CHAPTER ONE

REVIEW OF LITERATURE

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INTRODUCTION

Man has made tools for more than a million years, but his crop plants have evolved under the influence of his powers of observation, selection and imagination for only about ten thousand years. Man's survival is dependent on his crops. Crops and man have evolved together in a kind of symbiosis. As Darlington (1969) had stated -

> *In the silent millennia during the expansion of agriculture the men themselves were transformed by the new relations with the plant and animal which they themselves were in the process of establishing.*

Pulses constitute a group of crops of the legume family. They are an important source of dietary proteins and oils in the vegetarian diet in developing countries. Legumes occupy an important place in the diet of the people in our country. Pulses have high protein content (about 30 per cent) which is nearly three times greater than in cereals. The amino acid composition of pulse proteins is such that a mixed diet of cereals and pulses has greater food value. Pulses supply the major portion of the protein requirement of vegetarian population. Pulses are the best source of overcoming the protein malnutrition, generally among children and pregnant and nursing mothers.

According to the Food and Nutritional Board of the U.S. National Academy of Science, nutritional standard for protein requirements is greater than fat and carbohydrates. Man's food must support his growth and maintain his body and satisfy his energy requirement. Diet survey data marked by 'FAO' gives an idea of pulse utilization in various countries, according to which India's daily consumption is 71 g. per capita which is greater than that of any other nation. This indicates how pulses are important in Indian diet (Aycroad and Daugty, 1964). With this view pulses are considered as a "poor man's crop".

Pulses occupy an unique position in Indian Agriculture, as they not only provide the high protein content of an average diet but also restore the fertility of soils in the absence of adequate manuring by a variety of their symbiotic nitrogen fixing Rhizobia in the root nodules. Pulses are able to do relatively well, even under poor soil fertility conditions, due to their penetrating root system. They are able to utilize the available soil moisture more efficiently than many other crops. Pulses vary in maturity period and thus have an advantage of being utilized in different cropping systems.

The physiology of legumes differs from that of cereals as they fix atmospheric nitrogen symbiotically in their root nodules. Photosynthates from leaves serve as a source of energy and carbon skeleton to nodule bacteria. When flowering begins and fruit setting starts they provide apparently a stronger site for the utilization of photosynthates. At this stage nodules possibly are deprived of photosynthates and consequently start disintegration. The developing seeds would have heavy requirements of nitrogen, which is presumed to be met by degrading leaf proteins. A reduction in leaf nitrogen would bring down the rate of photosynthesis by reducing leaf area due to senescence and of reduced RuBP-carboxylase activity which forms usually 50 per cent of soluble protein of leaves. These interdependent processes probably would restrict supply of nitrogen and photosynthates to the developing reproductive parts and consequently lead to flower shedding. This appeared to be the general phenomena in pulses (Shanta Kumari and Sinha, 1972; Sinha, 1974).

According to the production planning, India would need 18.6 and 22 million tons of pulses during 1980 and 1990 respectively, against which the present production of pulses in India is 13.4 million tons (Chokhe Singh and Yadav, 1978). Raising the pulse production to this level seems to be difficult, though not impossible.

C.cajan is one of the most widely grown pulse crops of India next in importance only to chickpea. A major disadvantage with C. cajan is the long duration, i.e., about six months. Even though a few varieties of shorter duration are evolved recently, any spectacular increase in yield is still not in sight, as the short duration cultivars, in general, are low yielders.

Intensive work is in progress to evolve high yielding short duration varieties with better quality grains. Although economic yield has been the main basis of selection, there have been numerous attempts to find selection criteria based on the physiology and biochemistry of the development of crop yield. It is a well known fact that pulses produce a large number of flowers and flower-buds but the percentage of fruit setting is poor (Sinha, 1973).

C. cajan and P. tetragonolobus are grown almost in every state of India. The average annual area under C. cajan is 2.8 million hectares and production of grain is nearly 2.1 million tonnes in India.

A) Importance of Legumes in Human and Animal Diet:

The growth rate of human's relative to that of other animals of comparable adult live weight is exceedingly slow. The consequence of this is that the respective needs of the growing animal and the child are rather different qualitatively. The human infant requires a greater proportion of energy producing nutrients that other more rapidly growing mammalian young and a lesser proportion of the body building foods. This is reflected very strongly in the different composition of human milk and cow's milk for example.

It is commonly observed by health workers in developing regions that the condition of infants at the end of their period of sucking is often very good, but that nutritional disorders due to protein deficency very often set in after weaning. After weaning there commonly occurs a period of nutritional stress particularly in unsophisticated society where nutritional needs are not appreciated and food consumption is merely a matter of satisfying hunger. In these circumstances the more powerful adults, the men, demand the best flavoured foodstuffs, containing most of the protein, and the women and children compete for what is left, with the result that the least strong children, the recently weaned, receive far less than their requirements of protein-rich food. This results quite rapidly in the development of Kwashiorkar and other conditions of acute nutritional deficiency. Although such conditions are not confined to immediate post-weaning phase, infants at this stage of development are especially susceptible and likely to be to poor nutritional conditions. They are, thus, heavily at risk both to direct effects of malnutrition and to secondary conditions and infections.

Table-1.1 shows how the needs of man for proteins compares with those of other mammals and how man's protein needs vary throughout life. Ths figures in Table-1.1 show how greatly the protein requirements for maintenance and growth differ in man and other mammals. (Ref ?)

a) Basic Nutritional Concept:

The chemical composition of edible legume seeds is variable between species. The general common characteristic is that, the protein content is high and the general level protein found, is commonly more than twice that of the cereal grains, usually about 20 per cent of the dry weight. The nutritional value of legume seeds is is not confined to their usefulness as a source of vegetable protein. The balance of catyledonary food reserves commonly takes the form of either carbohydrate (e.g. Pisum and Vicia) or oil (e.g., Arachis and Glycine) in addition to carbohydrate. Legume seeds may also be the source of other nutritionally important materials such as the vitamins and minerals.

