

**Genetic manipulation through induced mutation for  
yield & gum content in clusterbean (*Cyamopsis  
tetragonoloba* (L.) Taub.)**

**THESIS**



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**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya**

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*By*

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**2018**

**CERTIFICATE –I**

*This is to certify that the thesis entitled, “**Genetic manipulation through induced mutation for yield & gum content in clusterbean (Cyamopsis tetragonoloba (L.) Taub.)**” submitted in partial fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY** in **AGRICULTURE (GENETICS AND PLANT BREEDING)** of **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bona-fide research work carried out by **Ms. Jaya Rathore**, under my guidance and supervision. The subject of the thesis has been approved by the student’s Advisory Committee and the Director of Instruction.*

*No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by the scholar.*

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## **Abbreviations and Acronyms**

%	Percentage
&	And
/	Per
°C	Degree Centigrade
ANOVA	Analysis of Variance
C.D.	Critical Difference
cm	Centimeter
d.f.	Degree of freedom
e.g.	For example
<i>et al.</i>	And others
F.(cal)	F calculated
F.(tab)	F table
gm	Gram
<i>i.e.</i>	That is
kg	Kilogram
M.S	Mean of Squares
M.S.S.	Mean Sum of Square
mg	Milligram
ml	Millilitre
mm	Millimeter
N.S.	Non-significant
R.B.D.	Randomized Block Design
R.H.	Relative Humidity
S	Significant
S.S.	Sum of squares
S.D.	Standard Deviation
S.Ed.	Standard Error of difference
<i>viz.</i>	Namely

re	Environmental correlation
rp	Phenotypic correlation
rg	Genotypic correlation
kR	Kilo Rad
No.	Number
Fig.	Figure
Ha	Hectare
bs	Broad sense

## Chapter - I

### INTRODUCTION

Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) ( $2n=14$ ) is a member of leguminosae and subfamily papilionaceae. It is an important multipurpose crop specially grown for feed, green fodder, vegetable and green manuring. It is a self pollinated crop with four different species, namely *C.tetragonoloba* (L.) Taub., *C. serrata* Schinz., *C. senegalensis* Guill and *C. dentata* ). It is cultivated as a *kharif* crop and it is clearly rain dependent crop. Clusterbean also known as guar and is a native plant of India, mainly grown in the dry habitats of Rajasthan, Haryana, Gujarat and Punjab. 80% of the world production of this crop is in India, and due to strong demand it is also being introduced in non-traditional areas of semi-arid tracts.

Initially it was used as green vegetable, fodder and green manure, as it is a rich source of protein. However, today Guar is highly commercialized for its economic importance due to World War II and modern chemistry. Guar was not known for its industrial application until the times of World War II, when there was shortage of locust bean crop and the paper and textile industry of the world was searching for a substitute. They found efficient alternative in the form of guar gum and since then, this derivative of guar ruled out locust bean from this scenario and it was readily accepted for application in many other industries (CRN India). After its industrial production commenced in the late 1950s, many other applications of guar gum were found. These are based on the functional properties of this hydrocolloid as a viscosifier, stabilizer, emulsifier, and so forth. Being cheaper among most hydrocolloids readily available, it has found many new applications and replaced many earlier used gums in some of the specific applications. Derivative guar gum products have further enhanced the scope of their wider applications. In oil-well drilling, guar gum acts to prevent water loss from the viscous drilling mud and also as a suspending agent for bentonite clay used in the mud. These functions are performed very satisfactorily by guar gum and it is more cost effective than most of the other mud thickeners. It has the limitation of being thermally less stable compared as to xanthan gum at temperatures more 100°C. To a large extent, this limitation has been overcome by employing guar-hydroxypropyl derivatives, which is thermally more stable. For enhanced oil recovery or oil-well stimulation by fracturing

of the oil well, a popping agent (e.g., sand suspended in thickened guar gum or a hydroxypropyl-guar gum solution) is pumped into the well under pressure to pop up and widens the cracks in the rock formations. This permits more oil and gas to percolate into the well. Frequently cross-linking agents (e.g., borate or transition metal ions (zirconium and titanium) are added to cause *in situ* gelling of injected guar gum paste. Having completed the fracturing, the gel is broken (by enzymes or acid) and flushed out, leaving minimum residue after the break (Whistler and Hymowitz, 1979 and Dhugga *et al.*, 2004). Today, the largest consumer of guar gum is the petroleum industry, which uses it to reduce fluid friction and as a substrate carrier in gas well development. Currently, greater than 90 percent of guar gum that is used by world petroleum industries is imported from India (APEDA, 2014).

In paper industries, guar gum was initially introduced as a substitute for LBG, where it worked well in improving recovery of pulp and providing additional strength to the paper. During the past several years, the use of clusterbean in paper making has been reduced in favor of cationic starch, which also reduces the cost, for cheaper grades of paper (Rowland, 1945).

In explosives, making water-resistant slurry and gel explosives based on ammonium nitrate, a gel of the latter is made of guar gum paste. Guar gum prevents leaching out of the explosive material and such gelled explosives are suitable in the mining industry where they can be given any desired shape. Water gels or slurry-based explosives were first introduced in 1958. These were mixtures of ammonium nitrate, trinitrotoluene (TNT), aluminum or magnesium powder, water, and a gelatinizing agent, which usually was guar gum and a cross-linking agent such as borax. (Cross-linking is due to covalent or hydrogen bonding.) Later, aluminum powder and other metallic fuels were also incorporated into the gel explosives. Clusterbean proved to be a vastly better gelatinizing agent for these gel explosives. In addition non explosive sensitizers were developed that could replace the TNT if desired. When the highest possible concentration of strength is needed, large quantities of TNT are still used. Water gels have many advantages over conventional solid explosives (Whistler and BeMiller, 1993a).

Mining is one of the major industries using guar gum for effective beneficiation of nonferrous metallic ores by the froth floatation process. During concentration of ores by froth flotation, the metallic ores are rendered hydrophobic by interaction with

a floatation agent (e.g., alkyl xanthates) and these float with the froth. The impurities or the gangue mineral (silica, silicates) adsorb guar gum on their surface to become hydrophilic and these are depressed. Guar gum has proven to be an economical and effective depressant compared to most other hydrocolloids. Its major use as a depressant is in nonferrous ores of copper, nickel, gold, uranium, and potash minerals (Whistler and Hymowitz, 1979).

The tobacco industry uses guar gum for moisture retention in tobacco and for making reconstituted tobacco preparations from tobacco leaves, which are broken or powdered during processing. Generally guar gum acts as a better moisture retention agent than other gums (Whistler and BeMiller, 1993a).

Cosmetics and pharmaceuticals are the new emerging industries to use guar gum products. Highly refined, modified, and derivatized guar gum products are used by these industries. The gum products have functions of thickening, suspending, binding, and emulsifying in cosmetic products like shampoo, conditioner, moisturizer, and toothpaste, and in many liquid medicinal preparations. Cationic and hydroxypropylated guar gum are extensively used in cosmetics (Chudzikowski, 1971).

In medicinal tablets, guar gum is used as a binder and drug-release control agent (Eherton *et al.*, 1955). Depolymerized guar gum has been found to be a good bulking agent and a source of fiber for dietetic food. When taken orally in food, the galactomannan-based soluble dietary fiber slows the absorption of sugars and lipids from the intestinal tract into the body fluids. This helps in controlling blood glucose levels in healthy and diabetic persons. The slowing of fat absorption controls blood lipid level (low-density lipoprotein (LDL), cholesterol, and triglycerides), which helps to prevent cardiovascular diseases. As a food fiber it helps in sugar and lipid metabolic control, particularly for diabetic and heart patients (Hosobuchi *et al.*, 1999; Frias and Sgarbieri, 1999 and Morris, 1992).

Although clusterbean seeds have been used in the pharmaceutical and nutraceutical industries (Morris *et al.*, 2004), the composition and content of fiber, isoflavonols and flavonols in clusterbean seeds has largely been ignored. Thus significant genotypic variability for both total dietary fiber and soluble dietary fiber was found in seed from several clusterbean accessions (Kays *et al.*, 2006). Several

clusterbean accessions also showed significant variability for seed derived daidzein, genistein, quercetin, and kaempferol (Wang and Morris, 2007). When compared to soybeans, clusterbean seeds produced very low amounts of daidzein and genistein, however clusterbean seeds produced significantly more kaempferol than soybeans.

In India and in many other countries, one of the major applications of guar gum has been in textile printing, particularly for printing of cotton with fiber-reactive dyes. Depolymerized and anionic derivatives of guar gum, particularly the carboxymethyl (CM) and sulfonic derivatives of guar gum, have proven to be good and reasonably cheaper substitutes of sodium alginate as a print paste thickener. A large amount of guar-gum-based products are exported from India for use in carpet printing and dyeing, where it works very well. In dyeing it acts as an antimigrant. Guar gum is also used in blends of textile size where it improves film forming and spreading of other sizing materials (Sharma, 2005).

These are the common requirements of any food hydrocolloid additive. Hence, guar gum is used as an economical additive in many food preparations. The principal food uses of galactomannans are in dairy products. It has been used as a stabilizer and promoting fine ice crystal structure during freezing and for enhancing the creamy mouth feel (Hearld, 1986). In fresh cheese, galactomannans help in binding the water set free by shear impact and increase viscosity (Fox, 1992). Galactomannans also find application as thickeners in desserts, as low-energy fat substitutes in e.g. mayonnaises, and as gelling agents in fruit-based water gels and in powdered products (desserts and hot milk puddings). In soups, sauces, and ketchup guar gum is used as a thickener and stabilizer. In many baked foods, it prevents staleness, reduces crumb formation, increases the shelf life of a product, increases the dough volume, and prevents loss of moisture. It is also used in soft cheese, noodles, icings, dressings, meat bindings, and spreads. In beverages and instant drinks it improves mouth feel and aftertaste. It is used as a binder in pet food. Depolymerised guar gum is a consumer-acceptable food fiber, which has been used in preparation of low calorie food. Other uses are in bakery goods (icings and cake mixes), dietary products, coffee whiteners, baby milk formulations, dressings, sauces and soups, tinned meats, and frozen and cured meat foods (Reid and Edwards, 1995), about 40% of the total guar gum produced is used as a food additive. Use of

guar gum in food in India is still low, but it is fast increasing with the growth of the food industry.

Young tender pods of clusterbean of edible type and used as vegetable in India and African regions. Tender pods are nutritionally rich in energy (16 Kcal), moisture (81g), protein (3.2g), fat (1.4g), carbohydrate (10.8g), Vitamin A (65.3IU), Vitamin C (49 mg), calcium (57 mg) and iron (4.5 mg) for every 100 g of edible portion (Rai, 2010 and Kumar and Rodge, 2012).

Leaves are used in asthma and to cure night blindness whereas the pods and seeds are used to cure inflammation, sprains, arthritis, as anti-oxidant, antibilious, laxatives and in polluting boiling. As per *Ayurveda* the plant is used to reduce fire and can be used as cooling, digestive tonic, galactogogue, useful in constipation, dyspepsia, anorexia, agalata, hyetalopia and vitated condition of *kapha* and *pitta*.

Clusterbean grows upright, reaching a maximum height of up to 2–3 m. It has a main single stem with either basal branching or fine branching along the stem. The guar plant can access soil moisture in low soil depths. Additionally, this legume develops root nodules with nitrogen-fixing soil bacteria rhizobia in the surface part of its rooting system. Its leaves and stems are mostly hairy, dependent on the cultivar. Its fine leaves have an elongated oval shape (5 to 10 cm length) and at alternate position. Clusters of flowers grow in the plant axil and are of white to bluish colour. The developing pods are rather flat and slim containing 5 to 12 small oval seeds of 5 cm length. Usually, mature seeds are white or gray, but in case of excess moisture they can turn black and consequently lose germination capacity. Its kernel consists of a protein-rich germ (43-46%) and a relatively large endosperm (34-40 %), containing big amounts of the galactomannan. The latter is polysaccharide containing polymers of mannose and galactose in a ratio of 2:1 with many branches. It exhibits a great hydrogen bonding activity having a viscosifying effect in liquids.

Although guar is drought-tolerant and sun-loving crop, but frequent drought periods can lead to delayed maturation. There is an increasing need for guar gum in the food industry in recent years. High gum content variety development is required to meet this demand. Understanding the inheritance of gum content is key to its successful genetic improvement. Gum content expression was reported to be controlled by additive, dominance, and epistasis effects, and by environment as well.

India earns huge amount of foreign exchange from the export of its gum and its derivatives. Moreover, as a field crop, Guar is an excellent soil improving crop with respect to available nitrogen. Boutra and Sanders (2001) reported that water stress during both flowering and pod-filling stages leads to low seed yield.

