REVIEW OF LITERATURE

Chickpea (*Cicer arietinum* L.) is one of the important pulse crops widely cultivated in India. It is an ancient crop plant commonly called as Bengal gram or garbanzo. It belongs to family Fabaceae.

**Origin:**

The chickpea has been cultivated since 5450 B.C. (Helback, 1959). It is claimed that chickpea originated in the Turkey-Syria region and then spread towards South Asia. According to van der Maesen (1987), there are more than 30 wild species, of which 13 perennial species are found in the Afghanistan-Pakistan-India region. An annual species, *Cicer reticulatum*, considered to be the progenitor of the cultivated chickpea, has not been found in the Afghanistan-Pakistan-India region. It is a matter of speculation that the presence of wild species of a domesticated species in a geographical area indicates the origin of the latter, as also its domestication. Accordingly, West Asia is claimed to be the region where chickpea was domesticated. The colored Kabuli type chickpea most probably arrived in this region only about 200 years ago apparently through Afghanistan and its Hindi name Kabuli chana, is an illusion of the Afghanistan capital Kabul. According to van der Maesen (1987), the Greek word *erebinthos* was mentioned in the *Iliad* of Homer (c. 1000–800 BC), but Theophrastus (370–285 BC) specified it for chickpea. Alexander III of Macedon (336–323 BC), who invaded northern India in 326 BC, was a contemporary of Theophrastus. It is easily possible that the Sanskrit word *harimanth* was corrupted, during the Greek-Indian interaction, to the word *erebinthos*. The common Greek word for chickpea is *krios*, meaning ram’s head, indicating the
resemblance of chickpea to a ram’s head. By the time Theophrastus specified the word *erebinthos* for chickpea, the *desi* chickpeas had become a very common crop in India. Regarding the origin of *kabuli* and *desi*, it is almost certain that *desi* originated first followed by *kabuli* type developed by selection and mutation (Sant, 2001).

Ethiopia was also considered as a possible center of origin for chickpea (Vavilov, 1926).

**Systematic position:** The systematic position of chickpea can be outlined as follows;

- **Kingdom:** Plantae
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Order:** Fabales
- **Family:** Fabaceae
- **Sub-family:** Faboideae
- **Genus:** *Cicer*
- **Species:** *C. arietinum*

The binomial nomenclature of chickpea is *Cicer arietinum* L., where *Cicer* is the genus and *arietinum* is the species.

**Common name**

Chickpea has been described by different names garbanzo (Spanish), pois chiche (French), kicher or chicher (German), chickpea, Bengal gram or simply gram (English). In India chickpea has various names in different parts like *chana* in Uttar Pradesh, Rajasthan, Bihar, Madhya Pradesh, Gujarat and Haryana; *chhole* in Punjab; *chholla* in
West Bengal; *boot* in Orissa; *butmah* in Assam; *canagalu* in Andhra Pradesh; *harbhara* in Maharashtra; *kadalai* in Tamil Nadu; *kadala* in Kerala and *kadale* in Karnataka.

**Botanical characters:**

The genus *Cicer* which was traditionally placed in the tribe *Vicieae* has now been removed and placed in its own monogeneric tribe *Cicereae* Alef (Kordi et al., 2006) in subfamily Faboideae of family Fabaceae. The genus contains two subgenera *Pseudononis* and *Viciastrum* (Sant, 2001) which comprise 44 species, 8-annual wild, 35-perennial and one the domesticated chickpea, *Cicer arietinum* L. (Toker, 2009).

**Types of chickpea:**

Two types of chickpea are grown in the world, *desi* (microsperma) and *kabuli* (macросperma) types. Both are generally distinguished by their size and seed coloration. The *desi* types are characterized by smaller, sharply angular, variously pigmented seeds and generally have seeds that are less than 26 grams per 100 seeds. There are 2-3 ovules per pod but on an average 1-2 seeds per pod. While the *kabuli* types are characterized by generally larger seeds that weigh in excess of 26 grams per 100 seeds, are rounded, and white or cream colored. They can vary widely in size. The plants are medium to tall in height, with large leaflets and white flowers and contain no anthocyanin. Often the *kabuli* seed type is referred to as “Ramshead.” There are some kabuli types smaller than 26 grams per 100 seeds and some desi types that are larger than 26 grams per 100 seeds.

Chickpea is primarily grown in four regions viz. the Indian subcontinent, east Africa, the Mediterranean region and Latin America. The first two regions primarily grow *desi* type and the latter two regions the *kabuli* type (Singh, 1990). In India, *desi* type accounts for nearly 90% area under chickpea cultivation and *kabuli* type is grown in around 10% area.
**Morphology:**

Chickpea is a small herbaceous plant. Majority of the types are semi-spreading and show profuse branching. A few are semi-erect and have less number of branches. Plant height is variable being highly dependent on environmental conditions. It ranges from 20-100 cm; some tall cultivars under favourable conditions can reach height upto 150 cm. Glandular hairs are present on all green parts of the plant.

