
M. M. Mia (R_3 and R_4)

v. Time period covered: 5 years

Period	Contract No.
1 November, 1972 - 31 October, 1973	1312/GS
1 October, 1974 - 30 September, 1975	R_1
1 November, 1975 - 31 October, 1976	R_2
1 December, 1976 - 30 November, 1977	R_3
15 April, 1978 - 14 April, 1979	R_4

(b) Description of research carried out :

Rice

In rice, the work at the begining concentrated on screening of advanced generation (M_{10}) mutants (Haq, 1973), 16 hybrids (F_6), six recommended varieties and 34 local collections for protein content. The mutants IRATOM-24 and IRATOM-38 were also grown along with the parent variety (IR-8) and IR-20 (another recommended Aman variety) under uniform fertilizer conditions but in different locations in order to study their environmental adaptibility in respect of some agronomical and physicochemical parameters.

For chemical analysis, rough rice (paddy) samples were air-dried to 10-12% moisture content and the samples of each entry were dehusked by a grain testing mill. Unpolished grains were ground and used in all tests. For amylose determination, the grains were ground to 60 mesh in a Willey Mill. Protein content was determined both by Kjeldahl and DBC

methods. Amylose percentage was determined by the method of Simpson et al.(1965).

In later stages, 60 rice germplasms were collected from various Institutes in Bangladesh and also from farmers' fields of representative districts of the country. The varieties represented all three seasons, viz. Aus (Summer), Aman (Autumn) and Boro (Winter). Fifty-four premitive (local) cultivars of rice and six high yielding varieties e.g. IR-8, IR-20, BR-4, Chandina, Iratom-24 and Iratom-38 were compared for their nutritional and cooking quality. The characters studied were, length-breadth ratio, hulling recovery percent, 1000-kernel weight, protein content (both Kjeldahl and DBC), amylose content, alkali spreading value and protein quality index. Four of the nutritionally superior types were further analyzed for total amino acid content. A microscopic protein characterization technique was also used to screen all the 60 cultivars.

In the year 1978-79, 3000 germplasms of rice which are being maintained at the Bangladesh Rice Research Institute (BRRI), Joydevpur, Dacca were screened for protein content by the DBC method. This collection is said to have all the available germplasms of the country and adjoining areas. The results have been handed over to the BRRI and the plant breeders now have a scope to select the high protein lines for hybridization and other forms of breeding to develop high-protein and high yielding varieties of rice.

Pulses

Work in pulses under this research contract consisted of induction of mutation in chickpea (Cicer arietinum) and lentil (Lens culinaris), isolation of mutants, studies involving inheritance and performance of these mutants over successive generations, and finally determination of their yield potential and quality characters.

Dry seeds of these two crops were irradiated with various doses of gamma-rays (5 to 40 kR) from the ^{60}Co source of the Atomic Energy Centre, Dacca. In all, 205 mutants of lentil and 210 of chickpea were selected in the M_2 generation during 1972-73. These were multiplied during M_3 (1973-74). Further selection on the basis of seed yield was made and 30 mutants of chickpea and 25 of lentil were grown during M_4 (1974-75) in small plots in two places (Tongi and Mymensingh) for comparing yields with the respective controls. Protein contents of these mutants were analyzed by the Kjeldahl method.

Ten mutants were selected out from the micro-plot yield trial of 1974-75 and these were tried again in M_5 (1975-76) along with the respective control varieties. Data on various agronomic characters like plant height, number of branches, number of seeds and pods/plant, 500 seed weight,

yield/plant, maturity period and protein content of the mutants were recorded. Correlation between various agronomic characters including seed yield were also studied to determine the most important yield components.

The ten elite mutants of each of chickpea and lentil were put into yield trials in M_6 (1976-77) along with the controls of each species. Protein contents of the mutants were also determined.

Four mutants of chickpea e.g. M-55, M-29, M-669 and M-102 and four of lentil, M-274, M-522, M-524 and M-559 were selected out of the ten elite mutants of each spedies for higher seed yield and protein content.

