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Pigeon pea improvement - Strategy and approach

March 23, 1974

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Pigeon pea improvement - Strategy and approach

(D. Sharma)

Pigeon pea (Cajanus cajan L. Mill sp.) is one of the most important pulse crop of India, and recently it is drawing considerable attention as a promising crop under rainfed conditions in other countries of the semi-arid tropics. At present about 91 percent of the world acreage and 94 percent of the world production of pigeon peas comes from India. Other important countries where pigeon pea is grown to some extent are Uganda, Tanzania, Burma, Dominic Republic, Puerto-Rico, Brazil, British Gueana, Angola, China, Vietnam, Cambodia, Laos and West Indies. According to Rachie (1972) any production record for Africa is from Uganda and Malawi, but pigeon peas are grown extensively throughout the semi-arid to sub-humid tropics as a perennial garden crop or mixed with other species. He pointed out that because it is grown infrequently in pure stands on a field scale and the produce is almost entirely consumed locally, the available statistics on this crop are grossly under estimated at the international level.

In India the crop is grown in 2.7 million hectares and the production is about 1.84 million tonnes. On the basis of acreage, Maharashtra ranks first followed by Uttar Pradesh, Madhya Pradesh, Mysore and Bihar. However, Uttar Pradesh has the highest production followed by M.P. and Maharashtra.

The ecogeographical distribution (Fig. 1) indicates that pigeon pea is essentially a crop of semi-arid tropics. It has been found growing in wild state in Upper Nile in Egypt, Coastal districts of Angola and China, Vietnam, Laos, Cambodia and on the mountains of Mageland in Central Jawa and in Africa from Zanzibar to the coast of Guinea [de-Candolle (1904)]. Therefore it is difficult to point out a particular region as a centre of origin

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for the crop. According to Watt Africa is considered as the centre of origin but recently (De & Reddy 1972 & De, in press) De and Reddy have pointed out that if Atylosia spp. is the progeniter of Cajanus, then based on the distribution of the Atylosia spp. In India (Fig. 2) and the mention of the crop in the ancient Indian scriptures, western ghat in India is probably the centre of origin for the crop. The wide variability for maturity period, plant height, plant form and structure, seed size and seed colour available in the Indian material (slides), also indicates that probably the crop originated in India. However, this point can only be clarified by a careful study of the variation in the germ plasm from the various parts of the world.

In past there has been little effort to mobilize the available variability in the diverse types to develop high yielding superior types. The varieties under cultivation are generally the types which are adapted either to a certain agroclimatic situation or the crop use, for example short duration small seeded types in areas with low rainfall, frosty weather during winter months and shallow poor water retentive soils, while late maturing types are confined to moderate to high rainfall areas with heavey and water retentive soils. Very bold seeded late maturing perennial types are planted in areas where green beans are used. In past, the plant breeding work done in India was based on hybridisation between the types generally suited to a particular situation and therefore involved narrow genetic base. Only in late sixties a comprehensive collection of pigeon peas was made under RPIP Programme in India and some effort has been made to evaluate and utilize the wide base germ plasm by different institutes in the country. Recently besides extensive work being planned at ICRISAT some efforts are being made to take up breeding work in pigeon peas in West Indies, Puerto-Rico and Uganda.

The appraoch of improving a particular crop depends mainly on the agroclimatic conditions, farming systems, disease and pest situation, consumption pattern and quality requirements. In case of pigeon peas agroclimatic condition and farming systems are particularly important in determining the broad characteristics of varietal requirements.

Therefore the various situations under which the crop is grown in India are given as under:

1. Rainfall ranging from 25" to 60". The crop is highly susceptible to waterlogging therefore under high rainfall conditions it is grown on well drained soils or on field bunds.
2. Frost free areas are highly suitable, however, frost escaping early types can be successfully grown in such areas.
3. The crop can be grown on a wide range of soil types viz. on light red soils to heavy clay soils and can thrive well on alkaline and saline soils (pH 8). It does not do well under highly acidic soils (below pH 6).
4. Generally on deep water retentive soils it is grown as a mixed crop with a wide range of crops viz. Sorghum, Pearl Millet, Cotton, groundnut, paddy, minor millets like kodo and pulses like urad and soybeans.

