3. GENETIC IMPROVEMENT AND PRODUCTION PROSPECTS OF FOOD LEGUMES

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Place of Food Legumes in Indian Agriculture

Food legumes or pulses as many of them are commonly known occupy a unique position in Indian agriculture by virtue of the fact that they provide the only high protein component of the average diet. No other country in the world has so much area under these crops as India. It has been increasingly recognized in recent years that pulses offer perhaps the only and the most practical means of solving the protein malnutrition problem in India at the present stage, as it may take many years to bring about a major advance in the production of foods of animal origin. Pulses contain 20 to 30 per cent protein on a dry basis, which is nearly 3 times the value found in the cereals. The per acre production of protein is higher from pulses compared to the cereals and the quality can be greatly increased if the present varieties are replaced by high yielding types. Recent work at the Indian Agricultural Research Institute and other centres in the country has shown that with the development of high yielding and short duration varieties of pulses, it should be possible to grow cereals and pulses as complementary rather than competing crops.

Area and Production

Pulses occupy nearly 18% of the total area under food grains in India but their contribution to the total production of these grains is less than 12% (Table 1). It is, thus, clear that compared to the cereals, pulses give considerably lower yields. This difference has widened in recent years. While the production of cereals more particularly wheat has seen a significant rise during the last five years, the production of pulses has continued to fluctuate between 9 and 13 million tonnes over the past 20 years largely as a function of variation in seasonal conditions. During the last 4 years, the lower trend in production appears to have been maintained and this is almost entirely due to the fact that farmers have found it more profitable to grow wheat than crops like chickpea.

Table 1. Area and production of pulses in India

(1969-70)

Total area under food grains (million hectares)	Total area under pulses (million hectares)	Area under pulses as % of the total area food grains	Total production of food grains (million tonnes)	Total production of pulses (million tonnes)	Production of pulses as % of total food grain production
123.57	22,023	17.82	99.501	11.691	11.75

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Factors responsible for low yields of pulses

The average yields of pulses on a national basis compared to the cereals have been very low and this difference continues to widen. An important factors responsible for the low production of pulses in India stems from the fact that many of the available varieties of these crops take a long time to mature with the result that their growing season overlaps with that of the cereals. The per day productivity of these varieties is consequently low and the farmer has to choose between the two groups of crops. Another factor responsible for the poor yields is to be found in the fact that these crops have generally been grown in lands of marginal productivity without any investment in such inputs as fertilizers and pesticides. One result of this low level of management has been that those genotypes which have the capacity to do well under adverse conditions and cannot take advantage of more favourable factors of crop growth have been selected. This fact emphasises the need to build up extensive genetic stocks of pulses from different parts of the world so that breeding work making use of wider gene pools can be organized.

Important pulse crops and their improved varieties

i) Important pulses crops: Although a large number of pulse crops are grown in India, the most important of these are chickpea and pigeon pea, which taken together account for nearly half of the total acreage under these crops and for 60 per cent of the total production. The other important pulses are those of the *phaseolus* group (green gram, black gram and *moth*), lentil, peas, *Khesari dal* and cowpea. Some of the less important pulses include species of *Dolichos* and the more recently introduced soybean. Table 2 summarizes the more commonly cultivated pulses in terms of their area and production.

Table 2. The major pulse crops of India and their relative areas and production

Botanical name	English name	Common Indian name	Percentage of total	
			Area	Production
Cicer arietinum	Chickpea or Bengal gram	*Chana*	41. 0	51. 0
Cajanus cajan	Pigeon pea	*Arhar* or *tur*	9. 8	11. 2
Phaseolus mungo	Black gram	*Urd, mash* or *Kalai*	6. 5	3. 9
Phaseolus aureus	Green gram	*Mung*	5. 4	2. 5
Lens esculentus	Lentil	*Masur*	3. 3	2. 9
Phaseolus aconitifolius	——	*Moth*	6. 2	2. 6
Dolichos biflorus	Horsegram	*Kulthi*	6. 3	3. 0
Pisum sativum	Peas	*Matar*	5. 4	9. 8
Lathyrus sativus	Chikling vetch	*Khesari dal*	7. 9	7. 6
Other pulses	——	——	8. 2	5. 5
Total			100. 0	100. 0