Man's food intake must supply him with his energy requirements on the one hand and support growth and maintain his body on the other. The required elements can be thus considered as generally serving a structural function or as providing an energy source. Proteins to a large extent, and fats and carbohydrates to a lesser extent are concerned in basic body structure; yet they can also serve as energy sources. Certain inorganic elements, too, have important structural function. Calcium and phosphorus for example, which provide the great bulk of the human skeletal material. In addition, these elements are implicated in many metabolic processes and phosphorus is, of course, a component of the nucleic acids which genetically determined themselves. The organic and inorganic constituents of pulses can be utilized in human nutrition in a variety of ways.

b) Nutritional Properties of Pulse Protein:

Nutritional value of pulse protein depends on the amino acid composition of the storage protein laid down in the cotyledons.

In the case of C.cajan the amino acids concerned are isoleucine and tyrosine.

In human nutrition pulses can and do serve a useful purpose. In situations of acute protein shortage it is commonly found that pulses are being employed to ease the position. Pulses by themselves cannot retrieve situations of protein storage and all sources of nutritionally valuable protein must be exploited in the most efficient and appropriate way.

The use of pulses with cereals is a very common practice in India and this practice is considered to be very scientific because of the high protein contents in the pulses, which is required for balanced food for a large population in the country dependent upon vegetarian food. The area under pulses is about 17 per cent of the total cultivated area of the country. But adequate attention has not been paid so far to the development and release of high yielding varieties as has been done in the case of rice, wheat, maize, sorghum, bajara etc.. So, the production figure of the pulses in India has remained always static which is about 500 kg/hectare. But it is significant that inspite of low yields farmers continue to grow pulses because they fulfil the requirement in the diets of Indian masses.

C.cajan and P.tetragonolobus are the most important pulse crops of India. The nutritional requirement of grain legumes is different from that of other crops mainly because of their ability to fix nitrogen biologically, with the help of Rhizobia in the nodules on roots. Literature on physological changes during pod development of legume in general and pigeon pea, winged bean in particular with reference to time and method of studying physiology changes. Mouritus, Madagascar and India Pickerning et al. (1879) showed evidence that P.tetragonolobus was native of equatorial Africa. Leon et al. (1968) considered P. tetragonolobus originated from West Africa while Fairchild et al. (1917), Brown and Massey et al. (1929), Hutchinson and Dalzial et al. (1958) reported it in Africa. Rumphius believed that winged bean had been brought to Amboins from Bali or Java by Arabs.

B) Various Types of Legumes Used With Their Nutritive Value:

Grain legumes are an important grain legume of semi-arid tropics and source of dietory proteins. Red gram or pigeon pea and winged bean rank high amongst the pulse crops of Indian country as it does, into the daily food of a considerable number of people. NAS (1975) reported that winged bean has international fame among food reseachers. Winged bean and pigeon pea are largely eaten in the form of pulses as dal, while its tender green pods constitute a very favourite vegetable in some parts. Winged bean has high protein content anc each part is used for medicinal and nutritional purposes. (Claydon 1975)

The outer integument of its seed together with parts of Kernal provide a valuable feed for the mice, cattle. The stalks are utilized for various purposes such as roofing, walling sides of carts and basket making. In Phillipines green pods are preferred for consumption. In other countries roots, seeds are more poplar and flour, leaves may be eaten.

Seeds and fruits, tender part of plant are utilized in various ways.

Immature Pods (seeds):

Immature pods two or three weeks before lignification of the fibres occur remain fleshy and green and are utilized as green vegetable. Nutritionally immature pods have distinctly different property to those of the mature seeds, the protein content is lower but richer in soluble carbohydrates and vitamins. Tender pods of winged bean are tasty and commonly eaten in most of the Asia and Papua New Guinea. Tender winged bean pod can be eaten raw or included in salad or cooked in other food stuff, such as making curries, restews and soups. Young pods can by preserved by processing into a pickle in Tamil Nadu, South India.

Mature Seeds:

Matured seeds of winged bean are cooked or roasted and very frequently eaten. Matured winged bean seeds are utilised in the form of food products such as milk, curds, sauce, tempeh etc. (Cerný 1978) protein concentration of winged bean is used in bakery products. The crude protein content ranges from 29.8 to 37.4 per cent (Claydon 1978). As the protein content and energy contents of whole pod increase, the carbohydrate content ranges from 25.2 to 38.4 per cent. The minerals, the calcium content is similar to that of the soybean but is higher as compared to other legumes.

Germinated Seed:

The germinated and young seed has been used in sailing ships and more recently in Japanese prisoner of war camps as source of vitamin C.

Fermented Products:

Fermented products such as sauce, paste, tempeh and natto produced from C.cajan are consumed on a large scale.

Extracted Products:

Extracted products such as milk, curds, sauce, temph and others are used as substitutent items in baking and different food dishes.

Uses of Pulses:

Main Use:

The Pigeon pea is an important protein food in many tropical areas. In India it is consumed mainly in the form of 'dal'. In Africa and Indonesia the mature seeds are soaked several hours before being pounded and fried, steamed and eaten often in the form of Puree. The fresh green seeds are very popular vegetable. Barre (1928) describing its uses in Dasto, Rico stated that the seeds are believed to be rich in iron and iodine.

Subsidiary Uses:

The ripe seeds may be germinated similarly to Mung beans to produce sprout. Small seeded Pigeon peas are sometimes used for poultry food, but crushing is advisable as the seeds are very hard. In Hawai pigeon peas are used mainly for animal feeding. The green immature pods are sometimes boiled, eaten as a vegetable, similar to fresh beans, or as a constituent of curries. Pigeon peas are sometimes grown for forage. Ocneen (1931) noted that one becomes sleepy upon eating too many of the raw seeds. They may have slightly narcotic properties and seeds are harmless.