**Stem:**

The main stem is erect, woody, rounded, viscous, hairy, herbaceous, green, solid and branched. There are primary, secondary and tertiary branches (Cubero, 1987). The stem and branches are covered with hairs which are uniseriate and multicelled, the terminal cell being large, oval and hyaline. In some cultivars, the lateral branches are ribbed, sometime prominently giving the appearance of quadrangular stem. Primary branches are thick, strong and woody may range from one to eight in number and represent the most important character in determining the plant type; prostrate or erect. Secondary branches develop at buds located on the primary branches which are less vigorous than primary branches. The number of secondary branches varies from 2-12. Tertiary branches located on buds of secondary branches are rather leafy and not always present.

**Root:**

Chickpea has strong tap root system with extensive laterals. The laterals continue to elongate and branch resembling thread like structures, spreading far and wide, some times reaching a depth of over one meter, but the effective root zone is generally confined to 30 cm depth. Roots have bacterial nodules. The nodules are simple and multi-lobed.
and generally confined on tap-root. However, the later formed nodules develop on lateral roots. Under certain conditions, a single nodule may weigh anywhere from 1 to 3 gm and may be 2-5 cm in size.

**Leaves:**

Leaves are alternate, stipulate, petiolate, compound, pinnate or odd-pinnate about 5 cm long and yellowish-green to dark bluish-green with 11-18 leaflets with a small pedicel. Rachis is 3-7 cm long ending in top leaflets. Leaves have ovate to triangular stipules usually 3-5 mm long and 2-4 mm wide and toothed. Leaflets have serrate, ovate, elliptical or obvate margin. The leaflets may be opposite, or rarely alternate and normally 6 mm long and 4 mm broad. The size of *kabuli* type is generally larger than desi type. Green leaves have malic and oxalic acids which are prescribed for intestinal disorders. They are covered with glandular hairs which secret the acidic solution.

**Flower:**

Chickpea flowers are complete and bisexual. Flowers of *desi* types are typically violet or pink; whereas flowers of *kabuli* types are white. Flowers are single (rarely two, e.g. JG-62) or three, in axillary racemes; peduncle is 6-13 mm long ending in a small arista, 2-4 mm bracts small triangular up to 1.5 mm, pedicels 6-13 mm, straight when flowering, recurved when bearing fruits. Flowers have typical papilionaceous structure. The flower consists of a five leafy calyx with deep lacerolate teeth, which forms a tube that is persistent. Teeth are longer than the tube and have prominent midribs. The five sepals are subequal. The two dorsal sepals are closer to each other than they are to the two lateral ones in the ventral position. The fifth calyx tooth is separate from others. The calyx tube is oblique. Chickpea flowers have five petals. Corolla is polypetalous, includes
a standard (vexillum), two wings and two lower petals that lie inside the wings and are united at the lower margin to form a keel. The corolla is pinkish, purplish or red (fading into blue). The stamens are diadelphous (9) +1; nine stamens have fused filaments and are placed ventrally around the ovary forming androecial sheath, leaving the tenth stamen free, situated dorsally above the ovary. The staminal column is persistent. The fused part of the filament is 4-5 mm long and the free part is 2-3 mm, upturned, and dilated at the top. The stamens facing the petals are a little longer than others. The anthers of stamens are bicelled, basifixed and round. The other anthers are dorsifixed, ovate, and longer than the basifixed ones at flowering. The anthers burst longitudinally. The pollen grains are orange. The ovary is monocarpellary, unilocular and superior with marginal placentation. It is ovate, 2-3 mm, 1-1.5 mm wide, mostly with two and up to 4 ovules, style 3-4 mm long, linear, glabrous or hairy except for last mm upturned. The stigma is globose and capitate that hardly gets broadened when pollinated. Sometimes it may be of the same size as the style. Chickpea is quantitatively ‘long-day’ plant but flowers in all photoperiods (Smithson et al., 1985).

The floral formula is – K (5), C 2+2+1, A (9) +1, G1.

Pods:

Pods are usually borne singly, (two pods in JG-62) on the top portion of plant, usually a minimum of six to eight inches above the soil surface. Pods have an inflated appearance and usually contain 1 or 2 seeds, but rarely more than two. Pods are relatively resistant to shattering. Pods have glandular trichomes. The seeds are irregular in shape and have a pointed beak and small hilum. The seed is exalbuminous. The testa is smooth, wrinkled or rough, ranging in color from white, yellow, red, brown to nearly black.
(Purseglove, 1968). The seed germination is of hypogeal type. The anterior of the seeds of both types is ‘beaked’.