To breed stress tolerant genotypes genetic variation is a prerequisite for any crop & for its genetic improvement. Therefore, in any breeding programme, this is always the first step to generate unless variation it does not pre-exists. Genetic variation can be created by using various breeding methods eg. hybridization, domestication and plant introduction etc. In the clusterbean to create genetic variability through the recombination of genes by hybridization is very difficult and cumbersome owing to small, delicate flower structures resulting in low percentage of crossed seed setting in the manually hybridized buds. Due to these reasons, not much desirable genetic variability has been generated through conventional breeding approaches.

So, mutation breeding can be important tool for enriching genetic variation in a cluster bean and hence looking at this limitation, efforts were initiated to create variability in clusterbean by using the tool of induced mutations. Many desirable varieties of crops have been developed through mutation breeding (Gabriyal et al., 2009) for improving plant yield. We can find the variations due to spontaneous mutation in various plants. However, the frequency is very low and not induces the full range of variations. Therefore, the induced mutation through physical and chemical mutagen is very effective tool to induce variations for significant characters. A number of chemical and physical mutagens are widely used to induce genetic variability in plants. But according to (Gual H. 1964) gamma radiation is most widely used as physical mutagen in crop improvement. Induced mutation may bring changes in the overall morphological and physiological and genetic traits of the crop.

Therefore the present investigation is being undertaken to study the response of clusterbean genotypes to the physical mutagen gamma rays with the following objectives:

1. To study the pollen viability with different doses of gamma radiation in M<sub>1</sub> generation.

2. To study the mutagenic effectiveness and efficiency with different doses of gamma radiation in M<sub>2</sub> generation.
3. To estimate correlation, heritability & genetic advance for various quantitative traits in M<sub>2</sub> generation.
4. To study variability for morpho-physiological traits related to seed yield & quality in M<sub>2</sub> generation.
5. To identify/select mutant lines for high proline in promising mutant lines for heat stress in M<sub>2</sub> generation. .
6. To identify/Select mutant lines for high gum content in M<sub>2</sub> generation.

## Chapter - II

### REVIEW OF LITERATURE

Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.), popularly known as *Guar*. The vernacular name of '*guar*' is derived from the Sanskrit root word '*gou*' or '*gav*' meaning cow. In Hindi guar means "cow food", since clusterbean has been used as a fodder purpose in North India. Hence, in Northern and Central Indian languages such as Hindi, Marathi, Gujarati, Punjabi whose spoken language has the root of Sanskrit, this plant known as *gavar*, *gawar*, *goor*, *gowaree*, *gouree*, *govar*, *guar*, *guara*, *guwar* and *gwar*. In South India, guar is known to the Britishers as clusterbean, since it has bunch of pods in a single cluster. Hence, this vernacular name was taken directly the translation of the Tamil name for the plant, *Kothavarai* or *Cheeni avarai*.

Crop improvement depends on genetic variability and extent to which traits are heritable. Segregating populations are more suitable for improving the plant type by way of selection than non-segregating ones. A thorough understanding of the genetic diversity, extent of variation, genetic architecture of the plant and heritability of the character among the genotypes would help to carry out effective selection for improving yield.

Limited genetic variability in the population hinders the selection process. When genetic variability is exhausted in any crop, induced mutation using physical and chemical mutagens is applied as potent source to create new genetic variability in the population such as plant type, yield and its attributing characters, quality and a biotic/biotic resistance *etc.* and to remove certain demerits/toxic substances in short time.

Gamma radiation is an important tool for inducing the genetic variability, enhancing yield and yield related traits. However, there is a need to predict the most beneficial dose of gamma rays for improvement of specific traits of crop plant because gamma radiation can induce useful as well as harmful effects. According to Melki and Sallami (2008) low doses of gamma rays have positive effects on crop species.

With this purpose in mind a brief review of available and pertinent literature has been cited under the following headings.

## **2.1 Taxonomy and centre of origin**

The Cluster bean *Cyamopsis tetragonoloba* (L.) Taub. (Syn. *C. Psoralioides* D.C.) belongs to family Leguminosea (Fabaceae). The genus '*Cyamopsis*' belongs to the tribe 'Indigofereae' sub-family 'Papilionaceae'. Initially it was known as *Cyamopsis psoraloides* DC. Genera *Cyamopsis* and *Indigofera* there exists a diversity in dimensions and types of chromosomes which usually does not appear to be consistent with the accepted taxonomical classification (Frahm-Lelived, 1966).

Following is the Systematic position of Guar:

**Kingdom:** Plantae (Plants)

**Sub-kingdom:** Tracheobionta (Vascular plants)

**Super-division:** Spermatophyta (Seed plants)

**Division:** Magnoliophyta (Flowering plants)

**Class:** Magnoliopsida (Dicotyledons)

**Sub-class:** Rosidae

**Order:** Fabales

**Family:** Leguminosea

**Sub-family:** Fabaceae

**Tribe:** Indigofereae

**Genus:** *Cyamopsis*

**Species:** *Tetragonoloba*

Its established records and circumstantial evidence indicates that the cluster bean is of tropical African origin (Vavilov,1950). According to Whistler and Hymowitz (1979) clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) Originated from India-Pakistan area and latter it was introduced into the United States in 1903 and *C. tetragonoloba* is a summer, annual herb with no wild forms at present anywhere except in Rawalpindi and Afghanistan which are considered as one of its habitats from where it might have been introduced to India and species *C. senegalensis* has

been recorded in semi-arid savannah zone, south of Sahara and Senegal to Saudi Arabia. The *C. serrata* and *C. dentata* have been reported from the semi-arid regions of the Republic of South Africa, South West Asia & Botswana.

## **2.2 Morphology**

The Cluster bean is an annual, erect, herbaceous and robust legume. It has indeterminate growth habit and can grow up to 0.4 to 3.0 m. with a life cycle of 80 to 160 days. It has a deep taproot system with well developed lateral roots. Roots are covered with light colored root nodules. Effective nodules are slightly pink in color, while ineffective nodules are white or brown colored. Stem is an erect, single, unbranched and strong. Stem is angled or ribbed and hollow. Stem has appearance of small white hairs. Leaves are alternate, trifoliate and ovate with serrate margins. Leaves born on long petioles at the base of which is a marked pulvinus. The inflorescence is an auxiliary racemose type. Flowers borne in clusters giving the common name clusterbean. Flowers pass through an array of colours from white to deep blue from the bud stage to petal drop (Stafford and Hymowitz, 1980). The plants flower buds start out creamy white and changes to a light pink as the flower opens and turns into deep purple following the fleshy seed pods. Flower is complete and hermaphrodite with papilionaceous corolla usually having ten stamens. Each stamen has two anther lobes which get burst at maturity to liberate pollen grains when stigma is receptive. Thus ensures the self pollination. Cluster bean is a self pollinated crop due to cleistogamous nature and out crossing to the tune of 0.5 to 7.9% has been also reported by Saini *et al.* (1981). The style is curved and the stigma terminal capitates. Pods are linear, erect, clustered, beaked, compressed with double ridges on the dorsal side and single ridge on the front side. Pods are larger, fleshy and glabrous. A pod varies single and double seeded to twelve seeds. Seeds are light gray, purpled colored. As plant shows an indeterminate growth habit there is no uniformity in seed maturity. Saini *et al.* (1981) reported morphological characters of three species barring *C. dentata*

Cluster bean, has been named so because of the manner in which its pods are clustered together (was earlier referred to as *C. psoralioides*). It belongs to genus *Cyamopsis*. The genus *Cyamopsis* is an old world genus (tribe Galegeae of family Papilionaceae) and was assigned to family Leguminosae and subfamily Papilionaceae with four species *viz.*, *C. tetragonoloba* (L.) (Gillete, 2003).

### **2.3 Climatic conditions for the cultivation of cluster bean**

**Habitat:** It is cultivated in tropical, semi arid to arid regions. In India it is cultivated in Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Maharashtra, Karnataka and Andhra Pradesh.

**Altitude:** In India cluster bean grows at an altitude ranging from sea level up to elevations of about 900m. Environmental latitude is generally 30°S to 30°N (FAO, Peter Griffee, 2000).

**Soil:** The Cluster bean prefers a well drained sandy loam soil. It can tolerate saline and moderately alkaline soils with pH ranging between 7.5 and 8.0. Heavy clay soils, poor in nodulation and bacterial activities are not suitable for this crop. Soils with medium to light constituents, without excessive moisture, are suitable for its cultivation. Even soils with poor fertility and depleted plant nutrients are suitable for growing guar as a green manure crop.

**Temperature:** It is sun-loving plant. Dry land crop of tropic regions can tolerate the high temperature. For proper growth it requires a soil temperature about 25° to 30°C. It is susceptible to frost. It is definitely a kharif season crop in North India, but some varieties have been found to grow during March to June as spring- summer crop and other varieties grow during July to November as rainy season crop under South Indian climatic conditions. It is a crop preferring warm climate and grows well in the subtropics during summer.

**Rainfall:** It grows well in arid zone with 30-40 cm rainfall. Heavy rains, producing waterlogged condition or more compact soils disturb its root system with surface feeding nature and reduce nitrogen fixing bacterial activity.

**Day length:** It is a short day plant. It remains vegetative in long day conditions. During short day condition it flowers and also attains maturity of pods.

### **2.5 Cultivation in India:**

Cultivation of cluster bean in India for its best growth requires full sunshine, flushing rainfalls that are moderately frequent. The most important growing area is Jodhpur in Rajasthan in India. India produces 80% of the world's supply of cluster bean with 70% being exported to the United States and Europe (National Commodity Derivative Exchange, Ltd. 2005). Hingane (2005) revealed that Rajasthan has the

highest production as compared to Haryana, Gujarat and Punjab. Cluster bean is grown in almost 23.30 lakh hectare area in India.

## **2.6 Crop improvement through mutation breeding**

The process of bringing wild species under human management and cultivation is called as domestication. Crop improvement or Plant Breeding is an applied branch of botany that deals with the genetic improvement of crops and production of new crop varieties which are far superior to existing types in all the characters. Conventional plant breeding methods consist of domestication, plant introduction, selection and hybridization; but these are old age techniques used for crop improvement. To ensure the food security, high yielding and higher nutritious crop varieties is a major confront for today. So the plant breeders developed modern methods for crop improvement with the help of modern scientific tools. Induced mutation breeding is one of the efficient modern techniques. Inducing desirable mutations and exploiting them for crop improvement is known as mutation breeding.

The induced mutation through physical and chemical mutagen is very effective tool to induce variations for significant characters. Hugo de Vries in 1900 discovered mutations in *Oenothera lamarckiana* (Evening Primrose). Muller and Stadler laid foundations for mutational breeding. Muller discovered the action of X-rays in 1927 in *Drosophila*. He was awarded by the Nobel Prize for Physiology and Medicine in 1946. In 1929, Stadler described the mutagenic effects of X-rays in barley. The first plant breeding programme to exploit induced mutation was initiated in 1929 in Sweden, Germany and U.S.S.R. (Singh, 2003). This programme covered several crop species and generated a lot of information on mutation breeding. With the help of induced mutation one can achieve the desirable characters like increased yield, improved seed characteristics, increased disease resistance, improved agronomic characteristics, improved lodging resistance and shortened maturity type.

During 1950-1970, several countries including India, China, Netherlands, USA and Japan took up the crop improvement programme through mutation breeding. Many researchers have made significant contribution to the field of mutation breeding by producing superior crop plants (Konzak, 1954; Frey, 1955 in oats, Gregory, 1955; 1956 in peanuts, Gottashalk and Wolf, 1983 and Swaminathan *et al.*, 1962 in barley and wheat). In 1964, International Atomic Energy Agency (IAEA)

established Plant Breeding and Genetics Division and a fully functional Laboratory at Seibersdorf at Vienna in Austria (Giri, 2010). With the help of modern computer technologies FAO/IAEA has organized the data base programme in 1987. It is known as Mutant Variety Database (MVD). According to updates up to 2012 there are over 3200 officially released cultivars in over 200 plants.

## **2.7 Mutation breeding in guar**

### **2.7.1 Spontaneous Mutations**

Spontaneous mutations occur naturally, without any known reasons. Mittal *et al.* (1968) reported the male sterility in guar. Four abnormal plants, characterized with profused branching, smaller leaves and elongated peduncles producing 1 or 2 seeded pods. With the acetocarmine smear test, small flowers of these plants show the complete pollen sterility in flower. The few seeds appeared, may be because of natural cross-pollination. In further crossing studies in F<sub>2</sub> generation, Chi-square test shows the good fit to expected 3:1 ratio. So Mittal *et al.* (1968) concluded that the pollen fertility is probably monogenic dominant to sterility conditions.