Pulses as Food and Fodder:

In most parts of India pulses form an essential item of the daily diet of the people. It is good. Because a very large proportion of the vegetarian population would otherwise have suffered from acute deficiency of proteins in their diet; with the nuts the pulses are the richest among the vegetable foods in protein. The common cereals like rice, wheat, barley and maize contain a fair proportion of protein, but the outer layers of these grains which are richer in protein than the inner starch kernel. When highly milled there is a loss of some of this protein as well as vitamins and minerals. The protein contents of the major pulses and cereals are given in Table-1.1 (Ref 9)

Protein being one of the most important food factors supplying the building material for the body the important pulses in our diet, can be easily appreciated. The loss of tissue, which is constantly going on in every living body has to be made good by the proteins, and in the predominantly vegetarian diet of the Indian population, what item can be superior to pulses in supplying the proteins?

The pulses are used as food in a variety of forms. The most common form is the soup, the split pulse grains being boiled in spiced water and seasoned, the product being known as 'dal' or 'sambar'. There is a wide variety of dishes prepared in different manners. The grains may be ground and boiled, roasted or fried, whole grains may be sprouted and then cooked. They find use in the form of dal moth, papad, sweetmeats etc.. They are used also as flour for preparation of bread and other eatables. The grain and even the pods with grain are cooked in the green condition in the case of some pulses such as the pea, guar, cowpea and the beans.

Some of the pulses constitute fodder crops for the draught and milked animals. Gaur, usually grown in mixture with fodder millets, is specially valued for the draught animals in the form of green fodder in Punjab and Western Uttar Pradesh. Cowpea is valuable green fodder for the milked animals. Peas in most parts of the U.P. eastern U.P. and in large areas of Bihar, Orissa and Madhya Pradesh are common green fodders. As fodder crops, they are usually grown as pure crop although mixed sowing with millets and certain other crops is not uncommon. The yield may vary from 8,000 to 20,000 lb/acre depending upon the crop and conditions of growth.

The grain of the pulse crops is used as concentrate to enrich the diet of the animals. Guar grain is specially preferred for the draught animals. Bengal gram is a highly esteemed grain for feeding bullocks and horses.

C) Growth and Pod Development in Legumes:

Prehistoric humans gathered as preserved seeds for food and propogation. The rise of ancient civilization can be linked to cereals and pulses grain production. The seeds are the primary means of dissemination. Legume fruit consists of seeds and pericarp that develops from the carpel.

Anatomical as well as physiological functions of the pericarp on the one hand resemble those of leaves, on the other hand similarities exist with storage organs. This double function of pericarp is closely related to the maintenance of a continuous outegenic development of the embryo and contributes to the survival of the species. The fleshy and reserve accumulating pericarps of most of the agronomically used grain legumes may have been accidentally selected by breeders in the former times. A well developed system of relations between pericarp and developing seeds may have an evaluationary advantage too. Consequently, the optimally co-ordinated development of pericarp and seeds in fruits of grain legumes should also be of interest in breeding for increased yields.

Pericarps represent a protection against damage of the developing embryo and maintain a favourable micro-climate. All transport streams supplying nutrients to the developing embryo have to pass through the pericarp tissues. Pericarp vascular tissue mediates the transport between vegetative parts and the developing young plant organism. Like leaves, pericarp assimilates CO_2 as well as nitrate autotropically. During initial phase of embryogenesis, when the seeds are only small and slowly growing organs, the pericarp represents the centre of anabolism in the fruits and accumulates starch and amides that are degraded and transferred into the seeds, during subsequent stage of antogenesis when the cotyledons are growing rapidly. Pericarp metabolism seems to be controlled by the seeds. Temporarily physiological processes in the pericarp can differ seed development against damages by environmental and nutrient stresses.

The pericarp represents a characteristic constituent of the fruits of agronomically used grain legumes. After reaching its full growth, in most cases the pericarp is a thick and fleshy organ.

It develops from the carpel and bears the marginally attached seeds. These are set free after the pericarp has already died and the fruit has ripened. During the embryogenesis pericarp and seeds develop as one physiological unit. The space enclosed by the pericarp protects the developing embryo against technical damage and preserves special microclimate with high humidity. Seeds and pericarp tissues are closely interrelated by phytohormone transport and by metabolic activities. Some of the pericarp tissue layers contain chloroplast and exhibit active photosynthetic carbon dioxide assimilation. All substances that are transferred from the vegetative parts of the plants into the developing seeds have to pass through pericarp transport tissues. Simple analysis of the chemical composition and of the anatomy of the pericarp tissues indicates that storage processes take place and should be correlated to seed development.

There is storage of proteins and starch during the 1st period of embryogenesis. At the same time the growth of the pericarp is prevailingly based on cell enlargement and finally the pod reaches nearly full size. Parallel, an accumulation of storage compounds, mainly starch and amides, takes place within the pericarp tissue (Munty et al., 1976).

During the second embryogenic stage the cotyledons grow by cell enlargement and rapidly reach their final size. The cotyledon cells synthesize and accumulate large amount of storage compounds, leading to a corresponding increase of fresh and dry weights, respectively. Whereas, during stage 1 of embryogenesis anabolic processes prevail in the pericarp cells, catabolic metabolism becomes predominating in the 2nd developmental period. This results in a small but statistically significant decrease in the pericarps, dry weight and concomitantly in the loss of approximately 3/4 of the previous maximal carbohydrate and nitrogen content (Boulter and Davis 1968; Flinn and Pate, 1968; Muntz 1973; Muntz et al., 1976; Pate et al., 1977).

Finally during 3rd stage of embryogenic development, the seeds entre the resting stage. They lose water and all metabolic activities slow down. The hilum plays an essential role in the dessication of the seeds (Hyde, 1954). Seed coat and pericarp die and at the end of the pod opens and the seeds are set free.

a) Phases of Fruit Development:

For practical purposes one can distinguish the following phases in fruit development.

(1) A pre-anthesis period during which growth occurs mainly by cell multiplication

(2) A critical phase at anthesis during which pollination and subsequent fertilization of the ovules determine whether or not development will continue.

(3) Post-fertilization period during which most of the increase

increase in the size occurs.

(4) A period of ripening followed by senescence.

Successful fruiting depends on a number of external and internal factors. Pollen and ovules are functional organs to produce successful fertilization. Fruit development is influenced by -

1) Temperature
2) Light
3) Nutritive level, and
4) Moisture level.