In shallow poor water retentive soils and low rainfall areas early maturing varieties are preferred, while on deep water retentive soils late maturing tall types are grown. Under mixed cropping with sorghum and pearl millet, late, tall compact are suitable but with cotton, groundnut and minor millets and pulses, medium maturing, semi spreading to spreading types with high secondary branching are grown.

At present little acreage is grown under sole crop of pigeon peas, therefore it would be desirable to breed varieties which may suit the specific situations. The information on efficient plant type for various conditions is completely lacking. Also attempt should be made to develop types which would give high yields comparable to cereals under planting with proper management in rainfed conditions.

Pigeon peas are consumed as dhal made of dry beans in India and Africa and also as green beans in Carribean region and South America. Though bold seeded types are preferred in general but it is particularly important in case where green beans are consumed. There is apparent negative correlation between yield and bold seed size as bold seeded types are shy-bearers. However, a reasonable compromise can be hit by which the seed size of the early maturing types can be considerably increased. With simultaneous increase in the total yielding ability, early maturing types are in general have very small seed size. Bold grain varieties are milled more easily than can small varieties (Parpia 1972) and thus quality of dhal and milling out-turn can be considerably improved at reduced processing cost. The available variability for seed size ranges from 6 gms. per 100 seeds to 21 gm. per 100 seeds.

Physiological aspects of pigeon pea improvement

Pigeon pea is a very slow growing plant and has a poor harvest index. Tall and very bushy growth would have been a definite advantage in the wild state and in crop mixtures grown under adverse conditions on marginal fertility. However, these are the major limitations in obtaining high yield levels from the existing types.

Harvest index in pigeon peas can be improved by reducing the unproductive plant height, increasing primary and secondary branching resulting in increased pod number, and by increased number of seeds per pod and seed weight. An observation of individual plants provided with adequate space shows that the initial sink capacity of the plant is quite high, however the realisation of this capacity in the form of economic yield is extremely low/since there is a heavy drop of flowers and green young pods.

Sinha (1973) mentioned that the following factors individually or collectively could be responsible for flower shedding.

1. Limitation of photosynthate
2. Reduced light intensity in canopies
3. Limitation of nitrogen availability
4. Hormonal factors
5. Soil and water factors
6. Canopy temperatures
7. Gas exchange in plant canopies
8. Humidity in plant canopies

In case of cowpeas and Bengal gram Sinha pointed out that, limitation of photosynthesis and nitrogen availability were important. However, in pigeon peas, reduced light intensity in canopies and hormonal factors seem to have predominant role. There is no definite work on this aspect and it needs thorough study.

In wheat and rice photo-period insensitivity has been responsible for increasing the harvest index, since by controlling flowering it controls both harvest index and time required to achieve maturity ie., leaf area index (Wallace et al 1972). In pigeon peas so far no genetic stock is available which may be considered as photo period insensitive.

Due to photoperiod sensitivity the pigeon peas varieties have long vegetative phase which under field conditions results in over vegetation causing mutual shading particularly in indeterminate types. Determinate types are available in pigeon pea, but these do not seem to solve the problem as bearing in these is confined to the top portion only and these generally have big leaves, which due to short bunchy branches cause perfect internal shading and under high plant population these form a perfect canopy cutting the penetration of sunlight to the ground. Such complete shading is perfect situation for disease like new stalk rot caused by (Phytophthora drechsleri). Therefore, we might have to obtain determinate types, where the branches and the inflorescence is not very much crowded. This does not seem to be difficult to achieve by hybridization of the suitable types.

The problem of over vegetation and internal and mutual shading can also be solved by shortening the plant height. There is considerable variation for plant height and due to simple inheritance of the character it is not difficult to obtain any particular plant height in any maturity group or plant type i.e. spreading or compact, by the manipulation of the major genes and the modifier complex, however, the effect of plant height on yield under various crop culture situations will have to be worked out so that breeding work for appropriate plant height is taken up.