These four chickpea mutants were tried with Faridpur-1 at two locations, Ishurdi and Jamalpur during 1977-78. A randomized block design with three replications and 9 m x 9 m unit plots was used. Seed yields and protein contents were recorded.

A zonal cum-agronomic trial of the same mutants was carried out during 1978-79 with the mother variety and one other recommended variety, Sabur-4, in four locations of the country viz. Jessore, Ishurdi, Jamalpur and Comilla. A split-plot design with two methods of sowing e.g. line-sowing and broadcasting, and three replications were followed. Unit plot size was 13m x 4m (approx. 440 ft^2 = 1/100th of an acre). Each strain was therefore planted in six plots in the same location i.e. three-line sowing and three broadcast plots.

During 1977-78 the 4 lentil mutants were tried in two locations, Ishurdi and Jamalpur, with the mother variety and two other recommended varieties, L-5 and L-5501. A randomized block design with three replications and unit plot size of 9m x 9m was used. Seed yields, and protein contents were recorded.

A zonal trial of all the four lentil mutants with the recommended varieties was carried out in the same four places as with chickpea. Field plot design and other experimental conditions were same as in chickpea.

(c) Results obtained :

The variety IR-8 had 7.9% (K.P.) and 8.1%(DBC) protein in comparison with 8.0% and 9.0% respectively in IRATOM-24, and 9.5% and 10.7%, respectively in IRATOM-38. There was not much difference in percentage amylose among these varieties/strains. Three of the recommended Aman varieties showed higher protein content compared with others, and 11 out of 16 hybrid lines were in the range of 10-12% protein content. Amylose content of the recommended varieties and hybrid lines ranged from 15-29%. The maximum amylose content (29%) was in the hybrid line [illegible]-7-19-1. Wide variation in protein content was observed in the 3'

local strains (6.6-12.9%). The strains were in the range of 6-8%, 19 were in the range of 8-10% and four were in the range of 10-12% protein. (Tables 1 & 2).

Protein contents and other physico-chemical properties of the same variety/strain varied when grown in different locations. Thus protein contents ranged from 6.4-8.0% in IR-8, 7.5-8.7% in IR-20, 6.2-10.7% in IRATOM-24 and 7.0-11.9% in IRATOM-38, depending on locality. Similarly, a wide range of variation was observed in amylose content, starch-iodine-blue value and water absorption by grains. In general, however, the two mutants showed stability in respect of length and breadth of grain, 100-grain weight, seed yield and number of days to maturity. Moreover, in spite of variations, IRATOM-38 showed higher contents of protein in all except four localities. IRATOM-24 had also a slightly higher content of protein than in the mother variety IR-8.

In the screening of 60 rice germplasm, a good deal of variability was noted for almost all the characters studied (Table 3). It was remarkable that such a high degree of variation existed in the small number of genotypes analyzed in this study. Among the cooking characters studied, noteworthy variability was obtained in length/breadth ratio, spreading index and amylose content. Range of crude protein content from 6-13% in the analyzed material was of great significance.

The correlation coefficients recorded between various cooking and protein characteristics are shown in Table 4. It is of interest that length/breadth ratio was neither positively nor negatively correlated with any of the cooking or nutritional characteristics.

Results of aminoacid content of two high-protein and two medium protein varieties of rice (Table 5) show that lysine and other essential amino-acids were not negatively associated with the total protein content. This means that the proportion of amino acid in the protein remained constant even with 25% more protein in the rice grain contrary to the findings in wheat (Johnson et al. 1969). This study did not indicate that amino acid concentration depends in any way on the crude protein content except for sulphur-containing aminoacids, which seemed to have slightly reduced in the high-protein variety Hbj. B-VI.

Protein analysis of the 3000 rice germplasms revealed a range of 5-13% protein content among them. The breeders in Bangladesh Rice Research Institute will now be able to select parental material for hybridization.

Pulses :

The seed yields and protein contents of 10 selected mutants each of lentils and chickpea over three generations are compared in Tables 6 & 7, respectively. It is observed that there were appreciable

differences in the yielding capacity of various mutant strains. Protein content remained more or less unaffected in lentil but in chickpea the mutant M-669 showed higher protein content.