Characteristics of fruit development in Cajanus cajan and Psopocarpus tetragonolobus at various ages after anthesis (Data, E.S. and H.K. Pratt, 1980)

- 4th day after anthesis pod grows rapidly in length, width. Length of C. cajan is 1 cm long and P. tetragonolobus 2 cm long light green, still partly covered by dried petals.

- 5th day after anthesis pods growing rapidly in length and width, light green, dried petals hanging on persistent stigma.

- 10th day after anthesis pod growing rapidly in length and width. C. cajan is 5 cm in length and 4 cm in width while P. tetragonolobus 10 to 11 cm long and 1.19 cm width. Start rapid increase in weight, pods light green, dry stigma, still attached seeds pale green but very small.

- 15th day after anthesis pods growing rapidly with increase in length, rapid weight increase, pods are green but *C.cajan* shows purpulish coloured patches on pod wall. Seeds are green and beginnng rapid increase in weight. *P.tetragonolobus* pods marketable as fresh beans.

- 20 days after anthesis *C.cajan* shows 6 cm length while *P.tetragonolobus* 20 to 23 cm long seed might increase rapidly. Maximum pod width almost achieved.

- 25 days after anthesis pods grow full in size and fresh weight, but seeds still increase in size and weight. Fibre formation starts. Pericarp shows swellings from growth of seeds, fruits still green but tough and no longer usable as fresh beans.

- 30 days after anthesis pods approximately maximum in weight, full in size, seed weight increases slowly, pronounced pericarp swellings over seeds. Pods still green but with small yellow spots appearing in *P.tetragonolobus* and in *C.cajan* purpulish coloured spots. Finally natured pod starts senescence.

- 35 days after anthesis seed weight increases slowly. Pods become yellowish. Seed colour still light green but seeds bardening.

- 40 days after anthesis pods become 2/3 yellow. Seeds occur cream-coloured in P.tetragonolobus and brown-coloured in C.cajan and very hard, pods start drying.

45 days after anthesis pods become yellow with brown flucks, maximum in weight, freshness of seed attained.

- 50 days after anthesis pods dry, pedicels remain still green, colour of seeds becomes pale brown.

- 55 days after anthesis pods drying in P.tetragonolobus but pedicel remain still green, fresh weight of seeds decreasing, seeds become brown.

- 60th day pods and pedicels dry, seeds become dark brown and dry.

Transport Processes in the Pericarp:

Vegetative organ represents the main source of substances supplied for fruit growth and development. In the case of Pigeon pea and winged Bean organic substances are transferred into the growing seeds during fruit development. Autotrophic assimilation process in the pericarp may cover at the most 20 per cent of the carbon and nitrogen respectively, finally present in mature seed (Crooksten et al., 1974; Flinn and Pate, 1970; Schlesier, 1977; Pate et al., 1977). The leaf subtending the respective fruits preferentially contributes to the substance supply to the growing seeds (Lavell and Lovell, 1970).

Substances synthesized in the day time and to be transported into the fruits at the same day get into the stem where they are stored intermediarily. Only during the following night transport into the fruits is continued.

Presence of a number of stomata in the epidermis of the pericarp points to an active transpiration. The seeds are located in the inner closed space of the pods where high and content humidity excludes transpiration to be an essential force driving transport processes. In the xylem approximately 2/3 of the water supplied to the fruits during the ontogenetic growth cycle of transported and phloem transported 89 per cent N_2 and 98 per cent C from seive elements to mature seeds.

Substances to be translocated into the fruits pass through the vascular bundles of the fruit into pericarp before getting into the seeds, whereas compounds coming from the pericarp tissue as a result of autotraphic assimilation as well as from degradative process reach the seeds via internal transport tissues of the halves of the pod. Finally all transport streams directed into the seeds must be chanelled into those two non-branched ventral bundles bearing the funiculy of the seeds.

The vascular bundle represents the main pathway of substance transport into the seeds. In addition, some exchange of solutes takes place via the surface of the seed coat (Harvey and Hadley, 1975, 1976; Harvey et al., 1976).

b) Metabolic Changes:

From pollination to senescence, fruits pass through phases in which there is a changed balance between anabolism and catabolism as seen in all the metabolic constituents such as nucleic acids, proteins, cell wall constituents, pigments etc.. Fruit metabolism is divided into five general periods, viz.,

(1) a period of high respiratory rate in the young fruit;

(2) a period of lower rate while cells accumulate reserves, e.g., starch;

(3) a sudden rise in certain species which has been called 'climacteric' by Kidd (1935) and which marks the onset of the maturation process;

(4) a respiratory minimum accompanied by starch hydrolysis;

(5) a gradual decrease during the senescence and breakdown of the tissues.

Each of these phases has characteristic metabolic features. A striking feature of seed metabolism is the accumulation of reserves in the form of fats, protein, starch etc.. After a phase in which fresh weight increases, the growth curve of seeds shows a period during which the fresh weight remains constant, despite a steady decrease in water content. The balance is made up by the accumulation of reserves.

Developing seeds apparently decrease their N_2 from organic sources, as nitrates were not found in fruits, whereas they could be detected in all the other parts of the plant. During the early phase of growth, nucleic acid and protein synthesis are intense. The nitrogen found in fruits does not seem to enter as Nitrate ions, but in the form of organic nitrogen, thus even under conditions of heavy nitrogen fertilization when nitrate can be found in roots, stems, leaves and flower buds of tomato plants, none can be detected in the fruits (Murneck 1926). One should remember also that young embryos seem not to use nitrate nitrogen. In certain cases nitrogen may move to the young fruits as ureides . They account for 50 per cent of the soluble ritrogen transported in Acar pseudoplatanus (Brunel and Echevin, 1938) and allantoic acid is abundant in the pods of soyabeans (Glycin max). To other fruits, nitrogen may be supplied in the form of anides, especially glutamine or amino acid.