Generally high photosynthetic rate is considered to result in high yield. Evans (1971) argued that if photosynthesis was a major component of yield then atleast some high yielding varieties should have superior photosynthetic activity. However, he observed that poor yielding primitive wheats had higher photosynthetic rates of flag leaves than the present day high yielding wheat varieties. Nevertheless, several factors, which affect crop photosynthesis also affect yield in the same direction. Experiments on increasing CO_2 concentration in case of soybean, tomatoes etc. show that increased photosynthesis results in increased yield. Apel and Lehmann (1969) working with 115 barley varieties observed wide variation for photosynthetic ability (nearly 2 times the low rate) but most of the adapted varieties had rates near the positive maximum and at that level there was no variability.

In generall the work done on photosynthetic efficiency in various crops shows that:

1. Rates do differ markedly among varieties
2. In some cases it appears that superior genotyp· have been identified from lines which have superior capacity for photo-synthesis.
3. In some cases it appears that few genes control the diffe-rences and the heritability is sufficiently high to ensure success in selecting for high capacity for photosynthesis.

This suggests that specific information for each individual species on various aspects of photosynthetic efficiency and its diversion to economic yield should be accumulated. At present nothing is known about the hormonal or other physiological mechanisms through which genetic control of partioning the photosynthate into vegetative growth and economic yield is controlled.

Plant type concept and pigeon peas improvement

Approach to change the plant type for superior performance is based on the fact that the existing common plant architecture is not capable of exploiting the given physical and chemical energy sources efficiently and becomes a limiting factor in increasing the dry matter production.

This limitation poses problem only when all other input factors reach their optimum or maximum in a given situation.

The requirements of plant type or plant ideo-type vary from crop to crop and with crop culture and cropping system.

These days, orientation of leaf is getting maximum emphasis and efforts are being made to get erect leaves in the varieties. This may be true only when crop canopy becomes such that light penetration to lower areas becomes a limiting factor in crop production. However, exposure of leaf area to sunlight does not seem to be limiting factor in most crops, as Clegg (1972) reported that in case of sorghum 80 per cent of total radiation is intercepted by one half of the total leaf area and therefore change in the leaf angle or orientation of leaves is not likely to increase photosynthetic efficiency. The contribution of erect leaves towards photosynthetic efficiency and increased yield is matter of considerable controversy.

The pigeon peas crop is grown under:

1. Mixed cropping with sorghum
2. Mixed cropping in rows with cotton and groundnut
3. Sole crop of pigeon peas under poor water and fertility conditions.

   The plant type requirements would vary with the crop culture. One cannot take any rigid view on definite plant ideotype. Rather there is a need for extensive physiological work to find out which type of plant would be most suitable for a particular situation.

According to Donald (1968) in rice the efficient plant type in the context of the present day production practices is one which is capable of exploiting to its maximum, the given environment to each individual plant.

This means that efficient types are poor competitors and these do not interefere with other individual plants in the population.

This in turn implies that efficient plant types are like the thoroughbred race horses, which can given extremely good performance under specific good care, otherwise under adverse conditions are likely to do poorly. The efficient plant type bred for good management and crop culture lacks inter compensatory habit, which is important factor in case of crop, generally sown to take advantage of adverse agroclimatic situations.

This discussion clearly shows that before we really talk of an efficient plant type in pigeon peas we must have answers to several problems.

However, as it is exciting and stimulating to theorise, I may also indulge in the exercise and reason out as to what should be an efficient plant type in pigeon peas.

1. Better harvest index
2. 1.5 meters plant height
3. Semi-spreading in nature with long fruiting branches or semi-spreading type with profuse secondary branching
4. No. of seeds per pod 4
5. 100 seed weight between 10 to 15 gms.
6. Small leaves; which help avoiding mutual shading

Like wheat there is no well determined single factor (lodging resistance) which needs to be incorporated to change the plant type and increase the yield by overcoming the limitation of lodging, which was responsible for low response to high fertility and irrigation. Since, the situation in pigeon peas is not so simple , break through based on the change in plant type is slow to come and may not be so striking. In pigeon pea crop the plant physiologists have a vast virgin field to explore. However, information on various physiologoical aspects would be essential to improve the harvest index in pigeon peas.