**Cytogenetical Investigations:**

The diploid (2n) number of chromosomes in *Cicer arietinum* L. has been earlier reported to be 14 (Dombrovsky-Sludsky, 1927; Rao, 1929; Dixit, 1932a; Singh, 1964; Furnkranz, 1968) as well as 16 (Milovidov, 1932; Dixit, 1932b; Adulov, 1937; Iyengar, 1939; Ramanujam and Joshi, 1941; Meenakshi and Subramanium, 1966; Phadnis *et al* 1968). Information on cytological and cytogenetical aspects of chickpea is meager. Recently the diploid chromosome number of *Cicer arietinum* L. of 2n = 16 has been well established.

In chickpea, mitotic chromosome squash preparations have been quite difficult to obtain because of the presence of globular structures in the cytoplasm that hinder the staining, spreading and identification of chromosomes (Lather *et al*., 1990). Some workers carried out cytological studies on *Cicer* (Mercys *et al*., 1974; Lavania and Lavania, 1982; Sharma & Gupta, 1986; Venura *et al*., 1991; Galasso and Pignone, 1992; Ocampo *et al*., 1992; Ahmad and Hymowitz, 1993; Tayyar *et al*., 1994; Ahmad, 2000). Sharma and Kumar (2004) carried out meiotic studies in chickpea after EMS treatment.

Kordi *et al* (2006) have studied karyotypic analysis for 11 genotypes of chickpea in order to determine their potential genetic relationships. The characteristic features of chickpea karyotype emerged from these cytological studies indicated a pair of longest satellited submetacentric chromosomes, a pair with the shortest metacentric chromosome and six pairs of metacentric to submetacentric chromosomes. Intraspecific variability was
observed for haploid chromosome length, position of primary constriction and karyotype formula.

Tayyar et al (1994) and Gallaso et al (1996) reported that there are rearrangements both in heterochromatin and euchromatin during evolution of chickpea. Ahmad and Godward (1980) numbered chromosomes from 1 to 8 in order of decreasing size of the chromosomes, the size differences from pair one to pair eight being in the ratio of 3:1. The genome size of chickpea is a comparatively small (Arumuganathan and Earle, 1991) which is 750 Mbp (Sethy et al., 2006).

Systematic genetical research on chickpea, leading to the patterns of inheritance of qualitative and quantitative characters have been studied by various workers. Singh and Ekbote (1936) studied the inheritance of colour, shape and surface of seed and observed that these characters are all associated. Investigations carried out by Balasubrahmanyan (1937) on foliage colour and seed surface indicated that green and pale-green foliages were inherited in a monogenic fashion and the two alleles were designated as $L_g$ and $l_g$, respectively. Likewise, roughness and smoothness of the testa were governed by a single gene, $R_h$, with factors $T^1$ and $T^2$ showing darkening effect on testa. Later on, Balasubrahmanyan (1952) reported two more factor pairs, designated as $T^1 T^2$ and $T^3 T^4$, which affected seed coat colour. Black testa in chickpea was reported to be conditioned by two complementary genes, $T_{ba}$ and $T_{bb}$ (Argikar and D’Cruze, 1962). Pawar and Patil (1982) reported that testa colour in chickpea is governed by a single gene, $B_{sc}$, with dark brown being dominant to brown. Phadnis (1977) found that wrinkled testa is dominant to smooth, with evenness of seed surface being controlled by two complementary genes.
Athwal and Brar (1964) conducted genetical studies in respect of eight characters, like tiny leaf, stalked leaflet, simple leaf, bushy, double flower, round pod, giant and flat stem. All these characters were found to be governed by independent single recessive genes designated as $tl$, $sl$, $st$, $bu$, $df$, $rp$, $gt$ and $fs$, respectively. Gaur and Gaur (2002) reported a gene producing one to nine flowers per flowering node in chickpea.

Khosh-Khui and Niknejad (1971) reported that purple flower is dominant over white flower. Mian (1971) observed monofactorial inheritance for flower colour with pink flower being dominant over white. Gumber and Sarvjeet (1996) studied the genetics of time to flowering and found that it was controlled by two genes. Kumar et al., (2000) reported that flower color in chickpea was controlled by three independent genes ($B, C$ and $P$). Many researchers studied the genetics of chickpea and worked out the type of gene action for the important agronomic and quality characters in chickpea. Information emanating from these studies can be used by chickpea breeders to formulate the breeding methodology suitable for different situations. Varshney et al (2007) prepared molecular markers and genetic linkage maps of chickpea. Rajesh et al (2004) constructed a bacterial artificial chromosome (BAC) library and studied the stability of chickpea genomic DNA fragments upto 100 kb in size transformed into A. tumefaciens. Millan et al (2006) discussed the recent approaches and future prospects for functional genomics of chickpea. Sethy et al (2006) developed microsatellite markers and analyzed intraspecific genetic variability in chickpea. Recently research has been focussed on the use of genetics and biotechnological tools to enhance the knowledge of the genomics of chickpea (Muehlbauer, 2008).
Mode of reproduction: -