At the beginning of fruit development only very small amounts of nitrogen compounds are present in phloem exudates, but this quantity increases when proteins are synthesized and stored in the catyledon cells durng stage 2 of the growth cycle. These changes in the quantitative relations between non-nitrogen and nitrogen compounds in phloem exudates are mainly based on changes in amide content.

During the development of seeds, wages of protein synthesis and degradation occurs, one part being capable of using the material made available by the other. Thus in the case of Pisum, nitrogenous material in the form of peptides and amides is transferred from the pods, the seed coats, and the endosperm of cotyledons of embryo

Protein storage comparable to that in the cotyledons does not take place in pericarp tissue (Boulter and Davis, 1968; Flinn and Pate, 1968) but the large amount of starch grains coinciding with high carbohydrate content as well as the high concentration of amides indicate that accumulation and storage processes characterized special developmental stages in the pericarp, too (Muntz et al., 1976); protein and isoenzyme patterns of fully developed pericarps and leaves of vicia faba L. var, minor show many similarities (Muntz, 1973 a,b).

The decrease of N concentration, the disappearance of protein bands in polyacrylamide gels and investigations on the transloca-tion of proteinogenous amino acids from the pericarp into seeds have demonstrated that the majority of proteins is degraded during pericarp senescence. Under normal conditions of plant growth the degradation products are transferred into the growng seeds.

Protein pattern of the cotyledon exhbits striking differences in comparison with leaves and pericarp respectively (Flinn and Pate, 1968).

Storey and Beevers (1977) investigated the relationship of proteolytic activity to protein degradation in the pericarp and to the increase of protein content in the cotyledons of developing peas, respectively. Pericarp proteins have been used as protease substrates. Protease activity per organ increased upto day 18 after anthesis and it remained at a high level until day 24. Subsequently, the actvity of proteolytic enzymes diminished specific activity of proteasis also reached maximum at day 18. The protein content of the pericarp started to decrease 18 days after anthesis. At the same time the protein concentration in the cotyledons began to rise linearly and with high rate.

Muntz et al. (1976) studied translocation of sucrose from pod coat to seeds. Carbon assimilated autotrophically by the pericarp is distributed in the same manner during stage 1 of fruit development. During stage 2 the 'attraction centre' for carbon and nitrogen was transferred into the seeds.

In the majority (80 per cent) of spp. lipids are accumulated. This phenomenon occurs relatively late in the development. In seeds which store carbohydrates, one observes first an increase in sucrose concentration which (in pea ovule) reaches its peak at the time of the most rapid growth rate (Bisson & Jones, 1932); starch granules, catalyzing starch synthesis *in vitro* from glucose C - 14 have been prepared from this material (Akamine et al., 1964). A steady accumulation of starch begins around 2-3 weeks after pollination in pea (Rasumou, 1931).

During fruit set there is an increase in reducing sugars.

Reducing sugars increase from 0.1 to 1.1 per cent of fresh weight while the level of sucrose decreases from 1 to 0.3 per cent starch also increases from 0.1 to 1.1 per cent (Marre and Murneck, 1953). The origin of these carbohydrates may be sought partly in the photosynthesis growing in the young fruit.

Minerals:

Mineral elements in the fruit ripening is complex; it might be considered to be -

(a) a respiratory source of energy for ripening, providing the fuel;

(b) the synthesis or formation of new sets of enzymes;

(c) the action of these enzymes in bringing about the fruit ripening.

Mineral nutrition in developing legume seed and pod coat is complicated, involving all organs and many vital physiological activities of plants and exhibit a species specificities suggesting a genetic control of plant response to nutrient regine (Hocking and Paté, 1977). Legume fruit remains green for longer period during the development. The process of pod development is carried out by Paté et al. (1977).

West African Journal Biol. Appl. Chem. (1967) has done chemical studies on pulses like V.unquiculata, ground nut, lima bean, pigeon pea and soybean. In soybean Ca^{-1} was 0.30 per cent, in others 0.05 to 0.10 per cent, 'P' was 0.40 in others 0.31 to 0.54 per cent. 'P' ranged from 30 in soybean to 133 mg/100 mg in cowpea. Percentage of 'P' is 13 in pigeon pea to 33 in ground nut. According to Hocking and Pate (1928) mobilization of minerals to developing seeds of legumes like P. sativum, 2-Albus, and L.angustigolia changes in content of specific minerals in leaves, pods, seed coat and embryo are described P, N, and Zn in organ relative to dry matter accumulation, other elements more or less parallel with K, Mn, Cu, Mg and Fe. Sixty to ninety per cent of N, P and K is lost from the leaf. Khokar and Warsi (1987) studied in gram seeds and stated nutrient uptake in Cicer arientinum the rate of N, P and K is increased with or without Zn. Robertson (1988) showed the mineral nutrition of lupin K, Ca, Mn transport to seed. Wallace (1990) stated plant responses to some hardly known trace elements like Sn, Cr, Ni, Pb, V, Li.

Nutrition deficiency may be expected to affect the course of fruit maturation and ripening as well as other aspects of the plant development. Hulme (1958) discusses this problem for apples and pear with special reference to the biochemical roles played by minerals.

Total mineral and phosphor contents decreased significantly as maturity in Arachis hypogea advanced upto stage III (60 days) and then stabilized (Reddy et al., 1978). However, proportion of phytate phosphors increased at all the stages of maturity. Ca, Mg, Cu and Fe contents of seeds of different stages of maturity did not show marked differences. Thus, the composition of immature seeds is significantly influenced by the stage of maturity.

The calcium and iron contents are fairly in higher amounts than other legumes.

From the foregoing account on fruit development, seed development and their maturity, it is clear that a number of legumes and other grains have been investigated for the physiological changes during their development. There are quite a few attempts to study the physiology of very important legume Cajanus cajan and almost no attempt in the case of highly promising but most neglected legume, Psophocarpus tetragonolobus (winged bean). In the present investigation, therefore, an attempt has been made to investigate some physiological changes taking place during pod development and seed maturation. The emphases has been given on nitrogen, carbohydrate and mineral metabolism in the pod cover as well as seed during their development and maturation.