Ranges, means, standard deviations and coefficients of variability of different agronomic characteristics of chickpea and lentil are presented in Table 8. It is interesting to note that variability in different yield components, such as, branching habit, pods/plant and grain weight was encouragingly large. This indicated ample scope for selection of desirable plant types.

There was very little intraspecific variations for protein content in lentil but in chickpea the variation was appreciable as is evident from the coefficients of variability (Table 9).

Phenotypic correlation coefficients among different characters of chickpea and lentil are shown in Tables 10 and 11. Correlations between branching habit and seed yield, and, between branching habit and seed weight are interesting. Protein content was not found to be negatively correlated with seed yield and its components.

Four highest seed yielding mutants of chickpea (M-55, M-29, M-669 and M-102) and four of lentils (M-274, M-522, M-524 and M-559) were selected out of the yield trial of ten elite mutants of each species in M_6 (1976-77).

Chickpea (Cicer arietinum): The results obtained from the yield tiral of 1977-78 are presented in Table 12. It is evident that the mutant M-669 produced significantly higher seed yield in both places than the other mutants and the mother variety. Moreover it had more protein content than the others.

The seed yield data of the zonal-cum-yield trial of 1978-79 from various places are presented in Table 13. It is apparent that the mutant M-669 produced significantly higher seed yield in three out of the four places. The increase of seed yield in M-669 over Faridpur-1 and Sabur-4 was, on average, 15.8% and 23.9%, respectively. The mutant had, on average, 4% higher protein than the mother variety.

Lentil (Lens culinaris): The results of the yield trial in two places during 1977-78 are shown in Table 14. From Table 14 it is observed that the mutant M-522 had produced slightly higher seed yield than the mother variety, Mukdia-15 but there was no difference in protein content among the strains studied.

The results of the zonal-cum-yield trial of the lentil mutants during 1978-79 in four places reveal that there was no statistical difference in seed yield between any of the mutants and the three recommended varieties. Hence no data is presented.

(d) Conclusions drawn :

Rice

1. The two rice mutants, Iratom-24 and Iratom-38, which have since been released as varieties for early maturity, showed stability in respect of length and breadth of grain, grain weight, seed yield and maturity dates, than some other recommended varieties.

2. Iratom-38 showed higher contents of protein than the mother variety in all except four localities.

3. Extensive variability noted among the rice strains for almost all physical, chemical and cooking characters points to the possibility of developing varieties with desirable characters through hybridization.

4. These studies indicated that amino acid concentration does not depend on the crude protein content except sulphur-containing amino acids which was obtained in slightly reduced quantities in high protein variety Hbj. B-VI.

Pulses

1. A chickpea mutant (M-669) with 19% higher seed yield and 4% more protein content than the mother variety has been developed.

Strain	Seed yield (kg/ha)	% protein
M-669	2290	22
Faridpur-1 (mother)	1922	18

Application for releasing M-669 as a national variety in the name of Hyprosola has been filed to the Seed Board of Bangladesh.

(e) i. Citation of periodicals reporting work done under this contract:

1 - Evaluation of Seed Protein Alterations by Mutation Breeding. Proc. Res. Coord. Meet., Hahnenklee, 5-9 May, 1975, IAEA, Vienna, 1976. Pp. 138-139.

2 - Seed Protein Improvement by Nuclear Techniques. Proc. Res. Coord. Meet., Baden, Austria, 28 March - 1 April, 1977, IAEA, Vienna, 1978. Pp. 167-179 & 223-233.

3 - Bangladesh Journal of Agricultural Sciences 5:67-72(1978).

ii. Other relevant literature references:

1 - Haq, M.S., Rahman, M.M., Choudhury, M.H. 1973. Studies of the quality of induced mutants of rice. Nuclear Techniques for Seed Protein Improvement. Proc. Symp. Neuherberg, 1972, IAEA, Vienna, 1973 pp. 139.

2 - Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.H., Deobald, H.J., Kester, E.B., Hogan, J.T., Batcher, O.M. and Halick, J.V. 1965. Quality evaluation studies of foreign and domestic rices, U.S.D.A. Tech. Bull. No. 1331.