Breeding Objectives:

A. High yield
B. Improvement in the nutritional quality of the grain
C. Resistant varieties to wilt and new stalk rot and other important diseases.

Field Improvement

In India pigeon pea crop is generally grown as a catch crop in various kinds of crop mixtures to take the advantage of the residual soil moisture during the winter months, or on saline soils, where other crops do not do well in absence of irrigation water. Therefore there is no definite crop culture for this crop and the average yield in India remains only 690 kg./ha against 1130 kg./ha in Puerto Rico (Highest) in the world. However, Rachie (1972) mentioned that according to RPIP reports, high yield upto 5000 kg./ha. has been recorded in India. This shows that the crop has a fairly good yield potential and given proper care it can compete with the best cereal crops and under rainfed semi-arid tropics it is more productive and remunerative than the cereals. The fact is yet to be appreciated by the farming community.

Pigeon pea production can be increased by:

1. Development high yielding early maturing (160 days and less) varieties. Early maturing varieties are essential so that the pigeon pea may continue to be grown in traditional areas even when the irrigation facilities are developed since after varieties one can easily take wheat or some other crop like potato or sugar cane. Also these would help in stablising pigeon pea production in areas where frost damage is frequent.

2. Development of high yielding medium duration (160 to 200 days) varieties. These varieties are likely to do well under unirrigated rainfed conditions.

Early maturing varieties generally have small and fewer seeds per pod. In past limited hybridization work involved parents of the similar maturity group as the breeding work was carried out for small region and similar types were prevalent in a particular region. The variation for seed size in the early group ranges between 6 gms./100 seed to about 11 gm./100 seed. However, in the medium maturity group, types with 21 gm./ 100 seed are available.

Since heritability for seed size (0.82 Sharma et al. 1972) and flowering duration (Sharma et al, 1973) is quite high it is not difficult to improve the seed size in the early maturing group. Though generally very bold seed size is negatively correlated with yield but a reasonable compromise can be easily hit in the broad based hybridization programme and it should not be difficult to have early maturing high yielding varieties with seed weight of 12 gm./100 seeds. In the medium duration varieties there is a wide range of variability for almost all the characters ie., plant height, branching habit, pod size and seed size. With a proper extensive brdeding approach the available variability can be mobilized to improve yield over the existing varieties. Detailed breeding methodology and approach is discussed separately.

Besides low yield of the existing varieties the production of the crop is very much limited by frost injury, wilt and stalk rot diseases and different pod boring insects (about 12 different species). Frost damage indicates the limit of a variety with a particular maturity period and in my opinion frost escaping variety is the only answer. Since, the crop has evolved and is confined to the humid and sub-humid tropics the search for for resistance to frost in real sense may not be fruitful. However, it is a problem, which may be probed by plant physiologist and parameters for selecting frost resistance type be worked out if possible.

Development of resistance to wilt and stalk rot is a possiblity for which the entire germ plasm will be screened to locate definite sourcesof resistance. Once these sources are available, breeding for resistant types could be easily taken up.

The damage by pod boring insects can be reduced only by complete understanding of the ecology of whole group of insects and developing and recommending varieties which escape the damage in a particular region. Also there is a need to develop information on effective insecticide sprays and the spraying schedule which controls the damage and is economical. Development of pod borer resistant variety seems to be a far cry, as a large number of species are involved in causing the damage and it is not possible to get resistance against all of them. Even the artificial screening would be a big problem. It may be interesting to study the effect of various crop mixture on the insect population and the damage to the crop, so that excessive damage may be avoided by following suitable crop mixtures.

The survey in the Nander area of Andhra Pradesh revealed that very good crop of pigeon pea on a large acreage had 100 percent damage due to the pod boring insects. Also in North western, M.P. and inparts of U.P. large acreage under the crop was completely ruined by frost.