Fruit Development:

With the successful pollination of the flower, a vigorous growth of the ovary occurs and development of fruit begins, usually with a simultaneous wilting and abscission of the petals and sometimes of the stamens. These changes which make the transition of flower into young fruit are called fruit set.

On the basis of embryogenesis three main developmental stages may be distinguished (Dure, 1975; Muntz and Scholz, 1974). Subsequent to the fertilization of the egg cell the growth cell of the embryo is almost entirely based on cell divisions and limited cell enlargement as it generally is the case in embryogenic tissue. This 1st stage stops after approximately 3 weeks under normal environmental conditions. During this time seed size increases slightly. At the end of stage 1 mitotic activity stops in the cotyledon cells whereas it continues in other embryonic tissues, e.g., plumule, radicle and embryonic axis. The cotyledon cells remain free of storage compounds.

As the fruit reaches the end of its growth period it may undergo some characteristic qualitative changes which are collectively referred to as ripening. In some cases ripening is stimulated by picking the fruit. The general changes associated with ripening, including softening of fruit flesh, hydrolytic conversion of storage materials in fruit and changes in the pigments and flavours can be attributed to energy provided by respiratory activities. Channelling the respiratory energies into the ripening processes involves marked changes in the enzymic components of fruit during ripening and formation of new enzymes.

D) About C.cajan and P.tetragonolobus:

1) Morphology:

Cajanus cajan: C.cajan is an annual, perennial shrub 2 to 12 feet high, cultivated nearly throughout India as a pulse crop. It is often grown for green manures or for cover in plantations. Its deep and penetrating root system makes it valuable as a renovating and counter hedge crop for checking soil erosion. In America and Hawai red gram is cultivated for fodder (Kroaus, 1932). In India and Java it thrives as an annual up to elevation approxmately 6000 ft. whereas in Hawai the limit for all the variety tested as perennials is 3,500 ft.

Root: Tall, upright cultivars produce long, vertical deeply penetrating root-system, while bushy cultivars produce shallower, more spreading roots. Under favourable conditions both have large clusters of nodules.

Stems: are angular, hairy and branched. The point on the main stem where branching begins and the number of secondary branches varies, but in most types, branching begins between 6th and 10th node. Secondary branches have positive direct effect on seed yield (Wakankar and Yadav, 1977).

Leaves: are pinnately trifoliate, with lanceolate/elliptical leaflets. They show considerable variation in size and shape normally ranging from 4 to 7 inches (10-17.5 cm) in length and are of various shades of green pubescent or glaborous.

Flowers: are borne on short, axillary or terminal racemes and are usually about 0.8 inch (2 cm) in length. They vary in colour from pale yellow to orange, often with the standard petal. Stripped or spotted with dark red or purple, they may be self-pollinated or 5-40 per cent Cross-pollination can occur.

Pods: are somewhat flattened, dehiscent, 4-10 cm in length and 6-12 cm in breadth, green, purple or maroon or green sploched with purpple or maroon. They are more or less downy, obiquely constricted between the seeds and terminate n a slender beak. In some types of C.cajan seeds are pendent and in others they are quite erect. They contain 2 to 8 seeds which vary in size, shape and colour.

Psopocorpus tetragonolobus:

Root: Tap root system with nitrogen fixing root nodules.

Leaf: Alternate, trifoliate with long petiole, small stipules and broadly ovate.

Flower: Racemose inflorescence, axillary peduncles are 6-15 mm in length, bracteoles with calyx tube. Flowers are of two colours, back side petals are pale green, inner side petal is pale blue or violate and less often white (Backer and Buah, 1963).

Pods: Four cornered, rectangular with fringed wings. Vary in length, 16 to 36 cm (Rachie and Robert, 1974) containing 520 seeds.

Seeds: Transversely oblong hilum lateral, ostrophiolate (Hutchinson 1964); seeds are shiny cream coloured, greenish brown, deep purple, black or mottled (NAS 1975).

2) Cultivation:

(C.cajan)

(1) Soil:

The C.cajan can be grown on a wide range of soil. They are not deficient in lime and are well drained as it cannot stand water loging for optimum results, deep loam are almost natural soils and are required excessive acidic in habits, nodulation and plants may become chlorotic. Many cultivars are tolerant of saline soils, from 6-12 mm mhos/cm.. Most studies indicate the need for phosphorous. Eexperiments have shown that the application of sulphur alone or in combination with phosphorus can increase significantly seed yield and nitrogen content of root nodules.

(2) Distribution:

A monotypic genus comprising C.cajan an important leguminous crop widely distributed in the tropics and cultivated extensively for its edible seeds. An annual or perennial shrub plant is probably native of Africa and it is now grown in almost all the tropical countries of the world including Africa, America, India, Australia, Hawai, East and West Indies (Anonymous 1950).

According to Watt (1908) the commercial products of India (Red gram 196-200) pp. 1:189 says that no Indian botanist has recorded the plant in the wild or even in the naturalized state, hence he concluded that it may have been introduced in India. Early botanists introduced it in the regions of upper Nile in Egypt and found its cultivation as well as wild state in the coastal districts of Angola, Portuguese, West Africa, Loureiaro. Watt (1908) mentioned its growth and cultivation in China, Vietnam, Laos and Combodia. The plant is said to have been found growing on the mountains of Magelong in central Java, and according to Candole (1908) in Africa from Zanzibar to the coast of Guinea. This shows its wide distribution.

P.tetragonolobus is identified in the humid tropics of South and South-East Asia. In South Asia the regions where Psopocarpus tetragonolobus are grown in Bangladesh, Shrilanka. In Shrilanka it grows in wet as well as dry zone regions upto an elevation of 1000 m (NAS, 1975). Winged bean has been grown in India in the states of Goa, Maharashtra, Karnataka, Tamilnadu, Kerala, Madhya Pradesh, Orisa, Bengal and Tripura (Rajendran et al., 1978).