ii) Genetic improvement of pulses: The work on the genetic improvement of pulses in India can be considered in two distinct phases. The first phase starting in the early part of the century ended about 10 years ago and has been described in a recent publication[2)] of the ICAR. A major characteristic of this phase has been that improvement was sought largely through simple selection procedures from local collections of land races available within the boundaries of the states, where experimental stations were located. This work has been most valuable as it has resulted in the availability of varieties which are at present commonly cultivated, and has provided a base from which more significant advances in yield can be obtained through intensive plant breeding programmes. The greatest limitation in the progress of this work has been the availability of restricted genetic variability with the result that it was not possible to exploit more favourable kinds of gene actions. Also, the selections were made under a low level of management corresponding to the conditions in the farmers' fields with the result that the varieties developed in the course of this work are not particularly suited to respond

Table 3. Some of the commonly cultivated older varieties of pulses

Varieties	Yield in quintals/hectare	Maturity in days
Chickpea		
G. 24	18. 00	120
T-1	21. 00	115
NP 58	18. 00	120
G-62-404	16. 00	110
BS-10	18. 55	125
Chaffa	15. 60	108
Pigeon pea		
NP (WR) 15	14. 50	280
C-II	10. 00	200
NO. 148	12. 50	188
T-17	14. 50	270
CO-1	8. 00	180
Green gram		
T. 1	8. 00	68
T. 44	5. 50	65
Jalgoan 781	5. 40	75
NO. 505	4. 70	85
B-I	6. 25	70
Black gram		
Mash 1-1	8. 00	90
Mash 48	10. 00	94
T-27	10. 40	130
T-9	9. 30	80
Cowpea		
Pusa Phalguni	12. 00	80
K-II	12. 00	85
JC-10	10. 00	85
T-2	15. 00	98
CO-1	10. 00	110
Lentil		
L 9-12	18. 25	110
T. 36	17. 43	96

to application of fertilizer, irrigation and other outputs. The more important varieties of the different pulse crops developed in the course of this work in various parts of the country are summarized in Table 3.

The second phase in the improvement of pulses started with the setting up of an all-India Coordinated Research Project on these crops with the participation of a large number of research centres in different parts of the country. This work has already made significant progress and a number of high yielding varieties have become available so that pulses can be increasingly brought under an intensive and commercial kind of cultivation. Some of the important advances are described below:

New concepts in the improvement of pulses: The pulse breeding work in India during the last 5 years has been greatly influenced by the concept of improved plant type, which has proved so very useful in the improvement of wheat and rice. Wheat and rice have been the two most intensively investigated crop plants but inspite of a long history of research, it was found necessary in recent years to give them a new form to the improve their productivity. Based on this finding, our group[3),4)] at the I.A.R.I. has made a re-examination of the plant type in several other groups of crops including the pulses. This examination has shown that a change in the plant type can be even more rewarding in the pulse crops, which have received much less attention from the plant breeders compared to wheat and rice.

A major reconstruction of the plant type in pulses has required a reduction in their spreading and bushy growth habit so that more plants can be raised per unit of land. Associated with this has been an improvement in their harvest index (weight of grains i.e. the economic yield/total plant weight i.e. the biological yield).

A high harvest index, which obviously is of so very great value in crop plants offers no particular advantage when these plants grow in a wild state. The process of domestication and subsequent selection of crop plants during the past thousands of years has brought about some improvement in their harvest index, but the transformation in this direction is by no means complete. It can be expected that some of the major advances in crop improvement in future will come through a genetic reconstruction of plants in the direction of a high harvest index.

The reconstruction of plant type in terms of improved harvest index is often difficult to achieve without changing their physiological structure, more particularly their photosensitivity. Thus, a major breeding objective in recent years in crops like pulses has been to cut down their excessive vegetative growth, improve the harvest index and reduce their maturity duration. This latter attribute is most important, as it helps to increase the per day productivity of the pulse crops and makes it possible to fit them in more intensive cropping patterns.