Improvement in the nutritional quality of the grain:

Cereals and pulses are the main sources of necessary calaories and the protein requirement in the developing nations of the semi-arid trop-ics. Though quantitatively cereals supply the major portion of the protein requirement but pulses are more important from the quality point of view, since these are the main sources of some of the important amino acids like lysine and threonin. According to Parpia (1973) cereal based diet is not deficient in p-rotein, if legume content is 50 to 80 gms. and the calorie intake is sufficient. Therefore, to ensure adequate nutrition to the growing population it is essential to develop varieties of pulses, which have highyield and high nutritional quality.

In pigeon pea the protein content generally varies from 18 percent to 24 percent. However, there are reports which indicate as high as 30 to 32 percent protein content. Like other pulses pigeon peas are also deficient in the amino acids cystine and metheonin besides tryptophan. Therefore, it is essential that beside breeding for increased protein content attention should be paid for improving the amino acid balance. At present there is little information regarding the available genetic variability for the limiting amino acids.

Bressani (1972) reported that the amino acid content of legume grains depends on species, varieties, localities and management practices. He also pointed out that uptake of zinc and application of sulphur increases methionine content in peas considerably. This aspect needs to be looked in case of pigeon peas. It may be easier to improve the protein quality by agronomic practices rather than by genetic manipulation in absence of required variability.

From the nutrition point of view high protein content with high biological value is essential. Increased methonin and tryptophan content increases the PER value of cajanus considerably. Bressani (1972) reported that the protein digestibility of two varieties of cajanus varied from 59 to 90 percent. This clearly indicates that at some stage in the varietal improvement program, due attention should be paid to not only yield and protein content but to the biological value of the protein also.

It may be kept in mind that many times high protein content is negatively correlated with yield. Also high protein has negative correlation with cystine and metheonine in case of field beans (Phaseolus Vulgaris) (Adams 1972). Adams (1972) suggested that in field beans additional protein stored, above about 21 percent, is of a progressively lower quality with respect to sulphur amino acids. On this basis he suggested that it would be desirable to select for 20 to 22 percent protein and in the selected population further selection be made for sulphur amino acids and high grain yield, which should be attainable considering the relationship of yield to low protein. However, one cannot rule out the possibility of getting a genotype like Atlas-66 of wheat, which has high protein and high yield combined together. In case of pigeon pea no such information is available. However, it is proposed that while looking for high yield, attempt should be made to have about 24 to 25 per cent protein in the stable strains. These be further tested for the biological value of the protein.

The success of the programme would depend on the reliable and rapid testing procedure for various quality characteristics which will have to be worked out for the crop by the quality testing laboratory.

Besides improvement in protein quality and quantity attention needs to be paid on cooking quality, which involves easy and quick cooking of dhal and good texture and flaour of the cooked product. There is considerable variation for these characters from strain to strain and from locality to locality, but no information is available, as to what factors determine these attributes. The quality laboratory will have to pay attention on these aspects so that the varieties developed are tested for high consumer aceeptance.

Breeding methods and approach:

Cajanus is a monotypic genus, as it has only one species. Like other legumes it is highly self pollinated. However, cross pollination through insects particularly thrips is reported to be 10 to 30 %.

In past the crop evolved under adverse and marginal fertility conditions and has established itself as definite agroecotypes under various sets of conditions. The crop has yet to evolve to suit the conditions of advanced agricultural technology. Since, the crop belongs to a monotypic genus, most of the variability is confined to the agroecotypes of a single species. Atylosia lineata has been considered to be the closest to Cajanus. According to Reddy (1973) Cajanus represent a domesticated and an advanced form of Atylosia species, which may be a derivative of A.lineata.

These two genera can be easily crossed and it has been suggested that hybridization between Cajanus and Atylosia lineata could be utilised for incorporating resistance, to wilt and some insect pests. However, there is no systematic work on this aspect, and it needs to be thoroughly studied.