Chickpea is predominantly self pollinated plant with only 1.58 % - 1.92 % natural cross pollination. Flower and pod formation in chickpea is related to temperature. Excessive rain soon after sowing or at flowering can cause great harm to the crop. Severe cold is injurious and is very harmful. The flowering time of chickpea is variable depending on season, sowing date, latitude, and altitude (Summerfield and Roberts, 1988). Kumar and Abbo (2001) have reported that time to flowering plays a central role in determining the adaptation and productivity of this crop in short growing environments. The flowers are cleistogamous and protandrous. The anther bursts one to two days before the bud opens. Flowers start opening between 0900-1000 hours. However anthesis may take place on the previous day of flower opening between 0900-1000 to 1430 hours. The stigma remains receptive upto 36 hours, commencing 24 hours before flower opening. Keel is closed and foreign pollen cannot reach the stigma. The pollen remains viable for 8.30 hrs at 27.8 °C and 95% relative humidity and for 9 days at 7.7 °C and 100 % relative humidity. Pollination takes place from 0800 to 1200 hours in bud stage. Germination of pollen is generally highest at 25 °C and falls off drastically at cooler and warmer temperatures.

Antinutritional factors (ANF) in legumes: -

Even though the pulses are considered to be highly proteinaceous and nutritious food, they are known to contain toxic substances. These are called as antinutritional factors (ANF), which include trypsin and chymotrypsin inhibitors, phytohaemagglutinins (lectin), polyphenols, flatulence sugars, saponins and alkaloids. These factors impair
nutrient absorption from gastrointestinal tract and can result in detrimental effects on animal health and growth (Christodoulou et al., 2006).

1) Trypsin and chymotrypsin inhibitors:

The presence of protease inhibitors in legumes is a well known fact (Smirnoff et al., 1976). These are the substances that inhibit the activity of trypsin and chymotrypsin in the digestive system reducing protein digestibility. They have been found throughout the plant kingdom, particularly among pulses (Liener and Kakade, 1980; Gupta, 1987). These inhibitors have been identified in different pulses in varying degrees.

Trypsin inhibitor was first reported by Read and Hass (1938). Later on Bowman (1946) purified it and Kunitz (1945) isolated it in crystalline form.

A comparative study of inhibitors from different pulses by Prabhu et al (1984) revealed that the field bean, kidney bean and chickpea were more active in inhibiting bovine pancreatic proteinases, whereas cowpea and red gram were more effective in inhibiting the human chymotrypsin.

2) Lectins (Phytohaemagglutinins):

Lectins are carbohydrate-binding proteins (or glycoprotein) of non-immune nature, and bind reversibly to specific mono- or oligosaccharides (Goldstein et al., 1980, Van Damme et al., 1998). Lectins adhere to the glycol-proteins present on the inner linings of the small intestine and inhibit absorption of food particles. Legume lectins are divided into two groups, one and two chain lectins. The two chains are the product of proteolytic cleavage of a precursor protein. Lectin proteins are stored in protein bodies within the cell (McPhee and Muehlbauer, 2002). They play an important role in plant defense against pests, and have been found to be toxic to viruses, bacteria, fungi, insects.
and higher animals (Arora et al., 2005). Lectins have been reported to affect survival and development of insect pests (Janzen et al., 1976; Shukle and Murdock, 1983; Czapla and Lang, 1990; Habibi et al., 1993; Gatehouse et al., 1993, 1995; Powell et al., 1995; Law and Kfir, 1997).

3) Saponins:

Saponins are secondary metabolites of mixed biosynthesis. They consist of a triterpene or steroid nucleus with mono or oligosaccharide attached to this core. Saponin containing food when taken in large quantity causes abdominal pain, vomiting and diarrhoea. They have long been considered undesirable due to toxicity and haemolytic activity. However, there is enormous structural diversity within this chemical class, and only a few are toxic (Rochfort and Panozzo, 2007). They have been reported in a wide variety of foods like chickpea, soybean, navy beans, haricot beans and kidney beans (Fenwick and Oakenfull, 1983). The seeds of such plants contain saponins 56, 43, 21, 19 and 16 gm/kg of seed material, respectively (Fenwick and Oakenfull, 1983). They were not destroyed by processing or cooking.

The role of saponins in the plant is not clear. It is suggested that they play a role in chemical defense. Studies of some lupin saponins have shown that they possess moderate antifungal activity (Rochfort and Panozzo, 2007).