The new varieties: Based on the concepts outlined above, efforts have been made for a genetic improvement of several of the pulse crops in order to increase their yields and extend their cultivation both in time and space by fitting them in new cropping patterns. These studies[5-10)] have been particularly successful in the case of pigeon pea, green gram, black gram, cowpea, lentil and peas. Thus, a number of new varieties of pigeon pea developed during the past 5 years have been released and their seed is being multiplied on large scale by the National Seeds Corporation. Some of these varieties allow a population of 72,000 plants per hectare as against 35,000 allowed by the older types. The maturity duration of these varieties has been reduced to 5–6 months, which is nearly half that of the older varieties. The reduced duration should make it possible to cultivate pigeon pea in rotation with wheat in the north-western wheat belt, where this has not been possible because of the overlapping maturity of the two crops. The per day productivity of some of the new pigeon pea strains amounts to nearly 27 kg per hectare which compares favourably with 17 kg per hectare of the older varieties. Under conditions of suitable management, these varieties have given an yield of 25 quintals per hectar. Three of these varieties named Pusa Ageti, Sharda and Mukta were released during 1971. Pusa Ageti is the earliest in maturity taking about 160 days from sowing to harvest. The variety is particularly suitable for growing with high plant populations. The new variety Sharda is semi-spreading in its growth habit taking about 170 days to mature. The variety is particularly suitable for non-irrigated conditions and also for mixed cropping. It has a protein content of 22 per cent. The third variety Mukta takes about 180 days to mature and has shown wide adaptability. This variety is relatively resistant to the wilt disease, which is a serious problem particularly in the north-eastern and central parts of the country.

Short duration varieties marked by a high harvest index have also been developed in the case of green gram and cowpea. A particularly significant contribution has been made by one of the new green gram varieties named Pusa Baisakhi, which is now widely cultivated in many parts of the country. Ready for harvest within a period of 70 days ,Pusa Baisakhi can be grown as an additional crop during the summer months in between the main *rabi* and *kharif* seasons. With an yield potential of nearly 10 quintals per hectare, this variety makes a significant contribution to the farmer's income.

Another pulse crop which is particularly important in the states of Bihar, Madhya Pradesh and Uttar Pradesh is the *Khesari dal;* it is known for its adaptability to adverse soil and climatic conditions. This pulse, however, is known to contain a neurotoxic material and excessive consumption of its grains causes a disease known as *Lathyrism.* Following intensive work during the past 5 years, it has been possible to evolve varieties of *Khesari dal,* which are relatively free from the toxic material and, therefore, are safe to consume. A number of these varieties are being tested at present in the all-India coordinated trials and are expected to be released shortly.

Chickpea is the most important pulse crop of India and it is generally cultivated in non-irrigated areas or less commonly as a second crop under irrigation. As a mixed crop, chickpea is grown as an insurance against the failure of rains. A number of early maturing varieties with good yield potential have been identified and are being tested in countrywide trials at present. Some of the most important problems in the improvement of chickpea relate to breeding for resistance to the wilt and blight diseases; in the absence of extensive genetic stocks from different parts of the world, it may take several years before resistant varieties become available.

Table 4. Variability for protein content in different pulses crops (1969-70)

Pulse crop	Variety×location	Protein (%)	
		Range	Mean
Chickpea	16×12	12.4 — 28.1	19.5
Lentil	10×10	20.4 — 30.5	14.8
Arhar	11× 5	18.5 — 26.3	21.5
Green gram	10× 6	20.8 — 33.1	25.3
Black gram	15× 9	21.2 — 31.1	25.1
Peas	12× 9	17.2 — 31.1	24.9
Cowpea	7× 4	21.2 — 30.6	24.6

Nutritional improvement: Pulses are known to be characterized by a high protein content and in view of this fact improvement for yield has received major attention. However, attempts have also been made to increase their protein content and also the content of such essential amino acids as methionine and cystine, which tend to be low and limit the biological value of protein in these crops. As a first step, screening of genetic stocks has been undertaken by Kaul and his associates[11] for protein content and quality. The extensive analysis has clearly shown that considerable variability exists wihch could be used for the upgrading of pulses with regard to their nutritional value. Thus, the frequency distribution of the samples of chickpea analyzed indicated a range from 1.00 to 3.5 mgs methionine/g sample. Considerable variation was also found in the protein content of varieties in the different crops as can be seen from the data

Table 5. Some of the newly evolved or tested* varieties of pulses

Varieties	Yield in quintals/hectare	Maturity in days
Chickpea		
C 35	31. 5	125
Early S3	29. 3	115
BGS-1	25. 9	120
Pigeon pea		
S 103	15. 00	275
Pusa Ageti	27. 00	150
Sharda	25. 00	160
Mukta	25. 00	170
T-21	20. 00	154
Green gram		
Pusa Baisakhi	10. 00	65
Jawahar-45	10. 00	80
S-8	12. 00	60
PS-7	12. 00	60
G. 65	10. 00	65
Black gram		
Pusa-1	15. 00	84
H-10	12. 50	95
G-1	15. 00	94
Cowpea		
C-152	25. 00	88
C-20	18. 00	85
Lentil		
Pusa-1-1	20. 00	80
Pusu-6	22. 00	90