Broadly the breeding methods and approach in the crop has to be based on the following facts:

1. The crop is self pollinated with occasional out crossing to the extent of 10 to 15 per cent.

2. There has been little sharing of genes between different agro-ecotypes.

The high degree of self pollination requires that true breeding high yielding types should be fixed in the form of a finished variety. This is possible only by accumulation of desirable genes through recombination and selection. Since, the gene-action for yield in the crop is mainly additive or additive X additive type, it should be possible through recurrent crossing and selection programme.

The 2nd aspect points out that the programme should have a very broad genetic base and should capitalize on the genes for yield and yield components in different types. With these considerations in view the following breeding programme is proposed.

1. Development of highly variable populations from genetically diverse genotypes is the first step. In the ideal situation variable populations are created by hybridization between the elite geno types already evaluated and recognized. However, this in turn narrows the genetic variability between the parents and operates only on the fraction of the available variability in the species. Also proper evaluation of the genotypes for their total performance and their genetic potential as parents is time consuming and very cumbersome procedure. Since, in Cajanus little is known on this aspect it is decided to mobilize the entire range of available variability in the germ plasm (about 3500 lines).

To achieve this the material will be grouped into 10 composite populations on the basis of maturity duration, plant type, seed size and seed colour. These broad based populations will be planted in ½ acre each and mass cross pollination programme will be taken up, to obtain a set of diallel crosses among these 10 parental populations, attempt will be made to get about 250 to 300 seeds.

3. On the basis of the perofrmance of F_1 in the diallel set, crosses will be selected and equal quantity F_2 seed from each selected cross will be composited in a single population to plant about 50,000 plants in an area of 2 hectares. This will be designated as population 'A'. In F_2 little selection will be made for plant performance. The major emphasis will be laid on the partioning of the population into 3 maturity groups and 3 different plant types. At present recurrent crossing in F_2 population would not be desirable as recurrent crossing and selection is useful only when thorough random mating, through natural crossing or hand pollination is possible. In pigeon peas this does not seem possible for the present, therefore, stress would be laid on large populations and very mild mass selection.

4. F_3 of early and medium maturity sub populations will be advanced with 30,000 plants per population during off-season.

5. In F_4 again 30,000 plants per sub population will be planted under normal spacing. Mild mass selection and categorisation of the segregates on the basis of maturity period and plant type would be followed, and the segregates would be assigned to the individual sub-population.

6. Grow F_5 again in off-season as in case of F_3.

7. In F_6 plant the sub-population at the normal spacing and at the rate of 30,000 plants. Select individual plants on grit basis at 10% selection intensity in each of the sub-populations. The selection should be based on per plant yield and 100 seed weight.

8. In F_7, 300 plant progenies will be evaluated for their performance in three row plots with suitable checks after every sixth progeny. Selection of top 10% be made.

9. In F_8, replicated yield test should be done on several locations.

The above proposed outline avoids quick erosion of genetic variability, which is inherent in early generation selection in self pollinated crops and also avoids undersirable inter plant competition between variable plant types.

The crosses between F_1s will be composited in another population designated as population 'B'. This population will also be handled in a similar manner as stated above.

The programme outlines above is a long range programme, however, for rapid and immediate gains suitable sub-subpopulations could be easily derived in F_4 itself and these could be tested for yield in replicated trials. Since, these would have attained pratical uniformity by then and could be released for cultivation in F_6, if substantial advance in yield is ensured. Also next cycle of crossing the sub-populations in diallel fashion could be taken up.

Besides this six groups of varieties represented by six varieties in each group are being selected on the basis of their yield potential and other important characteristics. These 36 varieties will be crossed in a diallel fashion. The diallel set will be tested in F_1 and F_2. This programme is likely to supply necessary genetic information on the potential of the different groups and the individual varieties with in a group against a large number of diverse genotypes.

The selected crosses will be handled in some what similar manner as discussed above.