Stafford (1988; 1989) reported mutant having a rosette-raceme and reduced fertility in a released breeding line, TX76-328S in South Africa. Inheritance of the rosette-raceme trait was found to be inherited as a monogenic recessive and is expressed on every raceme. The name rosette-raceme and the gene symbol, *ros*, are proposed for the new mutant trait. Stafford suggested that the trait should be useful in genetic studies as an easily identifiable phenotype. But the practical utility of male sterility, partial male sterility and rosette raceme mutants has not been demonstrated yet (Arora and Pahuja, 2008).

### **2.7.2 Induced mutations**

Crop improvement of guar using hybridization is difficult because of delicate flower structure resulting in low percentage of crossed seed settings in manually hybridized bud (Arora and Pahuja, 2008). So the desirable genetic variation is not induced with conventional breeding methods. Here the induced mutations play a vital role in generating the exploitable and useful genetic variation in guar. Many researchers induce the mutation in guar using physical mutagens, chemical mutagens and combination of physical and chemical mutagens. Mutations provides the great range of variability related to quantitative as well as qualitative characters

of guar. Nutritious biochemical composition and high gum yielding characters were also recorded in guar, using mutation studies.

### **2.7.3 Mutation Studies using Physical Mutagens (gamma rays)**

The first successful attempt of induced mutation in guar with the physical mutagen was made by Vig in 1969.

Singh (1972) and Lather and Choudhary (1972) were used different doses of gamma radiation (5kR, 10kR, 20kR and 30kR) from source Co60 for irradiation of two varieties and germination percentage, survival of plants, chlorophyll variations and morphological changes in the guar were studied. The reciprocal translocation was observed in the 20kR. They were found germination percentage and survival of seedlings decreased with increased dose. Gradual reduction in germination and subsequent survival of the treated population were observed with the increased mutagen dose in both cultivars. Four different types of morphological mutants were observed with the maximum mutation frequency of spreading types in case of higher doses of gamma rays. Positive association was observed between mutagen dose and mutation frequency of morphological traits in  $M_2$  generation. Three different types of chlorophyll mutant *viz.* chlorina, xantha and albina were observed. Chlorophyll mutants induced with gamma rays had higher frequency than EMS induced mutants. Fifty best performing progenies, identified in  $M_3$  on the basis of earliness and higher seed yield, were further tested and fifteen of them were selected in  $M_4$  generation.

The separately effect of gamma rays, EMS and combination treatments on seed germination of Cluster bean variety Sharada were studied by Dube *et al.* (2011). They observed that reduction in the germination percentage induced by gamma rays in alone treatment was less as compared to EMS and combination treatments. However, EMS in alone treatments induced the maximum inhibition in seed germination with the corresponding increase in its concentration. Bhosle (2014) take two varieties of clusterbean for irradiation using gamma rays. In the progeny, phenotypically typical plants with regard to chlorophyll development were marked and their frequency recorded. The  $M_3$  generation along with respective normal was studied to analyze the mutagenic activity of gamma ray on cluster bean.

Mahla *et al.* (2018) irradiated three genotypes viz., HG-2-20 (hispid branched), CAZG15-6 (branched glabrous) and CAZG 15-3 (single stem, hispid and regular bearing) with gamma rays (100–1600 gray) with 100 gray intervals. The mutation rate increased with increasing dose up to 300 gray, there after gradually reduced indicating decline in rate of recovery of mutations with respect to increasing M<sub>1</sub> damage. At higher dose of 800 gray, mutation efficiency drastically reduced with reduced survival and high level of pollen sterility in M<sub>1</sub> generation. Beyond 800 Gy dose all the seedlings died within a few days (15 d) of germination. Based on mutation efficiency and effectiveness a gamma radiation dose between wide ranges (200–700 Gy) was found appropriate for inducing variability.

Ulukap *et al.* (2018) determined the morphological changes and the proper dose of gamma [irradiation](#) for the mutation breeding programme of [commonbean](#) (*Phaseolus vulgaris* L.). The effects of different doses (100, 150, 200, 250, 300, 350, 400, 450 and 500 Gy) of gamma irradiation (<sup>60</sup>Co) on [seedling](#) growth parameters and survival rates of the plants were investigated. In order to determine the proper dose and morphological changes; shoot length, root length, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, stem diameter, leaf width, leaf length, [chlorophyll](#) index and number of survival plants of M<sub>1</sub> plants were evaluated. It has been determined that the doses of gamma and the varieties used are significant on the number of surviving plants and plant growth parameters. It was determined that low doses gamma irradiation stimulative effected on shoot fresh weight, shoot dry weight, root dry weight and root fresh weight. A negative correlation was obtained between all plant growth traits and stem diameter, and the stem diameters are thickened due to the increase in gamma doses. The applications of [gamma rays](#) were effected on survival plant rate considerably than the percentage of [germination](#). Applicable proper dose for Efsane was determined as 318.22 Gy while appropriate dose for F16 was determined as 303.17 Gy.

## **2.8 Macro mutation**

They involve change in a whole constellation of characters and thus, have a viable phenotypic expression.

### **2.8.1 Chlorophyll mutants**

Chlorophyll mutations are one of the reliable indices to assess the genetic effects of mutagenic treatments. Velu *et al.* (2008) and Patil and Rane (2015) studied the frequency and spectrum of morphological mutants and chlorophyll mutants in cluster bean with the gamma rays treatments. They found the highest frequency of sterile mutants and reported that increased frequency of chlorophyll mutations with increasing doses of gamma rays.

### **2.8.2 Visible mutants**

Rao *et al.* (1982) observed determinate and spreading variants in the M<sub>1</sub> and M<sub>2</sub> generations of Pusa Navbahar, when soaked in 200, 400 and 600 ppm kitazin and 1000, 2000 and 3000 ppm Saturn for 12 and 24 h.

Velu *et al.* (2008) reported that increasing dose/concentration of gamma rays and EMS decreased the values of morphological and yield parameters in M<sub>1</sub> generation.

### **2.9 Mutagenic effectiveness and efficiency**

In mutation breeding, mutagenic effectiveness and efficiency are the base parameters to predict the mutagenic potency of any mutagen. Velu *et al.* (2007) estimated the mutagenic effectiveness and efficiency of gamma rays and EMS in the clusterbean and reported that the frequency and efficiency of mutation was more in EMS as compared to gamma rays. Their finding suggests that EMS induced more number of mutants effectively and efficiently than gamma rays. The maximum value of effectiveness was recorded by Bhosale and Kothekar (2010), while they found varied mutagenic efficiency with different biological parameters in the mutagenesis studies on Guar. Mahla *et al.* (2010) studies the effectiveness and efficiency of gamma rays and EMS in clusterbean and observed steady reduction in germination and subsequent survival of the treated population, seedling height and pollen fertility with increasing doses/concentration of mutagens. Dube *et al.* (2011) were recorded inhibitory effect on germination, seedling height and survival of cluster bean through mutation studies with gamma irradiation. Patil *et al.* (2015) studied the mutagenic effectiveness and efficiency of a physical mutagen gamma rays in the cluster bean (*Cyamopsis tetragonoloba* (L) Taub) variety NCB-12. The seeds of cluster bean

variety NCB-12 were mutagenised with the increasing doses of gamma rays 10kR, 20kR, 30kR, 40kR and 50kR. The effectiveness and efficiency was determined by accounting lethality, injury and sterility in  $M_1$  generation of mutagenised seeds and frequency and spectrum of chlorophyll mutations in  $M_2$  generation. The increasing doses of gamma rays decreased plant survival, seedling height and increased pollen sterility. Four types of chlorophyll mutants albina, xantha, chlorina and striata were screened in  $M_2$  progeny. It was observed that the frequency of mutations increased with increasing doses of mutagen. The highest mutation frequency was noticed in 50kR dose of gamma rays. The mutagenic effectiveness and efficiency was decreased with increased doses of gamma rays. The highest mutagenic effectiveness was recorded 0.187 in 10kR and lowest 0.084 in 50kR dose of gamma rays. Whereas maximum mutagenic efficiency was recorded 0.231 in 10kR and minimum 0.132 in 50kR dose of gamma rays. Thus the lower doses of mutagen like gamma rays were effective and efficient than the higher doses of gamma rays in cluster bean variety NCB-12.

## **2.10 Micro mutation**

### **2.10.1 Mean performance of mutant lines**

Chowdhury *et al.* (1975) evaluated the effects of irradiation ranging from 10 to 250 kR gamma rays on clusterbean for quantitative characters assessed in the  $M_2$  generation showed that the number of branches and seed yield/plant were less in the  $M_2$  generation than the control but the peduncle length and plant height were greater. Amrita and Jain (2003) found on the basis of progeny means that the progeny numbers 108 and 50 showing higher values for all the traits except 100 seed weight and number of clusters per plant. Amrita and Jain (2003) was recorded maximum plant height, number of clusters/plant, number of pods/cluster, number of pods/plant and seed yield/plant but the induced variation reduced the number of seeds/pod and pod length in  $M_2$  progenies of clusterbean through gamma irradiation.

Velu *et al.* (2012) observed that the reduction of germination, survival, growth of seedlings, plant height, number of leaves/plant, number of branches/plant, number of pods/plant, number of clusters/plant, pod length, pod breadth, fresh and dry weight of matured plant were decreased with increasing doses and concentration of

gamma rays and EMS in clusterbean, whereas days to first flowering increased with increasing doses and concentration of gamma rays and EMS.

### **2.10.2 Genetic variability, Heritability and Genetic Advance in mutant lines**

Mutation breeding has been perceived as an important tool to foster additional variability in qualitatively and quantitatively inherited traits in a number of crop plants. The variability thus created enhances opportunities for selection of new genotypes with the desired characteristics. Induced mutation can play a momentous role in the restructuring of the plant, leading to yield improvement. It could create additional genetic variability to supplement conventional crop breeding.

Genetic variability is the basic requirement of any crop improvement programme. Successful crop improvement highly depends on the presence of variability for yield and its attributing components in the base population. Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop. The total variation present in the population arises due to cumulative effect of both genotype and environment. Hence, it is essential to partition the overall variability into heritable and non-heritable components with the help of genetic parameters like genotypic and phenotypic coefficients of variation. The phenotypic coefficient of variation is a measure of the total variability existing in a population which includes both genotypic and environmental components of variation. Knowledge on magnitude of heritability coupled with nature and extent of variability in the breeding material gives an idea for effective genetic improvement through selection.

The high genetic variation were found in terms of plant height, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, seed yield per plant and 100 seeds weight by an array of researcher (Amrita *et al.*, 2003; Chaudhary *et al.*, 2003; Hanchinamani, 2004; Singh *et al.*, 2010; Pathak *et al.*, 2011c; Rai *et al.*, 2012; Sultan *et al.*, 2012; Girish *et al.*, 2013; Kumar *et al.* 2013) in clusterbean.

While, the higher estimates of GCV was found for primary branches/plant, biological yield/plant and days to 50% flowering by Chaudhary *et al.* (2003), Hanchinamani (2004), Singh *et al.* (2010), Pathak *et al.* (2011c), Rai *et al.* (2012)

and Kumar *et al.* (2013) and they found similar trends for Phenotypic Coefficient of Variation (PCV). Reflecting the susceptibility to environmental fluctuation they observed wide differences between PCV and GCV for number of clusters/plant, number of pods/ plant, seed yield/plant, biological yield/plant, harvest index and seeds/pod.

Yadav *et al.* (2004) recorded the higher estimates of genotypic and phenotypic coefficient of variation for yield contributing traits.

Singh *et al.* (2010) and Kumar *et al.* (2013) reported high GCV and PCV for harvest index. Whereas the estimate of GCV and PCV moderate was observed for plant height, cluster per plant, days to maturity, pod length, seeds per pod and test weight.

Wide range of variability for different morphological traits of cluster bean *viz.*, number of secondary branches (10.8–29.8) and number of seeds/pod (6.9–9.4) were reported by Pathak *et al.* (2011c).

High variation in germplasm was found for days to maturity and comparatively, low variation was noticed for days to flowering initiation, days to 50% flowering, branches per plant, clusters per plant, pods per cluster, pod width, pod thickness, seeds per pod, seed yield per plant and 100-seed weight by Sultan *et al.* (2012) and Kumar *et al.* (2013).

Wide variations in different biochemical parameters of clusterbean seed, *viz.*, endosperm (30.4–46.3 %), gum content (23.5–33.5 %), crude fibre (4.1–8 %), fat content (1.8–5.2 %), crude protein (28.3–35 %), ash content (3.5–6 %) and carbohydrate content (38.8–59.1 %) were reported by Pathak *et al.* (2011a).

Girish *et al.* (2013) were observed high GCV and PCV for stem girth, pod yield per plot, and gum content.