3 - Johnson, V.A., Mattern, P.J., Whited, D.A. and Schmidt, J.W. 1969. Breeding for high protein content and quality in wheat. New Approaches to Breeding for Improved Plant Protein. Proc. Panel Rostanga, 1968, IAEA, Vienna. pp. 29.

4 - Muhammad, A, Shakoor, A., Nadim, M.T., Ali, A., Ifzal S.M. and Sadiq, M. 1976. Seed protein improvement in wheat by mutation breeding. Evaluation of Seed Protein Alterations by Mutation Breeding. Proc. Res. Coord. Meet., Hahnenklee, F.R.G., 5-9 May, 1975, IAEA, Vienna, 1976. pp. 107-117.

5 - Naraharí, P., Bhatia, C.R., Gopalkrishna, T. and Mitra, R.K. 1976. Mutation induction of protein variability in wheat and rice. Ibid. pp. 119-127.

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7 - Tanaka, S. 1976. Induction of mutations in protein content of rice. Ibid. pp. 139-140.

8 - Denic, M., Dumanovic, J., Ehrenberg, L. and Ekman, G. 1976. Heritable variations in protein yield and its components, induced by radiations and mutagenic chemicals. Ibid. pp. 142.

9 - Harn, C. 1976. Studies on the high-protein mutants of rice. Ibid. pp. 143.

10 - Ismachin, M. 1976. Rice seed protein improvement through mutation breeding techniques. Ibid. pp. 143.

11 - Singhal, N.C., Jain, H.K. and Austin, A. 1978. Induced variability for protein content in bread wheat. Seed Protein Improvement by Nuclear Techniques. Proc. Res. Coord. Meet., Baden. 29 March - 1 April, 1977. IAEA, Vienna. pp. 41-50.

12 - Nadim, M.T., Shakoor, A., Ali, Abid and Sadiq, M. 1978. Seed protein improvement in wheat and pulses through induced mutation. Ibid. pp. 59-67.

13 - Walther, H. and Seibold, K.H. 1978. Induced variation in protein mutants after multiple EMS and X-ray treatments. Ibid. 131-144.

(f) An explanation of any significant departure from the level of activity foreseen by the contract.

There was no significant departure.

Table 1. Protein and amylose content in the grains of the mother variety and its mutants (Boro and Aus) and some recommended varieties and hybrid lines of Aman rice).

Entries	(% protein) DBC (Udy)	K.E. (N x 5.95)	Amylose %
Mother variety and mutants (Boro & Aus)			
IR-8	8.11	7.87	29
IRATOM-24	8.99	7.98	27
IRATOM-38	10.72	9.48	28
Recommended (Aman) varieties.			
TN16	10.65	11.28	23
Badshabhog	13.15	9.53	16
Nizersail	11.15	9.11	15
Chitraj	11.00	11.41	19
Latisail	10.15	8.87	25
DA-31	12.25	11.70	15
Hybrid lines (Aman)			
INA7-1	11.25	9.91	15
INA7-3	12.18	11.70	19
INA7-7	11.40	11.57	16
INA7-10	11.20	9.80	23
INA7-13-1	11.50	11.45	-
INA7-13-2	12.20	11.63	16
INA7-13-3	11.20	9.25	22
INA7-13-4	11.50	10.15	22
INA7-13-7	11.70	10.54	-
INA7-17-2	11.40	10.25	24
INA7-19-1	11.80	10.41	15
INA7-19-2	9.80	9.62	29
INA8-2	10.75	10.45	23
INA9-14	11.28	11.70	15
INA9-17	11.50	9.40	17
INA10-1	11.10	10.95	23

Table 2. Percentage of protein in the grain of local strains.