(3) Historical Account (Origin):

Although red gram (Cajanus cajan) has long been a cultivated crop, it is doubtful if it occurs wild anywhere in India. It has been reported to occur in the wild state of Africa in the region of upper Nile to the coastal districts of Angola. It appears to have been introduced into the West Indies through the slave trace and has now spread to Brazil, British Guiana and most of the warm parts of America. It has introduced into Australia about 80 years ago and grows well in the warmer parts there as a fodder crop (Turner, 1982) and also as a vegetable for cultivation in the north-eastern area of New-South Wales. Probably it was introduced in India by ancient traders trading on the route between Zanzibar, India, Ceylon. In India it is mainly grown in U.P., Madhya Pradesh, Bihar, Maharashtra, Gujarat, Andhra Pradesh and Madras.

Sturtevant (1919) states that Cajanus cajan certainly is one of the oldest cultivated plants in the world. Schweinfurth (1966) stated that it was found in Egyptian tombs of twelfth Dynasty (2200-2400 B.C.). The C.cajan was introduced into the new world in the sixteenth century and in the pacific during the eighteenth century.

P.tetragonolobus appears to be indigenous to Africa. The winged bean's origin remains in dispute. Four sites have shown possibilities: Papua New Guinea, Mouritious Madagascar and India. Pickering (1879) showed evidence that P.tetragonolobus was native of equatorial Africa. Leon (1968) considered P.tetragonolobus originated from West Africa, while Fairchild (1917); Brown and Massey (1929); Hutchinson and Dalzial (1958) reported it in Africa. Rumphius believed that winged bean had been brought to Amboins from Bali or Java by Arabs.

Origin of P.tetragonolobus is not firm. There are a few doubts about its origin that we have seen earlier. Its ancient history is not known. Pickering (1879) identified P.tetragonolobus was spread out at equatorial Africa but due to some discrepancy in the native place of P.tetragonolobus this evidence was not further flurished (The wealth of India 1969) stated that P.tetragonolobus was found in West Africa, Cadamoso (1970) found that rainfall in this region is not sufficient for the growth of P.tetragonolobus, the rainfall is 122 cm/yr. Leon (1968) considered the P.tetragonolobus was originated from West Africa.

Burkhill (1935) described that the origin of P.tetragonolobus was in East Africa. This thought was supported by Purseglove (1968). Baker (1877) listed that this spp. was not found in East Africa but was found in Mouritious, according to Phytogeographic evidence. It was proved by Smartt (1980) that P.tetragonolobus has an African origin, but this origin was further supported by many botanists.

Vivilow (1951); Cobely (1956); Barrau (1965); Herklots (1972); Cobely and Steels (1976) promptly said that its origin is India, but due to lack of further floral discription it was introduced to India (Loureico, 1988; Hocker, 1878). Ryan (1972) observed that New Guinea is the origin of P.tetragonolobus. Hymowitz and Boyd (1977) were unable to get literature to prove Ryan's conclusion and availability of evident points put forth. Papua New Guinea is the centre of origin for P.tetragonolobus

(2) Sowing Time:

Sowing time is critical affecting their growth period and height. Many of the day neutral cultivars give lower average yields and poor quality of seeds.

According to Agronomic studies on C.cajan vegetative and reproductive responses of two early maturing and two late maturing C.cajan accession of 8 sowing dates were investigated. Preflowering to pod ripening duration varied depending upon interactions between climatic factors and the photoperiodic responses of accessions. Qualitative short day, day neutral and interonediate photoperiodic forms were identified.

Vieira, R.D., Veira, R.V., Carvalho (1989) worked on seed development in pigeon pea, hyacinth bean and velvet bean and observed that 30th November sown seeds start flowering on 17th April, 17th May and 21st May in S.aterrimum, P.lablab.

C.cajan, variety ICPL - 87 were sown on 14th July 1990, sowing time of P.tetragonolobus is done early in the wet season.

Field work is done in 1 acre area. First the land was ploughed on 20th April. Then it was borrowed first on 5th of May, second harrowing was done on 30th May. Collections of stubbles were done on 4th June 1990. Applicants such as I.V.M. spread on 8th June 1990. Third harrowing was done on 12th June 1990. The seeds were sown on 14th July 1990 by giving basal dose of DAP. First weeding was done after 2-4 weeks. Later on Hoeing was done. Second weeding and third Hoeings were done after 2 and

4 weeks' later respectively. On top fret dressing by urea was done after one week. Proper irrigation was done and plant dusted with D.H.c. Pods were harvested on 14th November 1990. These pods were used for physiological studies from young till mature phase.

(3) Yield:

In India yields of C.cajan, when grown as a mixed crop, normally average between 200 and 800 lb/acre (225-900 kg/ha) and between 1500 and 1800 lb/acre (1680-2020 kg/ha) when grown as pure crop with efficient management. Several of the recently released cultivars have a higher yield potential, e.g., Pusa ageta 2400 lb/ac (2700 kg/ha). In E. Africa yields normally average between 400 and 600 lb/ac (450-670 kg/ha) but with good husbandry may reach 1000 lb/acre (1120 kg/ha).

Pospisil et al. (1971) reported the highest seed yield of P.tetragonolobus was 570.29 kg/acre (1400 kg/ha^{-1}) in Ghana. A few reports have indicated the seed yield of P.tetragonolobus more than 3 tonnes/ha (Khan, 1980) or 4 $tonnes/ha^{-1}$ (Wong, 1975). Range of fresh immature pods was 35 tonnes ha^{-1} (Wong, 1975; Martin, (1980). In Maharashtra 1035.19 kgs/ha to 2000 kgs/ha^{-1} dry seed yield about 10 tonnes ha^{-1} the pod yield has been reported by (Castrd, 1981).

(4) Nutritive value:

C.cajan seeds are rich in protein content. Two globulin contents such as cajanin and concajaniy 58 and 8 per cent of total protein content respectively. Khrishna *et al.* (1977) separated globulin into 3 fractions α, β, or γ fractions are rich in 'S' group containing amino acids.