Kumar *et al.* (2013) characterized 23 elite and released cultivars of clusterbean using morpho-physiological parameters. Phenotypic characters revealed the presence of sample amount of variation in cotyledon size, root length, hypocotyl length, epicotyls length, pubescence, plant height, leaf margin, branching habit, growth habit, flower colour, pod size for all the genotypes. They proved these elite lines were unrelated to geographical origin in terms of morphological and molecular grouping.

Maximum range of variability was observed for ten fresh pod weight (g), number of branches at 90 DAS and number of dry pod per plant (dual purpose type) by Malaghan (2013).

One hundred and forty germplasm lines of cluster bean for agronomic and yield traits were evaluated and observed wide variation among agronomic and yield-related traits among the accessions by Jukanti (2015).

Heritability refers to the extent to which the variability for a quantitative character is transmitted to the progeny. It is an effective tool in estimating the relative importance of the inheritance and environment on the variation of a character. Hanson *et al.* (1956) defined heritability in broad sense as the ratio of genotypic variance to total variance in the non-segregating populations. Heritability is a good index of transmission of characters from parents to their offspring (Falconer, 1981). The estimates of heritability help the plant breeder in selection of elite genotypes by phenotypic expression of a trait from diverse genetic populations and utilizing them in future breeding programme. Burton (1952) indicated that genetic variability together with heritability would give a better idea on the amount of genetic advance expected out of selection. Genetic advance refers to the improvement in the mean genotypic value of selected plants over the parental population. Heritability measures the relative amount of heritable portion of the variability while genetic advance indicates the amount of progress that can be expected with selection for a character. Estimates of heritability along with estimates of genetic advance are more useful in choice of selection method rather than heritability or genetic advance alone (Johnson *et al.*, 1955).

High estimates of heritability coupled with higher genetic advances were recorded for days to flowering, branches per plant, seed yield per plot, biological yield per plot, clusters per plant and pods per plant. by Singh *et al.* (2005). Rai *et al.* (2012) and Muthuselvi and Shanthy (2013) and also observed high heritability accompanied with medium to low genetic advance for the remaining characters

The high heritability coupled with high genetic advance were observed for plant height, number of pod per clusters, number of pods per plant, number of pods per cluster, pod weight, pod length, number(s) of pods per plant and yield per plant indicating the presence of additive gene action in the expression of these characters

by Anandi and Oommen (2007), Singh *et al.* (2010), Girish *et al.* (2013), Muthuselvi and Shanthy (2013) and Jukanti (2015). While, high heritability coupled with higher genetic advance were observed for the traits *namely*: branches per plant, biological yield per plant, plant height, harvest index, cluster per plant, pods per plant and seed yield per plant and high heritability coupled with moderate genetic advance were recorded for days to maturity, reproductive period and 100 seed weight. Moderate heritability coupled with low genetic gain was observed for pod length and seeds per pod by Saini *et al.* (2010), Singh *et al.* (2010), Rai *et al.* (2012), Muthuselvi and Shanthy (2013) and Jukanti (2015). While, high heritability coupled with low genetic advance were noticed in case of pod length, seeds per pod and 100 seed weight by Singh *et al.* (2010).

High heritability coupled with high genetic gain in percentage was observed for pod yield per plant but higher heritability with low genetic advance was shown for pods per cluster, number of seeds per pod and pod width by Rai *et al.* (2012), Muthuselvi and Shanthy (2013) and for number of branches at 90 DAS, pod length (cm) and ten fresh pod weight (g) by Malaghan (2013) and Premalakshmi *et al.* (2013b). They suggested that selection based on number of dry pod per plant, fresh pod weight, pod length and number of branches at 90 DAS might bring improvement in vegetable pod yield of cluster bean and its growth and yield components characters.

Girish *et al.* (2013) and Muthuselvi and Shanthy (2013) were reported high heritability coupled with higher genetic advance for stem girth, cluster length, protein content and gum content and moderate to low heritability for plant height, branches per plant, pod yield, 100 seed weight, seeds per pod and seed yield per plant.

Premalakshmi *et al.* (2013b) were found high heritability for all characters except days to first flower.

High genetic advance were observed for plant height, number of clusters per plant, numbers of pods per cluster, pod length and pod diameter indicating the presence of additive gene action in expression of these characters by Premalakshmi *et al.* (2013b) and Jukanti (2015)

High heritability with low genetic advance was observed for the trait except days to maturity by Muthuselvi and Shanthy (2013).

Jukanti (2015) was observed high heritability (< 85%) coupled with higher genetic advance (< 30%) for clusters on main branch (CLMN) and total pods per plant (TDP) explained 30% and 72% of variability in seed number per pod (SDN) and TY respectively.

Kumar (2015) evaluated to ascertain genetic parameters of variability, heritability, path analysis and genetic advance. The research findings depicted highest range of variation for pod yield (q/ha) followed by pod yield/plant (g). The coefficient of variation was minimum for number of branches/plant at maturity followed by days to maturity whereas, under pooled data analysis, it was found minimum for days to maturity followed by pod yield/plant (g). In all the three studies, coefficient variation was maximum for pod width (cm) followed by pod breath (cm). In the first year, heritability estimates were high for all the characters except pod width (cm), pod breath (cm) and days taken for first flowering, whereas in the second year pod breath (cm), days taken for 50 % flowering, pod width (cm), pod length (cm) and number of pods/plant attain lower heritability values. Under pooled data analysis, pod width (cm), days taken for first flowering, pod breath (cm), germination (%) and days taken for 50 % flowering were found with lower heritability estimates. High heritability with higher genetic advance were found with number of clusters/plant, number of pods/plant, pod yield/plant (g), plant height (cm), days to maturity, pod yield/plant (g), number of pods/plant, number of clusters/plant and pod yield (q/ha), indicating there by that selections based on phenotypic performance could be effective for improvement of these characters.

Kumar (2015) evaluated cluster bean genotypes to ascertain genetic parameters of variability, heritability, path analysis and genetic advance. Thirty genotypes of cluster bean showed wider variation for all traits. The research findings depicted highest range of variation for pod yield (q/ha) followed by pod yield/plant (g). The coefficient of variation was minimum for number of branches/plant at maturity followed by days to maturity whereas, under pooled data analysis, it was found minimum for days to maturity followed by pod yield/plant (g). In all the three studies, coefficient variation was maximum for pod width (cm) followed by pod breath (cm). In the first year, heritability estimates were high for all the characters except pod width (cm), pod breath (cm) and days taken for first flowering, whereas in the second year pod breath (cm), days taken for 50 % flowering, pod width (cm), pod

length (cm) and number of pods/plant attain lower heritability values. Under pooled data analysis, pod width (cm), days taken for first flowering, pod breath (cm), germination (%) and days taken for 50 % flowering were found with lower heritability estimates. High heritability with higher genetic advance were found with number of clusters/plant, number of pods/plant, pod yield/plant (g), plant height (cm), days to maturity, pod yield/plant (g), number of pods/plant, number of clusters/plant and pod yield (q/ha), indicating there by that selections based on phenotypic performance could be effective for improvement of these characters. Pathak (2018) assessed the extent of genetic variability and qualitative characters of clusterbean (*Cyamopsis tetragonoloba* L. Taub.). The range, genotypic and phenotypic coefficient of variation, heritability, genetic advance and correlation among 7 qualitative characters were estimated in 40 genotypes of cluster bean. The genotypes showed considerable amount of variability for all the traits. Irrespective of their place of collection the genotypes were grouped into 7 different clusters. Cluster analysis revealed that genotypes 'HGS 884', 'HGS 26–01' and 'HGS 02–20' may be useful for genetic resources. High magnitude of heritability and genetic advance for gum, fiber and protein contents suggested that the genotypic variation in the present material for these characters is due to high additive genetic effects. Carbohydrates were positively correlated with endosperm and gum contents. Endosperm exhibited significant positive association with gum content while the association of protein was negative with gum and endosperm contents.

### **2.10.2 Correlation Coefficient Analysis in mutant lines**

Selection of a variety is mainly based on phenotypic characters in the breeding programme but the response to selection depends on many factors including the information on association of characters, direct and indirect effects contributed by each character (Mohammadi *et al.*, 2003).

Shekhawat *et al.* (2005) observed that pods/plant, branches/plant, clusters/plant, pods/cluster, 100-seed weight and plant height had direct and positive effect on seed yield. Seed yield was significantly and positively correlated with plant height, seeds/pod, pods/plant, primary and secondary branches/plant. Pods/plant, seeds/pod and 100-seed weight had the maximum positive effect on seed yield/plant. Also, plant height, seeds/ pod, gum content, primary and secondary branches had sizeable indirect effect *via* pods/plant. 100-seed weight had a positive

direct effect on yield and positive indirect effects via clusters/plant. It is desirable to improve both seed weight and clusters/plant for better seed yield.

Singh *et al.* (2004) and Weixin *et al.* (2009) reported negative association of quality related characters to seed yield. There are positive and significant correlation of seed yield with dry pod yield, number of pods/cluster, 100–seed weight, number of clusters/plant, branches/plant, seed recovery, germination, number of seeds/pod and dry biomass/plant. Whereas negative and significant correlation was recorded in days to flower initiation, plant height, days to maturity and days to 50 % flowering. Plant height, number of seeds/pod, days to 50% flowering, number of clusters/plant, dry pod yield/plant and dry biomass/plant had direct positive effects on seed yield.

Anandhi and Oommen (2010) reported positive association of number of pods/ plant, number of seeds/pod, pod weight and number of pod clusters/plant with vegetable pod yield and suggested that selection based on number of pods/plant, number of seeds/pod, pod weight and number of pod clusters/plant may bring out desired improvement towards enhancing the vegetable pod yield in clusterbean besides this selection of dwarf and early flowering genotypes would result in better yielding types.

Saini *et al.* (2010) evaluated hundred genotypes of clusterbean and reported positive direct effects on seed yield per plot obtained by the traits *namely* :pods per plant, clusters per plant, test weight, biological yield per plant, seeds per pod, harvest index and branches per plant and negative direct effects on seed yield per plot through the traits *namely*: days to maturity, days to per cent flowering, reproductive period, pod length and plant height.

Pathak *et al.* (2011) revealed that grain yield and gum content has positive correlation while seed weight has negative correlation with gum content, whereas endosperm always has a positive correlation with gum content. Similarly, seed yield and gum content were positively correlated with height, branch number and pod number whereas it had negative association with pod length and 100- seed weight, similarly endosperm had negative association with seed size and pod length.

Manivannan and Anandakumar (2013) investigated association analysis in 42 clusterbean genotypes during *khari* 2012 and reported that seed yield per plant showed positively significant correlation with pods per plant, cluster per plant, pods

per cluster, and branches per plant at both genotypic and phenotypic levels. But pod length and 100 seed weight exhibited significantly negative correlation with seed yield per plant. The cluster per pod, 100-seed weight, followed by seed per pod had positive and greater direct effects on seed yield per plant at the same time pod length, branches per plant and days to maturity had negative direct effect on seed yield per plant.

Kumar and Ram (2015) suggested that the number of clusters/plant, number of pods/plant, pod yield/plant, plant height and days to maturity are the important traits for selection to yield improvement in cluster bean.

Vir and Singh (2015) reported positive and significant correlations of number of seeds/pod, number of pods/plant, number of pods/cluster, number of clusters/plant, days to 50 % flowering and days to maturity with seed yield/plant.

## **2.11 Biochemical studies in cluster bean mutant lines**

In modern plant breeding one of the major trends has been supporting the traditional methods by biochemical investigation so as to obtain a better estimate of the breeding value of a strain. The economic importance of different plants is simply not restricted to the number and weight of seeds product. Several specific substances stored in the seeds such as proteins, oils, carbohydrates and minerals of a good amount of importance. In particular the seed protein and leaf protein has considerable significance for both human and animal nutrition. Since the biochemical analysis is a useful tool in understanding the basic architecture of an organism on the cellular and physiological level, a study of proline content of the control and mutants was undertaken in the present investigation.