Besides the above scheme based on complete self pollination population improvement approach can be adopted if extent of cross pollination is considerably increased by either finding male sterility system or by manipulation through some insects. The available cross pollination to the extent to 15 to 20 per cent can be utilised to some extent for population development only by developing a system based on suitable simple recessive markets. A line has already been marked which has single gene recessive obtuse leaf characteristic, in which the stigma is completely exposed due to modification of the keel. However, the various aspects of the population improvement based on the above mentioned factors need to be thoroughly worked before a specific programme is taken up. This aspect will receive due attention.

Anticipated yield in Pigeon peas:

Cereals crops have attained very high yield levels during last decade under high management condition and input cost. However, on an average a good crop of wheat, rice maize and sorghum gives 5,000 to 5,500 kg./ha. on the farmers field. I feel that with proper agronomy and normal conditions of growth it would not be difficult to attain a similar yield level ie., about 5000 kg./ha. under normal fertility and rainfed conditions on good neutral soils in the countries of the semi-arid tropics.

To achieve this one needs 50,000 plants per hectare yielding 100 gm. per plant. This may not be difficult as 250 pods with 4 seeds per pod and the seed weight of 10 gm./100 seed would meet the requirement of this projected yield. If the seed weight reaches 15 gms./100 seeds then only 200 pods per plant are required. Looking to the variation available in the crop this goal does not seem to be difficult to achieve.

Can one compare pigeon peas with wheat, and rice and wish for similar darmatic change in yield:

1. Comparison between cereals like maize, wheat, sorghum and rice and pulses is not valid.

In cereals through out the plant breeding or evolutionary history stress has been on the development of superior varieties performing well under good fertility and moisture conditions as these crops formed the very basis of the human civilization and organized agriculture. At no time the selection pressure was in the opposite direction.

In pigeonpeas the selection pressure has operated towards the direction where the crop has become drought hardy and can grow under poor soils like saline and alkaline. Now for higher yields these ought to respond to good fertility and irrigation.

This places emphasis on selection in the opposite and the different direction than in past.

Here it may be pointed out that pigeon peas and gram are so susceptible to irrigation that little excess of water kills the plant, since roots suffer from lack of oxygen and nitrogen supply. There is no response for increasing yield by extra inputs of water and fertilizer in pigeon peas, while cereals always respond favourably to it.

In cerals the major break through in yield was based on the favourable response to high inputs and just a change to dwarf plant type met this requirement (as it avoided lodging).

In case of pigeon peas there is no indication as to what one factor can remove any major bottle neck in production.

There is a need for extensive study on various physiological aspects related with yield in this crop.

This leaves us with only conventional approaches to breed superior varieties, performing well under arid rainfed conditions.

With conventional approaches the improvement in yield in any crop has been to the order of 10 to 15% or at the most one can hope about 20 to 25% at a time.

Therefore any expectation to make a jump of 50 or 75% in yield of pigeon pea would not be bzsed on scientific reasoning and knowledge.

Also the improvement is not easy to come by. Take the example of wheat itself where spectacular improvement has been made. The wheat improvement programme started in Mexico in 1943 and dwarf wheat programme started in 1954. The success or impact of dwarf wheats could only be realised around 1964 i.e. another 10 years later. This is the case of wheat, where so much information on various aspect as already available in the begining of the programme.

The success in introducing high yielding wheat varieties came easy, as it did not involve any major change in the wheat cultivation practices or cropping pattern.

In case of pigeon peas it is not so. Generally the crop is grown in mixtures and on poor soils under poor management. Any change in this situation based on different types of new varieties or cultural practices would not be easy, as it has sociological as well economic implications.

Change in the cropping pattern may not be easy and any drastic change in the plant type and other features of the pigeon pea varieties would necessarily require a definite change in the crop culture for maximum benefits.

Study of precise socio-economic factors responsible for certain crop culture or patterns is essential to affect any change warranged by the development of new high yielding varieties with specific requirement of crop management and practices.

We are just making the beginning and we may not find all the answers in near future. However, I am sure and confident that soon we will be better equipped to find answers to some of the major limiations and bottlenecks in the production of pigeon peas. It is just a matter of time.

DS/gbd