4) Alkaloids:

The alkaloid content of the legume seeds may be undesirable for human or animal consumption. There is evidence that the alkaloid content is protective for the plant (Rochfort and Panozzo, 2007). Alkaloids produce a bitter taste and are diverse in chemical composition. They have nitrogen in their basic components, comprised of
complex components derived from various amino acids, provide a characteristic color and fluorescence reaction with many reagents and produce pharmacological effects on various organs of humans and animals. Eight different categories of alkaloids have been established based on chemical structure; 1) pyridine, piperidine and quinolizidine, 2) tropane, 3) quinoline, 4) isoquinoline, 5) bisbenzylisoquinoline, 6) indole, 7) steroidal, and 8) purine alkaloids (McPhee and Muehlbauer, 2002). The lupins are found susceptible to a large number of insect herbivores to which the wild types are resistant (Rochfort and Panozzo, 2007).

5) Flatulence:

Pulses are known to produce flatulence, which causes considerable inconvenience when consumed in large quantities. Ingestion of cooked dry beans causes human flatulence. This characteristic discouraged broader use of such high protein food.

The specific factor/s responsible for flatulence has not been established. However certain oligosaccharides-sucrose, stachyose, raffinose and verbascose play important roles. It was reported that stachyose and raffinose in the beans were not rapidly digested. Anti-oligosaccharide enzyme is necessary to properly digest these sugar molecules. As a normal human digestive tract does not contain any anti-oligosaccharide enzymes, the consumed oligosaccharides are typically digested by bacteria in the large intestine. This digestion process produces carbon dioxide, hydrogen and to lesser extent methane gases as a byproduct. Production of these gases which leads to flatulence with symptoms of nausea, cramps, diarrhoea, abdominal rumbling, and social discomfort is associated with the ejection of rectal gas. This aspect of the bean digestion is the basis for the children’s rhymes “Beans, Beans, the Musical Fruits.”
Dry navy, kidney and pinto-beans produced more flatulence than dry peas, green gram or soybeans (Murphy, 1972). These differences were reported to depend on species, variety and growth conditions.

Chickpea also contains raffinose family oligosaccharides (RFOs) such as stachyose, raffinose and small amount of verbascose. *Kabuli* varieties have been reported to contain relatively low amounts of antinutritional factors (Rubio *et al*., 1998).

6) Polyphenols:

Polyphenolic compounds are found in various plants which are utilized as food and feed. These compounds are considered to be nutritionally undesirable. They form complexes with proteins, starch and digestive enzymes to cause a reduction in nutritional value of food (Bressani and Elias, 1980). Polyphenolic compounds were reported to be responsible for decrease in growth rate, feed intake, feed efficiency, net metabolic energy and protein digestibility (Hulse, 1980 and Price and Butler 1980).

Sorghum tannins have been reported to cause leg abnormality in hens and delaying of physical and sexual maturity or even death in hamsters (Butler *et al*., 1986).

The presence of high levels of dietary antinutritional factors from food legume can cause substantial reduction in protein and amino acid digestibility upto 50 % in animals.

The levels of the antinutritional factors determined in chickpea whole seeds are shown in Table -5 (a).
Table: 5 (a): The levels of anti-nutritional factors in seed samples of chickpea

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Component</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trypsin inhibitor (Units/mg meal)</td>
<td>8.1-15.7</td>
<td>11.6</td>
</tr>
<tr>
<td>2</td>
<td>Chymotrypsin inhibitor (Units/mg meal)</td>
<td>6.1-8.8</td>
<td>7.7</td>
</tr>
<tr>
<td>3</td>
<td>Amylase inhibitor</td>
<td>5.0-9.7</td>
<td>6.8</td>
</tr>
<tr>
<td>4</td>
<td>Stachyose (%)</td>
<td>0.8-1.9</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>Raffinose (%)</td>
<td>0.4-0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>Polyphenols (mg/g sample)</td>
<td>1.9-6.1</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Source: (Jambunathan et al., 1984)

Chickpea Research:

Work on chickpea improvement in India started in 1930s at the Imperial Agricultural Research Institute, Pusa, Bihar. At that time major emphasis was on selection of pure lines from the land races. Earlier the cultivars/ lines were evaluated on the basis of their yielding ability and later emphasis was laid on collection of germplasm, studying hybrid vigour and combining desirable traits through hybridization.

Systematic research on chickpea was started under the ambit of All-India-Co-ordinated pulses Improvement Project commissioned in 1967. Initially, the programme was launched at the 12 centers and the head quarter of the project was at the Indian Agricultural Research Institute, New Delhi.