The nutritive value of *P.tetragonolobus* in 100 g of uncooked edible portion reported by Hipsley and Clements (1947) was water content 79 g, protein 8.1 g, fat 3.9 g, carbohydrate D.C. 8.1 g, 97, thiamin 0.008, ascorbic acid 37. *P.tetragonolobus* contains proteins and amino acids such as methionine cystein and tryptophan. *P.tetragonolobus* is relatively deficient in the sulfur containing amino acids (Claydon, 1978).

TABLE-1.1

Chemical composition of pulses (per cent)

COMMON NAME	BOTANICAL NAME	MOISTURE	PROTEIN	FAT	CARBO-HYDRATE	FIBRE	ASH
1	2	3	4	5	6	7	8
Groundnut peanut	Arachis hypogaea	5.4	30.4	47.7	11.7	2.5	[illegible]
Pigeon pea	Cajanus cajan						
	(Whole)	10.1	19.2	1.5	57.3	8.1	3.8
	(split)	15.2	22.3	1.7	57.2	-	3.6
Jack bean	Canavalis ensiformis	11.0	23.4	1.2	55.3	4.9	4.2
Chickpea	Cicer metinum	9.8	17.1	5.3	61.2	3.9	2.7
Soybean	Glycine max	5.0-9.4	29.6-50.3	13.5-24.2	14.0-23.9	2.8-6.3	3.3-6.4
Lablab bean	Lablab niger	9.6	24.9	0.8	60.1	1.4	3.2
Khesari dhal	Lathyrus sativus	10.0	28.2	0.6	58.2	-	3.0
Lentil	Lens esculenta	11.20	25.0	1.0	55.8	3.7	3.3
Math bean	Phaseolus asconitifolius	9.3	23.0	0.7	59.0	4.0	4.0
Tepary bean	P.acutifolius	9.5	22.2	1.4	59.3	3.4	4.2
Adzuki bean	P.angulmis	-	21.0-23.0	0.3	65.0	-	-
Green gram	P.aureus	9.7	23.6	1.2	58.2	3.3	4.0

contd.

TABLE-1.1 contd.

1	2	3	4	5	6	7	8
Rice bean	P.calcaratus	10.5	21.7	0.6	58.1	5.2	3.9
Lime bean Butter bean	P.lunatus	12.6	20.7	1.3	57.3	4.3	3.8
Black gram	P.mungo	9.7	23.4	1.0	57.3	3.8	4.8
Kidney bean	P.vulgans	11.0	22.0	1.6	57.8	4.0	3.6
Garden pea	Pisum sarivum	10.6	22.5	1.0	58.5	4.4	3.3
Winged bean	Psophocarpus tetragonolobus	-	37.0	15.0	28.0	-	-
Broad bean	V.geba	14.3	25.4	1.5	48.5	7.1	3.2
Cowpea	Vigna unguiculata	11.0	23.4	1.3	56.8	3.9	3.6
Ground bean	Vomdzeia subterranea	-	16.0-21.0	4.5-6.5	50.0-60.0	-	-

Ref:

Fig: 1·1 - C. cajan showing nature habit

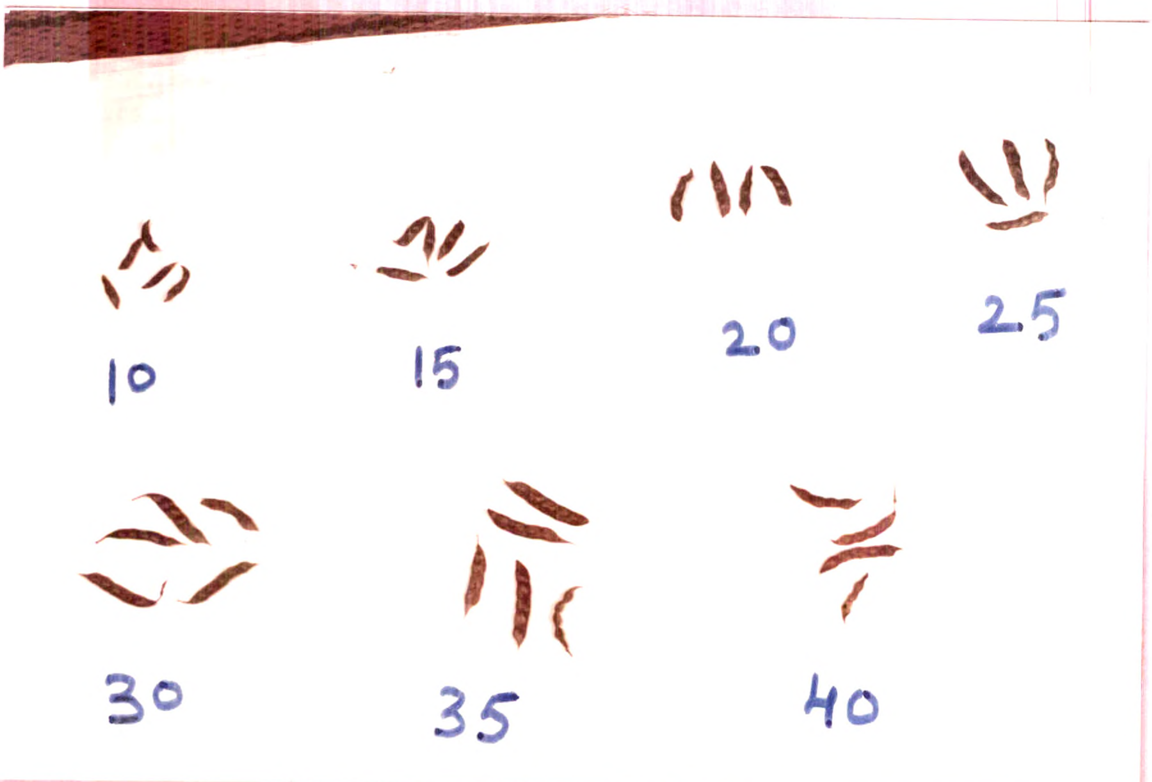

Fig. 1·3 :- Pods of C. cajan at different developmental stages

Fig. 1·2:- Parts of the P. tetragonolobus suitable for human consumption.