* These varieties have been evolved at a number of research centres including the Agricultural Universities. The yields are based on the results of the coordinated trials and agronomic studies at IARI.

presented in Table 4. This variability and other induced in the course of some mutation studies left little doubt that pulses can be an even better source of protein than they are at present.

The second phase of plant breeding work on pulses has resulted in the availability of a number of improved varieties, which combine such desirable characters such as early maturity, high harvest index and a good yield potential. The more important of these varieties are listed in Table 5.

Fuller exploitation of genetic potential

Pulses more than any other crops have formed part of an extensive agriculture in India for hundreds of years and while this fact explains the present low levels of productivity, it also holds the key to substantial increases in production in the future. Recent research at the IARI and other centres in the country has shown conclusively that with a small investment in improved management, production can be greately increased from the present levels of 12 million tonnels. Some of the important factors which should contribute to increased production are discussed below:

i) Cultural practices and chemical fertilizer: The pulse crops have been generally grown in India without application of any chemical fertilizer. In recent years, extensive agronomic studies by Chowdhury and his colleagues[12),13)] have shown that many of the pluse crops show very significant response to the application of phosphatic fertilizers. Improvement in production can also be achived by new planting patterns including adjustment of spacing and sowing dates. An impressive demonstration of increase in production following the application of phosphatic fertilizers is provided by the studies of these authors on the fertilization of the pigeon pea crop. Based on their studies, they concluded that contrary to the popular belief, the pigeon pea crop is highly responsive to applicatin of fertilizer and manure. The average grain yield of 12.9 quintals per hectare increased to 27.6 quintals per hectare when the crop received 100 kg per hectare of P_2O_5. They concluded that the use of fertilizer at all levels was highly profitable. The net profit per hectar increased from Rs. 964 to Rs. 2341 when the crop received adequate doses of phosphatic fertilizer. The net increase in profit, thus, amounted to 143 per cent, while the increase in cost amounted to 53 per cent. For each rupee invested in fertilizer, a return of Rs. 4.75 was obtained at the high level of fertilizer application.

While pigeon pea was found to be particularly responsive to fertilizer application, significant increase in yield was also recorded in the case of chickpea, peas and lentil. The response in the case of these three crops, however, was observed only on soils of low fertility, with less than 20 kg per hectare of P_2O_5 available. It was also observed that a starter dose of nitrogen (20 to 25 kg per hectare) was invariably beneficial to these crops. They also observed significant response in terms of increased yield to fertilizer application in the case of green gram.

While chemical fertilizers have been found to be most effective in increasing the yield of pulse crops, significant gains in production have also been observed following the Rhizobial inoculatin by Rewari and his colleagues[14)]. The development of different Rhizobial strains and their distribution to the farmers offer one of the more practical means of increasing pulse production.

ii) Control of pests and diseases: Considerable progress has been made in India during the last 5 years in the development of short duration and high yielding varieties of pulses. The new varieties, however, cannot make a significant contribution to production, unless their cultivation is combined with suitable plant protection measures. Few groups of crops suffer greater damage through insect pests and diseases than the pulses. The development of resistant varieties is already receiving serious attention in these crops.

It would, however, be unrealistic to believe that the evolution of resistant varieties alone should be attempted to reduce the losses from insect pests and diseases. Plant protection measures must become an integral part of crop management practices in pulse crops if a major advance in production is to be achieved within a short period. The kind of impact on production which the use of pesticides can make in these crops and the economic implications of such control measures have been studied by Saxena and his associates[15),16)]. The yield of green gram increased by more than 100 per cent following treatment with pesticides. Highly significant increases in yield were also recorded in the case of chickpea, pigeon pea and the peas crops.

iii) Strategy for a short term production advance

Production programmes on pulses have to be planned both on short and long term basis. It has been estimated that the country will have to produce nearly 30 million tonnes of pulses by the end of the present decade in order to bring about a significant improvement in the present levels of nutrition. A long term production strategy in pulses will require intensive research work in various fields. More immediately, considerable scope exists for doubling the production of pulses in India within a relatively short period. The major components of this production strategy which is now being adopted are as follows.