In 1977, the project was upgraded as the project Directorate and its head quarter was shifted to Regional Research Station of the IARI at Kanpur. Realizing the importance of chickpea, an independent All-India Co-ordinated Project was launched in 1993 with 9 mandatory and 12 verifying centers.
Varietal development:

In early fifties and sixties, the efforts were concentrated to select high yielding genotypes from germplasm or landraces, without putting much energy on hybridization and selection programme. The first variety of chickpea, Chaffa having medium size grain and early maturity was developed in 1948 through selection in Niphad (Maharashtra). The other variety CO 1 was developed through selection from Coimbtore Local and released in 1953 for rainfed black soils of Tamilnadu besides RS 10 from Sriganganagar and Annegiri from Bangalore. The variety C 235 was developed through hybridization (IP 58 x C 1234) at Ludhiana which is widely adaptable (suitable for rainfed areas), tolerant to *Ascochyta* blight, medium tall and with high-yield potential (2.0 – 2.5 tonnes/ha). In 1961-70, RS 11 was developed through selection from germplasm, for Rajasthan with average yield of 1.2-1.8 tonnes/ha. In the same period, a high-yielding, bold-seeded variety Radhey was developed through hybridization (197 x 76) for Uttar Pradesh and is still under cultivation in some parts of the central India. As a result of co-ordinated research efforts, more than 12 high-yielding varieties were developed through selection from germplasm and hybridization during 1971-80. Some of the important varieties developed through hybridization comprised: C 214 in 1971 from G 24 x IP 58 x G 24 at Hissar; G 130 in 1971 from 708 x C 235 and Hare Chole 1 in 1973 from S 26 x GG Bijapur at Ludhiana; B 108 in 1973 from N 31 x B 75 at Berhampore, which is tolerant to wilt; and H 208 was released in 1977, developed through hybridization of S 26 x G 24 x C 235 at Hissar. BDN 9-3, a selection from Badnapur and L 550, a Kabuli chickpea variety, were developed in 1974 through cross of Pb 7 x Rabat with 20-25 g 100-seed weight and 2.0-2.5 tonnes/ha yield. In 1980, Pusa 209 developed from the cross
of P 827 x C 255 at the IARI, New Delhi, has been released for rainfed and irrigated areas of north-west, north-east and central zone. It is resistant to wilt, root-rot and tolerant to grey mould and produces 2.2-3.0 tonnes/ha yield. The other important varieties developed during this period were H 335, G 543, Jyoti, CO 2, and B 124 for various parts of the country. Small-seeded, high-yielding variety Pant G 114 developed in 1979 at Pantnagar for general cultivation in northern plains showed tolerance to wilt and Ascochyta blight.

During 1981-90, Pusa 212, Pusa 244, Pusa 256, Pusa 261 through hybridization; Pusa 408, Pusa 413 and Pusa 417 through mutation have been developed by the Indian Agricultural Research Institute. The Kabuli chickpea variety BG 267 was also developed through hybridization during the same period.

Several other promising varieties such as Gaurav, Haryana Chana 1, GNG 146, RSG 2, Vikas, Vishwas, Vishal, Phule G 12, JG 62, JG 315, JG 74, Bheema, ICCC 37 (Kranti), ICCV 2 (Swetha), CO 3, PDG 84-10 and Akash have been released for various parts of the country.

Wide hybridization involving wild species has shown wide range of variability in respect of maturity, pods/plant, branches/plant, basal profuse branching, plant type, seed size and seeds/pod. To bring additional area under chickpea cultivation, early-maturing genotypes were developed which can be planted up to mid December and fit well in the major cropping systems. The genetic yield potential of these genotypes varied from 20 to 30 tonnes/ha. Pusa 329, KGD 1168, Pusa 362, BDNG 154 and Vijay have also been released which have resistance to wilt. The search for improved plant type was initiated
in eighties for breeding of chickpea with well-defined objectives. Through desi and Kabuli introgression and recombination breeding approaches, recently tall, compact and productive derivatives have been developed, which are being used in hybridization programme and some of them are being promoted for yield testing at the All-India level through the All-India Co-ordinated Project on Improvement of chickpea.

Induced mutagenesis has been undertaken at few places to generate desirable variability in chickpea. Wide range of induced genetic variability has been observed for morphological as well as polygenic traits. Some of the important macromutants are simple leaf, narrow leaf, tiny leaf, dwarfs, compact, upright tall, short internode and compact, bold seeds, bushy growth and gigas plants. Through mutation-breeding programme, BGM 408 for north-west plain, BGM 413 for north-east plain and BGM 417 for central zone have been developed. BGM 417 is highly resistant to wilt, tolerant to collar rot, foot rot and root rot, and is suitable for cultivation in rainfed as well as irrigated areas. The other varieties like RS 11 and RSG 2 have also been developed through mutation. Recently, Nuclear Institute for Food and Agriculture (NIFA) Peshawar, evolved high yielding desi chickpea variety ‘NIFA-2005’ through induced mutations (gamma rays).