Name of strains	Cropping season	Protein % KP (Nx5.95)
Kachalath	Aus	7.72
Murali	"	8.55
Dumai	"	7.66
Chalakia	"	9.59
Arkati	"	10.25
Matirchak	"	9.71
Begunbichi	"	12.95
Goria	"	8.61
Dongra	"	9.55
Dagla	"	8.71
Kalachengri	"	8.70
Baurosh	"	9.00
Aina Dumai	"	9.10
Indrasail	Aman	8.40
Kalizira	"	9.82
Balam	"	8.14
Chalanga	"	10.47
Gabura	"	8.71
Laxmitia	"	9.49
Khoyamotor	"	8.61
Billakoda	"	10.22
Haichcha	"	9.98
Dhalikhana	"	9.76
Katisail	"	8.37
Halsira	"	7.24
Joshora	"	6.55
Panisail	"	7.98
Jigasail	"	7.95
Tepa	"	6.75
Bangaldhari	"	7.44
Bhogbalam	"	7.90
Soiya	"	9.00
Lalbalam	"	8.20
Hashbadal	"	7.20

Table 3. Variability for various quality characters in sixty rice cultivars

Statistical parameter		L/B ratio	Hulling recovery (%)	TKW (g)	Amylose content (%)	Spreading index	Protein (Kjeldahl) (%)	DBC value (9)	Protein index (5)	Section score
Range	low	1.75	76	8.54	5.50	2.00	5.12	6.75	93	11.11
	high	4.07	86	26.34	32.81	7.00	12.79	12.32	111	63.63
Mean		2.47	80	17.10	26.17	3.32	8.46	8.47	100.26	30.15
S.D.		0.43	2	3.83	4.02	0.97	1.33	1.18	4.77	12.00
C.V.(%)		17	3	22	15	29	16	14	5	40

Table 4. Correlation between different nutritional and cooking characters of rice (data based on 60 varieties)

L/B ratio	Hulling recovery (%)	TKW	Amylose (%)	Spreading index	Protein (Kjeldahl) (%)	DBC (9)	Protein index (5)	Section score
L/B ratio	-0.09	0.02	-0.14	0.11	-0.24	-0.22	0.07	-
Hulling recovery		-0.22	-0.18	0.23	0.11	0.16	0.06	-
TKW			0.07	-0.07	0.08	0.05	-0.15	0.14
Amylose(%)				-0.87**	-0.50**	-0.52**	0.13	-0.46**
Spreading index					0.49**	0.45**	-0.30*	-
Protein % (Kjeldahl)						0.96**	-0.50**	0.97**
DBC value							-0.24	0.96**

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

Table 5. Amino acid content of four local rice varieties of Bangladesh.

Amino acid (g/16 g N)	Varieties			
	Hbj.B-VI (White core)	Tepi boro (White core)	Boiragi (White core)	Binni (Waxy)
Aspartic acid	8.89	8.87	8.89	8.19
Threonine	3.03	3.18	3.25	3.11
Serine	4.17	4.10	4.27	4.02
Glutamic acid	17.43	16.64	17.40	17.57
Proline	4.76	4.95	4.98	5.10
Glycine	4.27	4.54	4.41	4.22
Alanine	5.63	5.67	5.72	5.65
Valine	6.09	6.11	6.18	5.82
Isoleucine	4.08	4.01	4.11	4.04
Leucine	8.44	7.85	8.16	8.12
Tyrosine	5.36	4.74	5.01	4.73
Phenylalanine	5.03	4.75	4.91	4.82
Lysine	3.34	3.94	3.51	3.34
Histidine	2.10	2.31	2.25	2.10
Ammonia	2.31	2.08	2.21	2.36
Arginine	8.08	8.23	8.14	7.64
Methionine	1.80	2.31	2.35	2.85
Cystine	1.50	1.88	1.95	2.37
Tryptophan	1.27	1.15	1.35	1.23
Protein content (%) at 10% moisture level	12.69	8.61	11.09	9.54

Table 6. Seed yield and protein percentage in 10 elite lentil mutants in three subsequent generations.