Improved practices: Based on the research work during the last ten years, it has been possible to develop a package of practices involving the use of fertilizer, pesticide and certified seed of improved varieties. This package approach is being introduced in selected areas of pulse production in the country. The basis for this approach is essentially the same as that for the highly successful production programmes undertakes during the last five years in the case of cereals.

Multiple cropping: Pulses as explained earlier have fitted so far into an extensive agriculture. With the availability of short duration varieties, they are now being brought under intensive cultivation in several parts of the country where conditions for crop growth are favourable. This is being done by fitting pulses in multiple cropping patterns so that farmers with assured irrigation and other faciilties can take 3–4 crops from their land over a one year period. The Government has already adopted multiple cropping as one of its basic aproaches for increasing agricultural production in areas of assured irrigation. Pulses are finding an increasing place in such multiple cropping programmes particularly with the availability of short duration varieties as shown by the work of Bains[17)].

New cropping patterns: The short duration varieties of pulse crops have offered other possibilities of increasing production. With continued rise in the production of wheat during the past 5 years and with a major advance expected in the production of rice within the next 5 years, some of the coarse cereals like maize and millets have last their relative importance. In fact, many of the farmers are no longer attracted by these crops in view of continued fall in their prices with the result that a high yielding varieties programme in these cereals may be difficult to sustain. They will have to find increasing use as animal feed. The short duration varieties of pulses can profitably replace some of these cereals. This new development in Indian agriculture should be welcomed, for the additional production of pulses achieved in this way will contribute to improved nutritional standards on the one hand and better maintenance of soil fertility on the other.

The proposed diversion of land from coarse cereal pulses emphasizes the need for crop pwlanning in India, which should be regarded as a logical consequence of the success of the high yielding varieties programme in wheat and rice. The cereal crops have accounted for more than 60% of the total cropped area in the country. This is a disproportionately large acreage and the availability of the high yielding varieties of the more important cereals should be exploited to reduce it considerably. Pulses should find a particularly important place in these new cropping schemes.

In conclusion, it may be stated that the concept of new plant type and some of the other concepts, which have influenced plant breeding in recent years offer very great scope for the genetic upgrading of the pulse crops. The success of the future improvement programmes on pulses will depend on the application of these concepts and on extensive collections of germ plasms on a world-wide basis. It cannot be emphasized too strongly that the non-availability of pulse varieties comparable to the high yielding varieties of wheat and other cereals is almost entirely due to the fact that it has not been possible so far to make use of more than a fraction of the total genetic variability available in these crops. Also, it will be necessary to give to the pulses a better level of management than they have received so far. A significant increase in production on a short term basis can be achieved through improved agronomic practices involving the use of chemical fertilizer and pesticides and cultivation in multiple cropping patterns, where they would complement the cereals rather than compete with them.

Discussion

Sadikin, S., Indonesia: How far is the harvest index influenced by environmental condition?

Answer: It is affected more by cultural practices than by natural environment. While an improved harvest index can be manipulated genetically, an optimum level of agronomic management in terms of fertilizer, irrigation, spacing etc. is needed to maintain it.

T. Yamamoto, Japan: Is there any possibility to introduce soybean plant in future?

Answer: The plant has been there for many years. During the past ten years, research work has been intensified to establish it as a major crop. As part of this programme, the Government has offffered a support price to farmers. The problem of acceptability, however, remains. Soybean cannot compete with peanut as an oil crop, as its oil content is nearly one-third. It can be a success when both oil and protein are used as human food. We are, however, determined to make a success of it in view of its very high nutritional value.

C. P. Cheng, Republic of China: How do your people eat the pulses (mung bean)?

Answer: The mung bean is split through grinding and this product is cooked with the addition of fat, spices and, of course, water. Thus, it is eaten in a curried form. At times, it is also cooked with rice.

N. Yamada, Japan: In breeding good-plant type of chick pea, what criteria do you use in the selection of good-plant type?

Answer: We select for a relatively short and compact plant type so that a response to increased plant populations can be achieved. The general idea is to cut down the excessive vegetative growth which contributes little to yield. In fact such growth is a drain on the moisture and nutrient supply.

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