### **2.11.1 Proline content**

Proline acts as a membrane stabilizing agent under stress conditions (Poschenrieder and Barcelo, 2004). Two major pulses black gram (*Vigna mungo* L., cv. PU19) and green gram (*Vigna radiata* L., cv. Pratap) were studied to see the biochemical as well as physiological changes resulting from exposure to various osmotic stress intensities and subsequent relief of the same. Accumulation of proline in leaves was found to be increased during stressed period and decreased in the subsequent recovery stages. Watering was done regularly up to 36 days until the plants were grown to an average height of 4 cm. Then watering was stopped and a

condition of water deficit was maintained for 10 days, 15 days and 20 days in each type of plants and labeled as T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> respectively. Reduction in all the other parameters was observed during stressed period with substantial increase in recovery stage followed by net reduction in yield. Positive correlations of soil moisture with leaf chlorophyll, chlorophyll stability index, plant height, leaf area, cell membrane stability and yield were obtained while it is found to be negatively correlated with leaf proline concentration. Black gram variety PU19 was found to be more resistant than green gram variety pratap against drought stress ([Baroowa., 2012](#)). Vijayarengan (2013) raised cluster bean plants in pots containing the soil amended with various levels of zinc (control, 50, 100, 150, 200 and 250 mg kg<sup>-1</sup> soil). Five replicates were maintained for each level. Morphological parameters like root and shoot length, nodule number, total leaf area and dry weight of root and shoot of cluster bean plants were recorded at an interval of 20 days (20, 40 and 60<sup>th</sup> day). Biochemical constituents (chlorophyll a, chlorophyll b, total chlorophyll, carotenoid, sugars, starch, amino acids, proline and protein), antioxidant enzymes (catalase, peroxidase and polyphenol oxidase) were analyzed on 60<sup>th</sup> day. Zinc treatment at all levels tested (except 50 and 100 mg kg<sup>-1</sup>) decreased the various growth and yield parameters, biochemical constituents of cluster bean plants. However the 50 and 100 mg kg<sup>-1</sup> zinc level in the soil showed a positive effect on the overall growth and dry matter yield and biochemical constituents of cluster bean plants. But the proline content and antioxidant enzymes (catalase, peroxidase and polyphenol oxidase) of cluster bean plants decreased at low levels (50 and 100 mg kg<sup>-1</sup>) and increased at high levels (150-250 mg kg<sup>-1</sup>) of zinc in the soil.

Water deficit by polyethylene glycol (PEG) creates physiological and biochemical changes in pigeon pea. Stress was applied with polyethylene glycol (PEG) 6000 and water potentials were: zero (control), -0.3Mpa (PEG50mM), -1.1Mpa (PEG100mM) and -2.3Mpa (150mM). ICPL 85063(lakshmi) and ICPL 87119 (Asha) cultivars of pigeonpea were used. In increase in the free proline content during water stress condition suggests that proline is one of the common compatible osmolytes under water stress condition. A higher amount of soluble sugars and a lower amount of starch were found under stress. The maximum amount of proline in ICPL 85063 var where as ICPL87119 var depicted an opposite trend in accumulation of proline. There is an increase in root proline content than shoot in ICPL 85063. The

accumulation of soluble sugars in root and shoot in ICPL 85063 is high when compared to roots and shoots in ICPL 87119var. Starch content decreased in root and shoot of lakshmi var. than asha var (Devi, 2014).

### **2.11.2 Gum percentage**

Guar is a commercial crop used for the production of guar gum and its derivatives. So, most of the biochemical investigations were done for the analysis of guar gum and its derivatives. Tasneem and Subramanian (1986;1990) studied the nutritional quality of detoxified and aqueous alcohol extracted guar meal. Ramakrishnan (1957) reported that the guar seed and guar meal were good source of essential amino acids. Nagpal (1968) found the sufficient lysine and histidin, enough tryptophan and methionine deficiency in guar meal. Ambegaokar *et al.* (1969) were also reported the low methionine content in guar meal. Joshi *et al.* (1981) studied the fatty acid composition of guar oil. Singh and Misra (1981) also reported that the fatty acid composition of guar seed oil was similar to that of edible oils. Kaur and Bhatian (1984) studied the proteins and trypsin inhibitor activity of guar seed. Roy and Chakarborti (1993) studied the nutritional composition of green guar pods. The germ and the outer seed coat of guar seed together constitute the guar meal. Guar meal contains more protein than the guar seed.

Plant seeds have been an ancient source of industrial hydrocolloids or polysaccharide gums. Most of the edible seed grains of the Gramineae family have starches as their reserve polysaccharides. There are also several legume seeds derived from annual crops like guar and fenugreek as well as some full-grown perennial trees and shrubs, (*e.g.*, Carob tree and Tara shrub) that have endospermic galactomannans as their reserve seed polysaccharides. A reserve seed polysaccharide is that component of a matured seed that does not have other more important biological functions for a plant except to act as a reserve source of carbon for a growing plant embryo before it emerges out of soil and starts doing chlorophyll catalyzed photosynthesis utilizing atmospheric carbon dioxide. Reserve polysaccharides in plant seeds serve as an energy source for man and animals, when used as food (Reid,1985). Anderson (1949) found galactomannan polysaccharides bearing plants, out of 163 species of legume plant seeds, 119 plant seeds contained galactomannans as their endosperm mucilage. Dabas *et al.* (1982) conducted a classical study to determine the guar gum contents in elite guar

varieties and found that gum percentage varied from 15.92% to 31.81% in their study. Dwivedi *et al.* (1999) observed that gum content varied from 21.77% to 34.38%. Further the collections made from Rajasthan had exhibited more diversity for gum content due to climatic geographical conditions different from that in the other states. Pathak *et al.* (2011) analyzed guar gum in 40 genotypes and found that 23.5-33.5% of gum content. HGS 880 recorded the lowest value of 23.5 % and GAUG 9808 scored 33.5%. Pathak *et al.* (2011) reported endosperm percentage of 30.4% to 46.3% in 40 guar genotypes. Naik *et al.* (2013) conducted a study by using 22 guar genotypes and found that guar gum content varied from 28.47% to 32.89% and there was no significant variation in galactomannan content among 22 guar genotypes investigated. Naik *et al.* (2013) observed endosperm percentage in the range of 29-35% among 22 guar genotypes studied.

## Chapter - III

### Materials and Methods

The materials used and methods employed during the course of investigation on the topic entitled, “**Genetic manipulation through induced mutation for yield & gum content in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.)**”. A detailed account of the materials used, experimental procedure and methods employed during the course of field investigation are described in this chapter. The techniques applied and materials used are being described under following headings:

#### 3.1 Experimental site

#### 3.2 Experimental Location

#### 3.3 Soil

#### 3.4 Agro-climatic condition

#### 3.5 Experimental details of three season experiment:

#### 3.1 Experimental site

The experiments were carried out under the field condition during *Summer-2016* to *Khariif-2017* at experimental field of Department of Genetics & Plant Breeding, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) which is **located in the Gird region**. The Gwalior is situated at an altitude of 211.52 m above mean sea level, 26<sup>0</sup>13´ N Latitude and 78<sup>0</sup>14´ E Longitude.

#### 3.3 Soil

The soil is sandy loam, low in available nitrogen, medium in phosphorus and high in potash with pH of 8.5.

#### 3.4 Agro-climatic condition

The summer is hot and dry, May and June are the hottest months and minimum and maximum temperature varies from 41.9<sup>0</sup>C to 25.0<sup>0</sup>C, respectively. The average rainfall ranges between 115 to 180 mm most of which is received in the months of July, August and September with few showers in winter months.

Table 3.1: Meteorological data recorded during the experimental period

(Summer - 2016 to *Kharif*- 2017)

Year	Meteorological week	Temperature (°C)		Relative humidity		Rainfall (mm)
		Max	Min	Morning	Evening	
2016	Feb. 5-11	25.0	7.6	91.4	36.7	000.0
	Feb. 12-16	27.1	11.1	84.1	39.4	000.0
	Feb 19-25	29.2	11.7	87.0	31.32	000.0
	Feb- March 26-4	32.0	13.0	87.1	32.3	000.0
	March 5-11	31.5	16.1	84.4	39.1	022.0
	March 12-18	32.1	15.6	76.5	30.1	000.0
	March 19-25	34.9	16.7	68.8	17.4	000.0
	March-April 26-1	36.0	17.8	67	28.2	000.0
	April 2-8	40.1	22.8	50.1	20.1	000.0
	April 9-15	39.3	23.0	35.7	18.1	000.0
	April 16-22	41.9	26.0	28.8	15.8	000.0
	April 23-29	41.0	21.6	38.8	12.8	000.0
	April –May 30-6	42.8	24.5	42.4	20.0	010.0
	May 7-13	39.9	25.3	53.4	23.7	000.0
	May 14-20	45.3	27.6	39.4	16.2	000.0
	May 21-27	42.2	28.3	53.7	28.7	000.0
	May- June 28-3	41.9	27.7	55.8	27.4	000.0
	July- Aug. 30-5	32.0	25.0	94.8	73.1	118.0
	Aug. 6-12	32.4	25.6	92.4	76.0	81.2
	Aug. 13-19	32.1	25.5	90.2	73.5	65.0
Aug. 20-26	30.9	24.5	88.7	70.8	24.0	
Aug.-Sept. 27-2	34.0	26.0	88.7	70.8	10.0	
Sept. 3-9	33.4	25.6	74.1	57.7	1.0	
Sept. 10-16	34.6	25.9	78.4	55.2	0.0	

	Sept. 17-23	35.0	24.8	89.0	61.0	9.2
	Sept. 24-30	34.6	23.7	85.8	50.1	0.0
	Oct. 1-7	35.0	25.1	87.0	56.5	14.0
	Oct. 8-14	35.6	21.0	65.5	29.8	0.0
	Oct. 15-21	35.2	16.1	80.1	22.5	0.0
	Oct. 22-28	35.0	17.1	69.7	24.0	0.0
	Oct.-Nov. 29-4	32.1	13.5	92.1	29.4	0.0
<b>2017</b>	Aug. 6-12	32.4	26.4	88.1	72.8	92.2
	Aug. 13-19	34.6	27.3	78.0	56.7	0.0
	Aug. 20-26	35.6	26.2	86.0	60.2	19.0
	Aug.-Sept. 27-2	31.1	24.9	91.5	74.7	196.2
	Sept. 3-9	34.5	25.6	82.4	56.4	1.6
	Sept. 10-16	36.3	26.1	80.2	52.7	0.0
	Sept. 17-23	33.9	24.7	85.5	60.2	72.5
	Sept. 24-30	35.4	23.3	81.2	46.0	0.0
	Oct. 1-7	36.1	21.1	86.7	39.7	0.0
	Oct. 8-14	36.7	21.7	82.7	33.5	0.0
	Oct. 15-21	37.2	18.1	82.4	27.5	0.0
	Oct. 22-28	36.2	16.7	76.8	29.5	0.0
	Oct.-Nov. 29-4	33.3	14.5	86.0	39.0	0.0

During investigation, maximum temperature was ranging from to 25.0 to 45.3<sup>0</sup>C and minimum temperature from 7.6<sup>0</sup>C to 28.3<sup>0</sup>C.

### **3.5 Experimental details**

#### **3.5.1 First experiment for screening of genotypes (*Summer-2016*)**

The purpose for conducting the first experiment was to screen sixteen genotypes on the basis of mean performance for canopy temperature, yield and yield related traits.

**3.5.1.1 Experimental material:**

The experimental material used in the present study comprised of sixteen genotypes which were collected from two locations i.e., Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur and Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.).

**Table 3.2: Detail of experimental material used for present investigation**

<b>S.No.</b>	<b>NAME OF GENOTYPES</b>	<b>SOURCE</b>
1.	GST-15-101	Department of Agronomy, College of Agriculture, RVSKVV, Gwalior (M.P)
2.	GST-15-102	
3.	GST-15-108	
4.	GST-15-110	
5.	GST-15-202	
6.	GST-15-204	
7.	M-83	Rajasthan Agricultural Research Institute (RARI) , Durgapura, Jaipur (Raj)
8.	RGM-112	
9.	RGR-12-1	
10.	RGC-197	
11.	RGC-936	
12.	RGC-986	
13.	RGC-1033	
14.	RGC-1038	
15.	RGC-1055	
16.	RGC-1066	

**3.5.1.2 Design & Layout description**

The experiment was laid down in a RBD with three replications. Each genotype was sown in four rows. The recommended package of practices of clusterbean crop was followed during the conduct of experiment.

**Table: 3.3. Details of experiment of first experiment**

<b>Crop</b>	<b>Clusterbean</b>
Season & year	<i>Summer-2016</i>
Design of experiment	RBD
Number of replications	3
Number of genotypes	16
Total number of plots	48
Plot size	200 sqm
Spacing	50 cm (Row to Row), 20 cm (Plant to Plant)
Number of rows per plot	4
Plot to plot distance	40 (cm)
Distance between replication	50cm
Date of sowing	10 <sup>th</sup> Feb. 2016

### **3.5.1.3 Observations recorded**

The data were recorded on five randomly selected competitive plants from each genotype in each replication leaving the first two border rows from all the four sides, in order to avoid the sampling error. The observations were recorded as per the following procedure. Data from five plants were averaged replication wise and the mean data was used for statistical analysis for 9 characters.

#### **Quantitative characters**

##### **3.5.1.3.1 Days to 50% flowering**

The number of days was counted from the date of seed sowing to the date of emergence of 50 per cent flowering of the plants in each replication, and it expressed as in days.