Variety and mutant No.	M_3 (1973-74) Plant yield (g)	(M_4 (1974-75) Plant yield (g)	Protein (%)	(M_5 (1975-76) Plot yield (27 m^2) (g)	Protein (%)
Control (Mukdia-15)	6.8	2.0	23.8	877	25.9
273	7.3	2.2	21.5	743	25.2
274	7.4	1.8	22.5	1183	26.3
430	6.4	1.9	23.2	1067	25.5
464	7.1	2.1	23.0	810	25.8
482	7.9	2.0	20.8	1260	25.6
522	7.4	1.5	23.4	1037	25.7
524	6.0	2.4	24.0	1063	25.2
559	6.8	1.9	23.2	950	25.4
586	6.1	2.2	24.0	863	25.1
687	9.2	1.3	23.1	720	25.0
Mean of mutants	7.2	2.0	22.9	969	25.6
S.E.	0.9	0.3	1.0	183	0.4

Table 7. Seed yield and protein percentage in 10 elite chickpea mutants in three subsequent generations.

Variety mutant No.	M_3 (1973-74) Plant yield (g)	M_4 (1974-75) Plant yield (g)	M_4 (1974-75) Protein (%)	M_5 (1975-76) Plot yield (36 m^2) (g)	M_5 (1975-76) Protein (%)
Control (Faridpur)	21.9	1.9	16.9	2013	16.8
29	25.8	3.4	19.3	2457	19.0
35	26.3	2.4	19.5	1983	19.3
55	24.0	1.7	19.0	3007	19.0
102	32.6	1.7	18.6	4497	18.1
124	24.9	1.9	18.6	1970	18.4
215	23.9	1.5	17.8	1113	18.3
223	19.4	1.9	18.9	2147	18.6
584	26.0	2.1	18.1	2867	18.6
669	30.8	1.5	24.1	2650	23.9
716	23.6	2.9	18.5	2460	18.0
Mean of mutants	27.3	2.1	19.2	2515	19.1
S.D.	3.0	0.6	1.8	332	1.7

Table 8. Ranges, means, standard deviations and coefficients of variability of different agronomic characteristics in some strains of legumes.

Legumes No. strains studied	Statistical parameters	Plant height (cm)	No. primary branches	No. secondary branches	No. pods per plant	Seeding to maturity (d)	500-grain wt. (g)	Plant yeild (g)
Chickpea (Cicor arietinum)	Range	30.8-38.6	3.5-6.5	15.6-30.5	58.9-97.2	132-139	34.3-41.9	5.83-11.33
	Mean	33.6	5.2	23.1	74.6	135.3	38.6	8.26
(1 local + 10 mutants)	S.D.	2.8	0.8	4.9	14.7	2.7	2.4	1.66
	C.V.(%)	8	15	21	20	2	6	20
Lentil (Lens culinaris)	Range	26.7-32.5	3.1-4.9	8.0-20.4	64.7-157.6	106-113	8.9-11.3	1.78-4.01
	Mean	29.2	3.9	13.7	115.2	109.5	9.8	3.00
(1 local + 10 mutants)	S.D.	1.7	0.5	3.3	27.8	2.2	0.7	0.61
	C.V. (%)	6	13	24	24	2	7	20

Table 9. Range, mean, standard deviation and coefficient of variability of protein content in legumes.

Legumes	No. strains studied	Range in protein content (%)	Mean (%)	S.D. (%)	C.V. (rounded off) (%)
Chickpea (*Cicer arietinum*)	30 mutants + 1 control	15.1-24.1	17.47	1.72	10
Lentil (*Lens culinaris*)	25 mutants + 1 control	24.9-27.2	16.00	0.67	3

Table 10. Phenotypic correlation coefficients among different characters of chickpeas

Character	No. primary branches	No. secondary branches	Green weight	No. of pods	No. of seeds	500-seed weight	Yield
Plant height	0.66*	0.61*	0.82**	0.15	0.12	0.89**	0.39
No. primary branches per plant		0.73*	0.60	0.43	0.41	0.62**	0.63*
No. secondary branches per plant			0.63*	0.67*	0.65*	0.34	0.82**
Green weight per plant				0.33	0.27	0.64*	0.44
No. pods per plant					0.98**	-0.21	0.94**
No. seeds per plant						-0.22	0.94**
500-seed weight							0.05

* Significant at 5% level of probability; ** significant at 1% level of probability.