In recent years, the scope for improvement of crops by transferring useful genes creating more variability and reconstituting genomes through wide hybridization has been realized. The genes from *C. reticulatum*, *C. judaicum*, *C. bijugum*, *C. pinnatifidum* and *C. yamashitae* have been transferred to *C. arietinum*, the cultivated chickpea. Crosses among wild species have also been reported, viz *C. reticulatum* x *C. echinospermum*, *C.
C. judaicum x C. bijugum, C. pinnatifidum x C. bijugum and C. judaicum x C. pinnatifidum. Some of the useful traits present in wild species like resistance to Ascochyta blight, wilt, Botrytis grey-mould, earliness, cold tolerance, high methionine content and high-tryptophan content have attracted the attention of researchers. The segregants/derivatives of interspecific crosses have shown tremendous variability for maturity period, pods/plant, seeds/pod, 100-seed weight, branches/plant and number of basal secondary branches, at Ludhiana, Kanpur, Hyderabad, New Delhi, and several other locations. Several sources of resistance against biotic stresses have been identified during the last 50 years. Besides these donors, 6,214 active collections of chickpea have been made and these are being maintained at 23 centres of the All-India Co-ordinated Research Project on improvement of Chickpea. In different years most of these genotypes have been evaluated and considerable variability for several economic traits has been noticed. Projects on biotechnological researches were initiated in late eighties at several places and success in wide crosses through embryo-rescue has been achieved in chickpea. The work on identification of probable progenitors of Cicer arietinum is in progress at various places. Molecular characterization of genetic resources is the need of the present day and therefore projects have been initiated at the IIPR, Kanpur, IARI, New Delhi, and at several other locations involving that aspect.

**Importance of mutation breeding:**

Genetic variability is fundamental to successful breeding programs in vegetatively and sexually propagated plants. This variation can occur naturally or can be induced through mutations, using physical, biological or chemical mutagens and has attracted the
interest of plant breeders for many decades. Mutations have been used to produce many cultivars with improved economic value and to study genetics and plant development phenomena (Divanli et al., 2006).

The idea of inducing new mutational change artificially by use of mutagens and enhancing the variability for plant and animal breeding came after the discovery of mutations by Hugo De Vries (1901).

The physical radiations can significantly increase the frequency of mutations was confirmed by the experiments of Muller (1927) in the fruit fly *Drosophila melanogaster* and later by Stadler (1928) in maize and barley. This initiated a new field of induced mutagenesis, which later was to become the most important technique in locating genes on chromosomes, studying gene structure, expression, regulation and for exploring genomes.

Chemical mutagenesis was initiated by Auerbach and Robson (1942, 1947) in animals and by Rapoport in plants (1948). Successful application of induced mutation in plants was first achieved by Gustaffson in Sweden. He produced the first mutant cultivars, namely, Pallas and Mari, as erectoide mutants of cv. Bonus in barley during the 1950s. Since then the mutation breeding in plants developed rapidly. Mutation induction with radiation was the most frequently used method to develop direct mutant varieties (89%). The use of chemical mutagens was relatively infrequent. Gamma rays were employed to develop 64% of the radiation-induced mutant varieties, followed by X-rays (22%).

The high efficiency of mutation techniques to generate desired variation in crop plants has been widely proven and documented in many original and review papers. In
the history of induced mutations, there are many examples on the development of new
and valuable alteration in plant characters significantly contributing to increased yield
potential of specific crops. Induced mutations will continue to have an increasing role in
creating crop varieties with traits such as modified oil, protein and starch quality,
enhanced uptake of specific metals, deeper rooting system and resistance to drought,
diseases and salinity as a major component of environmentally sustainable agriculture.

The year 2008 was the 80\textsuperscript{th} anniversary of mutation induction in crop plants.
During the last 80 years, more than 2700 mutant varieties of 170 plants (Lagoda \textit{et al.},
2009) including cereals, oilseeds, pulses, vegetables, fruits, fibers and ornamentals have
been officially released in 60 countries all over the world. Most mutant varieties were
released in China (26.8\%), India (11.5\%), USSR and Russia (9.3\%), Netherlands (7.8\%),
USA (5.7\%) and Japan (5.3\%). Many induced mutants were released directly as new
varieties; others were used as parents to derive new varieties.

Mutation breeding particularly induced mutation has played an important role in
developing many crop varieties in various parts of the world apart from enhancing the
desired genetic variability in different traits of plants (Micke, 1988; Haq \textit{et al.}, 2003). In
the changing world ahead, mutation induction is bound to strengthen its role in
overcoming hunger and malnutrition, consolidating agriculture’s contribution to
sustainable economics and social development, conserving and exploiting the natural
resources base in sustainable way. Recent technology developed in the field of mutation
breeding and mutagenesis includes, TILLING (Targeting Induced Local Lesions IN
Genomes), space mutation induction, ion beam technology, doubled haploid technique,
SSR multiplexing and new high through-put marker technology.
In India, Swaminathan and his team at the Indian Agricultural Research Institute, New Delhi initiated a major programme on mutagenesis in crop plants. Besides IARI, mutation breeding work was pursued at several universities and research institutes, notably, at Bhabha Atomic Research Centre, Mumbai, Tamilnadu Agricultural University, Coimbatore, and National Botanical Research Institute, Lucknow. Up till now 313 mutant varieties of different crops are released for cultivation in India (Chopra, 2005).