##### **3.5.1.3.1 Canopy Temperature**

Six leaves from the base of plants were selected at post anthesis stage and temperature was recorded just after anthesis stage and leaf temperature was recorded by using a non-contact infra red thermometer (Model RC003).

#### **3.5.1.3.3 Days to Maturity**

The maturity were recorded from the date of sowing to complete drying of pods in days.

#### **3.5.1.3.4 Number of pods/cluster**

The total number of matured pods was counted in five random clusters.

#### **3.5.1.3.5 Number of pods/plant**

The total number of matured pods per plant was counted.

#### **3.5.1.3.6 Pod length (cm)**

The length of ten randomly selected well developed pods at random nodes was measured and expressed in centimetres.

#### **3.5.1.3.7 Number of seeds/pod**

The number of seeds from ten randomly selected mature pods were counted and averaged to obtain the number of seeds per pod.

#### **3.5.1.3.8 Plant height (cm)**

The height of plant from base of the main stem to the top most shoot was recorded in centimetres.

#### **3.5.1.3.9 100 Seed weight**

One hundred well filled and dried seeds were taken at random and weighed in grams.

#### **3.5.1.4 Statistical analysis**

Sixteen genotypes were analysed on the basis of mean performance.

#### **3.5.2 Second experiment for mutagenesis (Kharif-2016)**

The purpose of second experiment was to induce genetic variability through the use physical mutagen (gamma irradiation). Genetic variability is necessary in plant breeding programmes for crop improvement which can be induced

mutagenesis. Since hybridization in clusterbean is very difficult and cumbersome owing to small, delicate flower structures resulting in low percentage of crossed seed setting in the manually hybridized buds. Due to these reasons, not much desirable genetic variability has been generated through conventional breeding approaches.

**3.5.2.1 Experimental material & Doses of gamma irradiation**

Four selected genotype from the first experiment were used for treatment by using 10 different doses of gamma rays. Details of material used & doses are given in table: 3.5 & 3.6.

**Table 3.4: List of selected genotypes used for inducing mutation**

<b>S.No.</b>	<b>NAME OF THE GENOTYPES</b>
1.	RGC-1066
2.	RGC-1038
3.	RGC-1055
4.	GST-15-204

**Table 3.5: Details of radiation doses**

<b>S.No.</b>	<b>Mutagen</b>	<b>Source</b>	<b>Dose rate (gy/hrs)</b>	<b>Doses (KR)</b>	<b>Time (sec)</b>
1.	Physical mutagen (Gamma rays)	Cobalt 60	5.749	5KR	31
2.				10KR	62
3.				15KR	93
4.				20KR	125
5.				25KR	156
6.				30KR	187
7.				35KR	219
8.				40KR	250
9.				45KR	281
10				50KR	313

### **3.5.2.2 Mutagenic treatment of seeds**

Dry non-dormant seeds of cluster bean genotypes viz. RGC-1066, RGC-1055, RGC-1038 & GST-15-204 were selected for the present study. Sample of 100 hundred dry, healthy and uniform size seeds were treated with 5kR, 10kR, 15kR, 20kR, 25kR, 30kR, 35kR, 40kR, 45kR and 50kR of gamma rays from a  $^{60}\text{Co}$  gamma source at the National Botanical Research Institute, Lucknow, U.P, India.

### **3.5.2.3 Design and Layout description**

**Table 3.6: Details of Design & Layout description of experiment**

1. Crop	: Clusterbean
2. Design of experiment	: RBD
3. Number of genotypes	: 4
4. Number of doses	: 10
5. Mutagens	: Physical (Gamma Rays)
6. Source	: Co (cobalt)
7. Total number of plots	: 44
8. Plot size	: 200 Sqm
9. Spacing	: 50 cm (Row to Row), 20 cm (Plant to Plant)
10. Number of rows per plot	: 4
11. Plot to plot distance	: 40 cm
12. Distance between replication	: 50 cm
13. Date of sowing	: 04/08/2016

### **3.5.2.4 Raising the treated seeds**

The land was ploughed properly for sowing of the experimental materials. Normal cultural practices for raising the experimental materials were done before sowing. Fertilizers were applied @ 20 kg N and 40 kg  $\text{P}_2\text{O}_5$  per hectare. Total irrigation—one pre-sowing and three after sowing were given. The irradiated seeds along with controls were sown to raise  $M_1$  generation.  $M_1$  generation was raised without replication. The following observations were recorded in  $M_1$  to estimate the effect of mutagenic treatment.

### **3.5.2.5 Observation recorded**

#### **3.5.2.5.1 Germination %**

The number of germinated seeds were recorded at 25 days after sowing and expressed as germination percentage. During this period, all germinated seeds which had produced seedlings were considered for observation.

#### **3.5.2.5.2 Mortality (%)**

Mortality was determined by counting total number of dead plants/dose and were expressed in percentage.

#### **3.5.2.5.3 Pollen sterility and viability %**

The pollen sterility and viability were studied in each genotype by using 2 % aceto-carmin solution and examined under the low power three microscopic fields. Randomly five plants were selected and collected their pollen grains. Dark stained pollens show full viable or fertile pollen and wrinkled or colorless pollens show sterile or unviable pollens.

$$\text{Pollen sterility \%} = \frac{\text{No. of sterile pollen grains}}{\text{Total No. of pollen grains in the microscopic field}} \times 100$$

#### **3.5.2.5.3 Survival of plants at maturity (%)**

The number of plants surviving till maturity were counted in each treatment and recorded as per cent survival.

### **Harvesting of M<sub>1</sub> plants**

The mutant plants were selected from each treatment of each genotype on the basis of dominant mutation. The M<sub>1</sub> generation was harvested on single plant basis. From each treatment, about 10-16 plants were taken to raise the M<sub>2</sub> generation. The progeny of each individual M<sub>1</sub> plant (selfed) formed one M<sub>2</sub> progeny. Thus a total of 163 M<sub>2</sub> progenies were raised in next season.

### **3.5.2.5 Statistical analysis**

The observations recorded in M<sub>1</sub> generation were analysed on the basis of mean performance.

### 3.5.3 Third experiment for evaluation of mutant lines (Kharif-2017)

The third experiment was conducted to evaluate the mutant lines for mutagenic effectiveness, mutagenic efficiency, gum content, proline- level to heat stress, yield and yield related traits. The  $M_2$  generation grown during *kharif-2017* consisted of 163 progenies. These were sown in single row plot of 2m length. The control 4 genotypes, i.e. RGC-1066, RGC-1038, RGC -1055 & GST-15-204 were repeated at every replication of  $M_2$  progenies. The third experiment was also conducted in two condition (irrigated & unirrigated) for relative water content during kharif-2017.

#### 3.5.3.1 Experimental material:

Plants were individually selected from the  $M_1$  generation & seeds of these plants were used to raise  $M_2$  generation.

**Table 3.6: List of the 163 mutant lines with four controls**

S.No.	Mutant lines/Controls	S.No	Mutant lines/Controls
1	RGC-1066 (Control)	85	85-20kR-RGC-1038
2	RGC-1038 (Control)	86	86-20kR-RGC-1038
3	RGC-1055 (Control)	87	87-20kR-RGC-1038
4	GST-15-204 (Control)	88	88-20kR-RGC-1038
5	5-5kR-RGC-1066	89	89-20kR-RGC-1055
6	6-5kR-RGC-1066	90	90-20kR-RGC-1055
7	7-5kR-RGC-1066	91	91-20kR-RGC-1055
8	8-5kR-RGC-1066	92	92-20kR-RGC-1055
9	9-5kR -RGC-1066	93	93-20kR-GST-15-204
10	10-5kR- RGC-1066	94	94-20kR-GST-15-204
11	11-5kR-RGC-1066	95	95-25kR-RGC-1066
12	12-5kR-RGC-1066	96	96-25kR-RGC-1066
13	13-5kR-RGC-1066	97	97-25kR-RGC-1066
14	14-5kR-RGC-1038	98	98-25kR-RGC-1038
15	15-5kR-RGC-1038	99	99-25kR-RGC-1038
16	16-5kR-RGC-1038	100	100-25kR-RGC-1038
17	17-5kR-RGC-1038	101	101-25kR-RGC-1055
18	18-5kR-RGC-1038	102	102-25kR-RGC-1055

19	19-5kR-RGC-1038	103	103-25kR-RGC-1055
20	20-5kR-RGC-1055	104	104-25kR-RGC-1055
21	21-5kR-RGC-1055	105	105-25kR-RGC-1055
22	22-5kR-RGC-1055	106	106-25kR-RGC-1055
23	23-5kR-RGC-1055	107	107-25kR-GST-15-204
24	24-5kR-RGC-1055	108	108-25kR-GST-15-204
25	25-5kR-RGC-1055	109	109-25kR-GST-15-204
26	26-5kR-GST-15-204	110	110-25kR-GST-15-204
27	27-5kR-GST-15-204	111	111-25kR-GST-15-204
28	28-5kR-GST-15-204	112	112-25kR-GST-15-204
29	29-5kR-GST-15-204	113	113-25kR-GST-15-204
30	30-5kR-GST-15-204	114	114-30kR-RGC-1066
31	31-5kR-GST-15-204	115	115-30kR-RGC-1066
32	32-5kR-GST-15-204	116	116-30kR-RGC-1038
33	33-10kR-RGC-1066	117	117-30kR-RGC-1038
34	34-10kR-RGC-1066	118	118-30kR-RGC-1038
35	35-10kR-RGC-1066	119	119-30kR-RGC-1038
36	36-10kR-RGC-1066	120	120-30kR-RGC-1038
37	37-10kR-RGC-1066	121	121-30kR-RGC-1038
38	38-10kR-RGC-1066	122	122-30kR-RGC-1038
39	39-10kR-RGC-1038	123	123-30kR-RGC-1038
40	40-10kR-RGC-1038	124	124-30kR-GST-15-204
41	41-10kR-RGC-1038	125	125-30kR-GST-15-204
42	42-10kR-RGC-1038	126	126-30kR-GST-15-204
43	43-10kR-RGC-1038	127	127-30kR-GST-15-204
44	44-10kR-RGC-1038	128	128-35kR-RGC-1038
45	45-10kR-RGC-1038	129	129-35kR-RGC-1038
46	46-10kR-RGC-1038	130	130-35kR-RGC-1038
47	47-10kR-RGC-1038	131	131-35kR-RGC-1038
48	48-10kR-RGC-1038	132	132-35kR-RGC-1038
49	49-10kR-RGC-1055	133	133-35kR-RGC-1038
50	50-10kR-RGC-1055	134	134-35kR-GST-15-204
51	51-10kR-RGC-1055	135	135-35kR-GST-15-204
52	52-10kR-RGC-1055	136	136-35kR-GST-15-204
53	53-10kR-RGC-1055	137	137-35kR-GST-15-204
54	54-10kR-GST-15-204	138	138-35kR-GST-15-204

55	55-10kR-GST-15-204	139	139-40kR-RGC-1038
56	56-10kR-GST-15-204	140	140-40kR-RGC-1038
57	57-10kR-GST-15-204	141	141-40kR-RGC-1038
58	58-10kR-GST-15-204	142	142-40kR-RGC-1038
59	59-10kR-GST-15-204	143	143-40kR-RGC-1038
60	60-15kR-RGC-1066	144	144-40kR-RGC-1038
61	61-15kR-RGC-1066	145	145-45kR-RGC-1066
62	62-15kR-RGC-1066	146	146-45kR-RGC-1066
63	63-15kR-RGC-1066	147	147-45kR-RGC-1066
64	64-15kR-RGC-1066	148	148-45kR-RGC-1066
65	65-15kR-RGC-1066	149	149-45kR-RGC-1066
66	66-15kR-RGC-1038	150	150-45kR-RGC-1038
67	67-15kR-RGC-1038	151	151-45kR-GST-15-204
68	68-15kR-RGC-1038	152	152-45kR-GST-15-204
69	69-15kR-RGC-1038	153	153-45kR-GST-15-204
70	70-15kR-RGC-1038	154	154-45kR-GST-15-204
71	71-15kR-RGC-1038	155	155-45kR--GST-15-204
72	72-15kR-RGC-1038	156	156-45kR--GST-15-204
73	73-15kR-GST-15-204	157	157-45kR--GST-15-204
74	74-15kR-GST-15-204	158	158-45kR-GST-15-204
75	75-15kR-GST-15-204	159	159-50kR-RGC-1066
76	76-15kR-GST-15-204	160	160-50kR-RGC-1066
77	77-15kR-GST-15-204	161	161-50kR-RGC-1038
78	78-15kR-GST-15-204	162	162-50kR-RGC-1038
79	89-15kR-GST-15-204	163	163-50kR-RGC-1055
80	80-15kR-GST-15-204	164	164-50kR-GST-15-204
81	81-20kR-RGC-1066	165	165-50kR-GST-15-204
82	82-20kR-RGC-1066	166	166-50kR-GST-15-204
83	83-20kR-RGC-1038	167	167-50kR-GST-15-204
84	84-20kR-RGC-1038		

**3.5.3.2 Design & Layout description**

**Table 3.9: Details of Design & Layout description of experiment**

Crop	Clusterbean
Design of experiment	Compact Family Block design
Number of replications	2

Number of Mutant lines	163
Total number of plots	80
Plot size	780 sqm
Spacing	50 cm (Row to Row), 20 cm (Plant to Plant)
Plot to plot distance	40cm
Distance between replication	50 cm
Date of sowing	02/08/2017



**Plate 3.1: experimental field of M<sub>2</sub> generation**

### **3.5.3.3 Raising M<sub>2</sub> generation**

From M<sub>1</sub> generation selected 16 plants of each treatment were sown as individual plant progenies in compact family block design with 2 replications to study the variation among different plants of the same treatment.