Table 11. Phenotypic correlation coefficients among different characters of lentils

Character	Primary branches per plant	Secondary branches per plant	No. of pods per plant	No. of grains per plant	500-grain weight	Yield	Protein content
Plant height	0.48	0.75**	0.65*	0.57	-0.14	0.69*	0.31
Primary branches per plant		0.70*	0.74**	0.77**	0.12	0.83**	0.33
Secondary branches per plant			0.93**	0.86**	-0.35	0.82**	0.13
Number of pods per plant				0.94**	-0.42	0.86**	0.29
Number of grains per plant					-0.29	0.93**	0.34
500-grain weight						-0.02	0.04
Yield							0.37

* Significant at 5% level of probability; ** significant at 1% level of probability.

Table 12. The yield and quality performance of four mutants (M_7) of chickpea (*Cicer arietinum*) grown at two locations, namely Ishurdi (I) and Jamalpur (J) during 1977-78.

Strain	Station	Yield/plot (kg)	1000 seed weight(gm)	Protein %	BDC value
M-669	I	6.10	72.0	23.4	.304
	J	7.87	81.0	18.8	.320
M-102	I	4.65	73.5	23.0	.390
	J	5.43	93.0	17.7	.308
M-29	I	2.72	90.5	23.0	.386
	J	5.80	90.5	16.5	.280
M-55	I	2.87	82.5	21.4	.370
	J	3.54	100.0	16.3	.282
Faridpur-1 (control)	I	3.63	80.0	18.2	.310
	J	5.12	93.5	19.0	.335
Mean	I	3.99	79.7	21.80	.368
	J	5.43	93.7	17.66	.305

Table 13. Mean** seed yield (kg/ha of chickpea grown at four locations of Bangladesh 1978-79.

Strain/variety	Jessore	Ishurdi	Jamalpur	Comilla	Mean
V_1. Faridpur-1	1648.6	1914.5	2502.7	440.5	1626.6
V_2. Sabur-4	1112.8	1864.8	2457.2	648.4	1520.8
V_3. L-29	1213.7	1931.5	2696.0	879.3	1680.1
V_4. L-55	977.7	1851.0	2426.8	941.9	1549.4
V_5. L-102	1277.7	1936.7	2007.2	717.1	1484.7
V_6. L-669	1790.1	2088.3	2992.4	663.2	1883.5

Duncan's multiple range test :

Jessore :	$\underline{V_6}$	$\underline{V_1}$	$\underline{V_5}$	$\underline{V_3}$	$\underline{V_2}$	V_4
Ishurdi :	$\underline{V_6}$	$\underline{V_5}$	$\underline{V_3}$	$\underline{V_1}$	$\underline{V_2}$	V_4
Jamalpur :	$\underline{V_6}$	$\underline{V_3}$	$\underline{V_1}$	$\underline{V_2}$	$\underline{V_4}$	V_5
Comilla :	$\underline{V_4}$	$\underline{V_3}$	$\underline{V_5}$	$\underline{V_6}$	$\underline{V_2}$	V_1

* Treatments underlined do not differ significantly at 5% level.

** Mean of both line and broadcast sowing.

Table 14. The yield and quality performance of four mutants (M_7) of lentil (*Lens culinaris*) grown at two locations, namely Isturdi (I) and Jamalpur (J) during 1977-78.

Strain	Station	Yield/plot (kg.)	1000 seed weight(gm)	Protein %	DDC value
M-522	I	7.45	14.5	24.0	.395
	J	7.06	19.0	23.3	.402
M-274	I	7.25	12.5	23.6	.380
	J	6.61	13.6	22.4	.391
L-5	I	6.79	13.5	24.7	.398
	J	7.63	18.0	24.3	.400
M-559	I	6.72	12.5	23.6	.397
	J	4.89	18.3	23.4	.390
M-524	I	6.57	13.0	23.4	.392
	J	5.50	18.5	23.9	.400
L-5501	I	5.74	14.0	25.1	.402
	J	5.64	17.5	24.4	.405
Mahdia-15 (control)	I	6.57	12.0	23.9	.402
	J	7.55	18.0	23.6	.395
Mean	I	6.72	13.1	24.47	.395
	J	6.41	18.2	23.61	.397