Swaminathan et al (1962) proposed that higher frequency of chlorophyll mutations is due to the preferential action of EMS on chlorophyll development genes located near centromere. Higher frequency and wider spectrum of chlorophyll mutants in chemical mutagen have been reported (Koli & Ramkrishna, 2002; Sharma & Sharma, 1984; Marki & Bianu, 1970; Kawai, 1969). Kharkwal (1998) reported dose dependent decrease in the frequency of chlorophyll mutations with gamma irradiation. Shah et al (2006) firstly reported induced genetic variability for frequency and spectrum of chlorophyll mutations on the recombinant of desi x kabuli chickpea introgression genotype. EMS induced a wide spectrum and a high frequency of chlorophyll mutations as in mungbean (Khan et al., 2005) and barley (Gaul, 1964).

Extensive studies have been undertaken on mutagenesis in cereal crops (Konzak et al., 1965; Nilan et al., 1965; Saleem et al., 2005; Kumar and Rai, 2007) besides the quality of legumes like pigeon pea (Veerswamy et al., 1975; Chary and Bhalla, 1988; Dwivedi et al., 1989; Yadav and Padmaja, 2004), winged bean (Veeresh and Shivshankar, 1987; Kothekar et al., 1996), mungbean (Tickoo and Chandra, 1999 and Naik et al., 2000; Wani and Khan, 2006; Tah, 2006; Lal and Mishra, 2006; Singh, 2007),
The improvement aspects like quality and quantity of oil and protein have been successfully attained by several researchers through mutation breeding in oil crops like groundnut (Gregory, 1956; Prasad et al., 1984; Mathur et al., 2006; Mensah and Obadoni, 2007; Mondal et al., 2007), soybean (Rawlings et al., 1958; Koo, 1972; Bale, 1999 and Addai and Kantanka, 2006), mustard (Zareen, 1991; Sah et al., 1994; Gupta et al., 2004) and safflower (Ramchandram and Goud, 1983; Reddy, 1991; Satpute, 1994). The mutation breeders have visualized that the desirable mutants in different legumes and oil crops would be able to contribute effectively towards yield and protein content besides providing induced variation for disease, insect and pest resistance. Future research on induced mutations would also be important in the functional genomics of many food crops.

**Induced mutations in chickpea:**

Although induced mutations have been undertaken in the past on some grain legumes, however limited attempts have been made on chickpea. Pathak and Sahai (1964) recorded ten new mutants in chickpea. Dahiya et al (1984) and Gaur et al (2008) have reported Brachytic growth mutant in chickpea characterized by erect growth habit, thick and sturdy stem, short internodal and
interleaflet distances and few tertiary and later order branches. Sheikh et al (1982) reported high yielding and high protein induced mutants of chickpea. The differential spectrum of morphological mutations has been reported by Kharkwal (1999). Toker and Cagirgan (2004) also studied the spectrum and frequency of induced mutations in chickpea. Higher frequency and wider spectrum of chlorophyll mutants in physical and chemical mutagens have been reported (Koli & Ramakrishna, 2002; Sharma & Sharma, 1984; Marki & Bianu, 1970; Kawai, 1969). Shah et al (2008) studied comparative mutagenic effectiveness and efficiency of gamma rays and EMS in chickpea. Seeds of chickpea cultivars Vijay and Vishwas treated with different concentrations of mutagens like SA, EMS and gamma rays demonstrated the induced genetic variability in yield contributing traits in both the cultivars (Barshile and Apparao, 2007).

Two desi chickpea varieties i.e. NIFA-88, NIFA-95, a kabuli chickpea variety Hassan-2k have been developed through induced mutations and evolved for general cultivation on the basis of high yielding potential (Hassan & Khan, 1991; Hassan et al., 1997, 2001; Khattak et al., 2007).

Mutation breeding has been considered as one of the best approaches for improvement of chickpea crop. It is visualized that, through appropriate induced mutation, the development of high yielding and better quality chickpea genotypes can become possible. Keeping this end in view, the approach of mutation breeding has been considered worth utilizing in the present study for achieving the genetic improvement and for obtaining the desired mutant genotypes in case of chickpea under our local agroclimate.
Some of the major aspects studied during the course of present investigations are as follows:

1. Improvement in the chickpea yield potential.
2. Creation of variation in the chickpea population.
3. Evolving desirable plant types with respect to plant habit, maturity and increased level of proteins. And
4. The biochemical characterization of mutants with reference to seed proteins and antinutritional factors.