### **3.5.3.4 Observation recorded**

**Quantitative:**

#### **3.5.3.4.1 Germination %**

The number of germinated seeds were recorded at 25 days after sowing of counted seeds and expressed as germination percentage. During this period, all germinated seeds which had produced seedlings were considered for observation.

#### **3.5.3.4.2 Days to 50% flowering**

The number of days to 50 % flowering were counted from the date of seed sown to the date of emergence of 50 per cent flowering of the plants in each replication and expressed as in days (days).

#### **3.5.3.4.3 Leaf area index**

It is defined as an assimilatory surface per unit area of land. Leaf area index was worked out by dividing the leaf area per plant by land area occupied by the plant (Sestak et al., 1971).

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Land area occupied by the plant}}$$

#### **3.5.3.4.4 Canopy temperature (at vegetative stage)**

Six leaves from the base of plants were selected at post vegetative stage and leaf surface temperature was recorded by using a non-contact infra red thermometer (Model RC003).

#### **3.5.3.4.5 Canopy temperature (at reproductive stage)**

Six leaves from the base of plants were selected at post reproductive stage and leaf surface temperature was recorded by using a non-contact infra red thermometer (Model RC003).

#### **3.5.3.4.6 Macro mutation**

##### **3.5.3.4.6.1 Chlorophyll mutants (albino, xantha, viridis, chlorina)**

The treated and check population were carefully screened out for chlorophyll mutations during the first 2-3 weeks after germination when the seedlings were at

the two or four leaf stage. The identification and classification procedures proposed by Gustafsson, (1947) were followed.

- i. **Chlorina-** The leaves of plants were yellowish green (pale green). They are viable and survived for a longer period.
- ii. **Albina-** The leaves were white in colour, these are few lethal and the plant died after few days
- iii. **Xantha-** The leaves were completely yellowish, they are lethal and survived for only 7-8 days.
- iv. **Viridis-** mutants were light green in color, these colors later on change to the normal green color these seedlings survived up to 40-45 days.

The following methods were adopted to represent chlorophyll mutations rate:

1. Percentage of  $M_2$  families (The progeny of single  $M_1$  plant was regarded as  $M_2$  family) segregating and also number of chlorophyll mutation per 20  $M_1$  plants.
2. Number of chlorophyll mutations per 20  $M_2$  plants

#### **3.5.3.4.7 Plant survival reduction (at 30<sup>th</sup> days)**

The survival of plants was recorded after 30<sup>th</sup> days of sowing.

#### **3.5.3.4.8 RWC (relative water content) in irrigated and un-irrigated condition**

The related water content was estimated at the anthesis stage. Three leaflets of various portion in a randomly five single plant was excised from all the mutant lines and controls to estimate the RWC in percent. The leaves were collected early in the morning and immediately transported to the laboratory by keeping the leaves in polythene bags. Fresh weight (FW) of each leaf was measured immediately and the leaf was cut into 4cm long pieces. These leaf pieces were placed in petri plates containing distilled water. Leaf sample was hydrated to full turgidity for 4hrs under normal room light and temperature. After 4 hours the samples were taken out of water and were well dried of any surface moisture quickly and lightly with filter paper and immediately weighed to obtain fully turgid weight (TW). Samples were then oven dried at 80°C for 24h and weighed (after being cooled down in a desiccators) to determine dry weight (DW). All weighing was done to the nearest mg.

Relative leaf water content was calculated following the formula given by Barrs and Wetherley, (1962)

$$\text{RWC (\%)} = [(FW-DW) / (TW-DW)] \times 100,$$

Where,

FW – sample fresh weight

TW – sample turgid weight

DW – sample dry weight.

With good and careful work the method normally result in about 2% to 3% of RWC being a statistically significant difference between treatments.

#### **3.5.3.4.9 Days to 80% maturity**

The number of days was recorded from the date of sowing to 80% drying of pods were counted as the days to maturity.

#### **3.5.3.4.10 Plant height (cm)**

The height of plant from base of the main stem to the top most shoot was recorded and expressed in centimetres.

#### **3.5.3.4.11 Pod length (cm)**

The length of ten randomly selected well developed pods were measured and expressed in centimetres.

#### **3.5.3.4.12 Number of pods/plant**

The number of pods produced by the randomly tagged plants in each mutant lines & control were counted, averaged.

#### **3.5.3.4.13 Number of pods/cluster**

The number of pods produced on pod bearing clusters of randomly tagged plants in mutant lines & control was counted, average was calculated and recorded.

#### **3.5.3.4.14 Number of Primary branches/plant**

Number of branches arising from the main stem were counted on 90th day after sowing and recorded.

#### **3.5.3.4.15 Number of cluster/plant**

The number of clusters produced by the randomly tagged plants in each mutant line & control were counted and averaged.

#### **3.5.3.4.16 Number of seeds/pod**

The dry pods from each mutant lines & controls were randomly picked from tagged plants and seeds were taken out. The number of seeds was counted and average number of seeds per pod was worked out.

#### **3.5.3.4.17 Seed yield/Plant (gm)**

The seed yield was computed by adding the weight of seeds (g) harvested from the tagged plants of each mutant lines & controls in each experimental plot after maturity.

#### **3.5.3.4.18 100 Seed weight (gm)**

One hundred seeds from each mutant lines & controls were counted and their weight (g) was recorded.

### **Biochemical:**

#### **3.5.3.4.19 Proline content:**

Proline is a basic amino acid found in high percentage in basic protein. Free proline is said to play a role in plants under stress conditions. Though the molecular mechanism has not yet been established for the increased level of proline, one of the hypotheses refers to breakdown of protein into amino acids and conversion to proline for storage.

Proline in maintaining osmotic adjustment and adaptation stress and protect membranes proteins from adverse environmental stress increase.

Estimation of total proline was done according to the method of Bates *et al.*, (1973).

Fresh 250 mg leaf sample was taken from each mutant lines and controls. Leaf tissue was homogenized using 10ml of 3% sulfo-salicylic acid and centrifuged

at 3000 rpm for 10min. To 2 ml of the supernatant, 2ml of 6 molar orthophosphoric acid, 2 ml of acid ninhydrin reagent and glacial acetic acid in 1:1:1:1 ratio was added, the tubes were heated in a water bath at 100°C for 1h and subsequently cooled on ice for 10 min. To the resultant mixture, 4ml of toluene was added and incubated at room temperature for 30 min. The tubes were shaken for 15s and allowed to stand for 10 min to separate the phases. The upper phase (pink in colour) was separated and the absorbance was measured at 520 nm using toluene as a blank. L- Proline at the concentration of 60  $\mu\text{g ml}^{-1}$  was taken as a standard.

### **Calculation**

Express the proline content on fresh-weight-basis as follows:

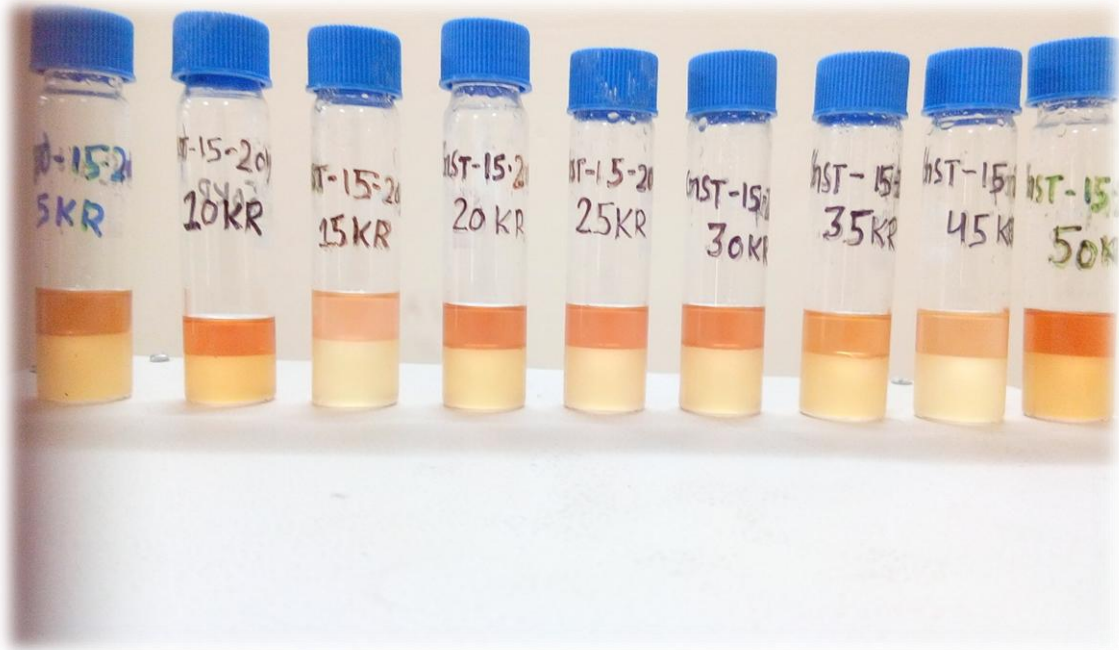
$$\mu\text{moles per g tissue} = \frac{\mu\text{g proline} \times \text{ml toluene/ml}}{115.5} \times \frac{5}{\text{g sample}}$$

Where,

115.5 is the molecular weight of proline.



Plate 3.2: Estimation of proline



**Plate 3.3: Development of two layer one upper layer (pink in color) and one lower colorless layer**

#### **3.5.3.4.20 Gum content**

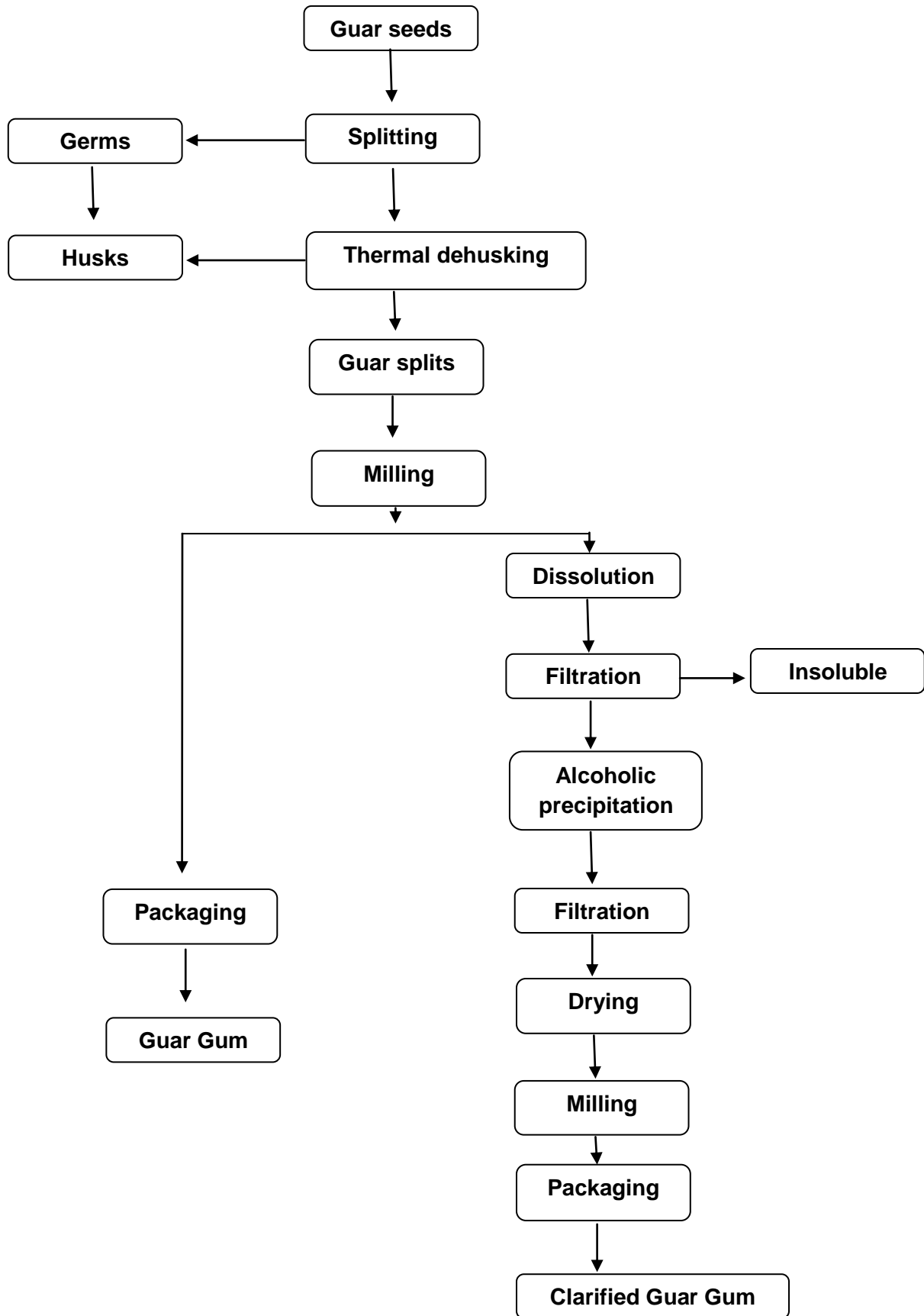
Guar gum also called as guaran or is a galactomannan. It is primarily the ground endosperm of guar beans. The guar seed are dehusked, milled and screened to obtain the guar gum. It is typically produced as a free-flowing, off-white powder.

The most reliable and accurate method of gum estimation involve extraction and purification of the galactomannan (Figure – 3.5). Gum can be estimated by a rapid and accurate method developed by Das *et al.* (1977) and Joshi (2004).

- Grind seed sample by using Cyclotec Grinding Mill (0.2 mm screen).
- Weigh 0.1 g ground sample and transfer in 100 ml conical flask and add 40 ml of 0.01 M  $\text{HgCl}_2$  solution.
- Place cotton plug and aluminium foil on the mouth of flask and keep in autoclave at 15 psi for one hour.
- Cool the samples and make 100 ml volume using 0.01 M  $\text{HgCl}_2$  solution.
- After shaking the samples, take 30 ml for centrifuge it at 5000 rpm for 20 minutes.

- Take 0.5 ml of supernatant in a centrifuge tube and add 4.5 ml ethyl alcohol to make 90 per cent alcohol. Keep the solution for overnight.
- Next day, centrifuge it at 5000 rpm for 20 minutes and discard supernatant.

**Guar gum flow chart** (Figure 3.1)



- Dissolve the residue in 0.01 M HgCl<sub>2</sub> (5 ml) by boiling in water bath for 1 hour and cool it. Make volume to 5 ml with distilled water. Shake rigorously on vortex.
- Take 1 ml of extract in a test tube of size 25 x 200 mm and add 2 ml of 2% phenol, finally add 5 ml concentrated sulfuric acid (GR).
- Shake sample and cool for 30 min. Run standard and blank simultaneously.
- Record the absorbance at 490 nm on spectrophotometer.
- Prepare standard curve using Galactose:Mannose (1 : 2 ratio). Take different concentration of 2 ppm standard solution (0, 1, 2, 3, 4 and 5 ml) in 100 ml volumetric flasks. Add 40 ml of 0.01 M HgCl<sub>2</sub> solution and 4.5 ml ethyl alcohol. Take 1 ml of extract in a test tube of size 25 x 200 mm and add 2 ml of 2% phenol, finally add 5 ml concentrated sulfuric acid (GR). Finally record the absorbance at 490 nm on spectrophotometer. Plot the curve by taking working solution concentration on X-axis and spectrophotometer reading on Y-axis. Repeat the process till get straight line relationship thereafter calculate the factor i.e. 1 spectrophotometer reading is equal to how much ppm of gum.

### **5.3.5 Statistical analysis**

The following statistical and biometrical tools were employed for interpretation of results of M<sub>2</sub> generation.

#### **5.3.5.1 Analysis of variance (Compact Family Block Design)**

Data recorded in M<sub>2</sub> generation for progenies in each family were subjected to the analysis of variance in compact family block design (Chandel, 2010).

**Table 3.7: Skeleton of Analysis of variance (ANOVA)**

<b>Between families</b>				
<b>Due to</b>	<b>D.F.</b>	<b>S.S.</b>	<b>M.S.</b>	<b>F cal.</b>
<b>Replication</b>	r-1	R	$R/(r-1)=V_r$	$V_r/V_e$
<b>families</b>	f-1	G	$G/(T-1)=V_t$	$V_t/V_e$
<b>Error</b>	$(r-1) \times (f-1)$	E <sub>1</sub>	$E/(r-1)(t-1)=V_e$	

Between progenies within families				
Due to	D.F.	S.S.	M.S. within families	F cal.
			F <sub>1</sub> , F <sub>2</sub> ....F <sub>12</sub>	
Block	r-1	B	B/(r-1) = Vr <sub>1</sub>	Vr <sub>1</sub> /Ve <sub>1</sub>
Progenies	p-1	P	P/(p-1) = Vt <sub>1</sub>	Vt <sub>2</sub> /Ve <sub>1</sub>
Error	(r-1) x (p-1)	E <sub>2</sub>	E/(r-1)(t-1) = Ve <sub>1</sub>	

f, p and r = number of families, progenies in a family and replications respectively.

### 5.3.5.2 Estimation of variability (Phenotypic and genotypic variance) among mutant lines & control in M<sub>2</sub> generation.

#### 5.3.5.2.1 Range

This is the difference between the lowest and the highest values of any observations.

#### 5.3.5.2.2 Mean

It is the sum of the values all observations divided by the total number of observations.

Therefore, each character observed in the plant, taken randomly was averaged in accordance with the formula as given below:

$$\text{Mean} = \frac{\sum X}{N}$$

#### 5.3.5.2.3 Standard Error of Mean (SEM)

Standard error of mean was calculated by the following formula:

$$\text{SEM} = \sqrt{\frac{2EMS}{r}}$$

#### 5.3.5.2.4. Critical differences (C.D.)

Critical difference was calculated by the following formula:

$$CD = \sqrt{\frac{2EMS}{r}} \times t_{cdr} \text{ at } 5\%$$

Where,

SEM = Standard error of mean

EMS = Error mean sum of squares

r = Number of replications

t value = Table value at error degree of freedom at 5% level of significance.

Significant and 'F' value indicates that there is significant difference among the treatment. But to compare any two particular treatments it is tested against C.D. value.

#### **5.3.5.2.5 Coefficient of variance**

$$\text{Coefficient of Variance (CV)} = \frac{\sqrt{SE}}{X} \times 100$$

#### **5.3.5.2.6 Genotypic variance**

Variance due to genotypic present in the population was calculated by the formula (Al-Jibouri *et al.*, 1958).

$$\sigma^2 g = \frac{\text{Genotype MSS} - \text{Error MSS}}{\text{Number of replications (r)}}$$

#### **5.3.5.2.7 Phenotypic variance**

Phenotypic variance was calculated by following formula (Al-Jibouri *et al.* 1958).

$$\sigma^2 p = \text{Genotypic variance} + \text{Error variance}$$

#### **5.3.5.2.8 Environmental variance**

The environmental variance is the variance due to environmental deviations.

$$\sigma^2 e = \text{Error mean sum of square (EMS)}$$

### **5.3.5.2.9 Coefficient of variation**

The phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were calculated by the formula given by Burton and De Vane (1953).

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

$$GCV = PCV = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

$$ECV = PCV = \frac{\sqrt{\sigma^2_e}}{\bar{X}} \times 100$$

Where,

$\sigma^2_p$  = Phenotypic variance

$\sigma^2_g$  = Genotypic variance

$\sigma^2_e$  = Environmental the character

$\bar{X}$  = Mean of the character

GCV and PCV values were categorized as low, moderate and high as indicated Shivasubramanian and Menon (1973). It is as follows.

0-10%	:	Low
10-20%	:	Moderate
20% and above	:	High

### **5.3.5.3 Heritability in broad sense**

Heritability is the heritable portion of the total phenotypic variance. It is a good index of transmission of characters from parents to off spring. The estimates of heritability help the plant breeder in selection of elite genotypes from diverse genetic populations.

Heritability in broad sense ( $h^2$ ) calculated using the formula suggested by Burton and De vane (1953).

$$h^2 = \frac{\sigma^2g}{\sigma^2g + \sigma^2e}$$

Where,

$\sigma^2g$  = Genotypic variance

$\sigma^2e$  = Environmental variance

The heritability was categorized as low, moderate and high as given by Robinson *et al.* (1949).

0-30%	:	Low
30-60%	:	Moderate
60% and above	:	High

#### **5.3.5.4 Genetic advance**

The genetic advance i.e. the expected genetic gain was worked out by using the formula suggested by Johnson *et al.* (1955). Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone.

$$GA = \frac{\sigma^2g}{\sigma^2p} k \cdot \sigma^2p$$

Where,

$h^2$  = Heritability

$K$  = Selection differential standard units which is 2.06 at 5% selection intensity

$\sigma^2p$  = Phenotypic standard deviation

$GA$  = Genetic advance

#### **5.3.5.5 Correlation coefficient analysis**

The genotypic and phenotypic correlation coefficients were calculated to determine the degree of association of characters with yield and also among the yield components themselves in each environment. Correlations were computed as per the method suggested by Johnson (1955).

$$r_p = \frac{\text{Cov}_{xy}}{\text{Var}_y}$$

Where,

$r_p$  = Phenotypic correlation

$\text{Cov}_{xy}$  = Phenotypic covariance between the characters x and y

$\text{Var}_x$  and  $\text{Var}_y$  = Phenotypic variance of the characters x and y respectively

$$r_g = \frac{\text{Cov}_{xy}}{\text{Var}_y}$$

Where,

$r_g$  = Genotypic correlation

$\text{Cov}_{xy}$  = Genotypic covariance between the characters x and y.

$\text{Var}_x$  and  $\text{Var}_y$  = Genotypic variance of the characters x and y respectively.

### **Chlorophyll mutations**

The chlorophyll mutations were screened and recorded in the field when the seedlings were 7-10 days old. The types of chlorophyll mutations scored like albino, Xantha, chlorina and Viridis. These are classified according to the terminology of (Gustafsson, 1940). The frequency of chlorophyll mutants was calculated according to (Gaul, 1960) i.e. Number of mutants / 100 M2 plants.

### **Estimation of mutagenic effectiveness and efficiency**

Mutagenic effectiveness and efficiency of different mutagens were calculated according to the formulae suggested by (Konzak et al., 1965). The mutagenic effectiveness can be measured of the frequency of mutations induced by a unit dose of mutagen (kR or time x concentration) while mutagenic efficiency gives an idea of the proportion of mutations in relation to biological damage such as lethality, pollen sterility.

$$\begin{aligned} \text{Mutagenic effectiveness} &= \frac{\text{Mutation frequency (MF)}}{\text{Dose or (Time x Concentration)}} \\ &= \text{MF/kR or MF/TC} \end{aligned}$$

Where,

MF = % of chlorophyll mutations in M2 generation.

T = Period of treatment with chemical mutagen.

C = Concentration of chemical mutagens,

kR = unit of gamma radiation.

$$\text{Mutagenic efficiency} = \frac{\text{Mutation frequency}}{\text{Biological damage}}$$

$$= \text{MF/L, MF/S,}$$

Where,

L = % of lethality in M1 generation.

I = % of seeding injury in M1 generation.

S = % of pollen sterility in M1 generation.

MI = % of mitotic abnormalities in M1 generation

## Chapter - IV

### RESULTS

The present study entitled, “Genetic manipulation through induced mutation for yield and gum content in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.)” was carried out in three crop seasons from the Summer 2016 to Kharif 2017. The 16 genotypes were screened for yield and its attributing characters during summer 2016. Four genotypes were chosen for irradiation treatment based on mean performance of various yield attributing traits & canopy temperature. Gamma irradiation was exposed to 4 selected genotype viz., RGC 1066, RGC 1055, RGC 1038 and GST 15-204 to create variability. Selected mutant lines of M<sub>2</sub> generation were evaluated for gum content, proline content, mutagenic effectiveness and efficiency, yield and its related traits. The detail of results are presented as under:

#### 4.1 Screening of 16 genotypes

##### 4.1.1 Mean performance

The mean values of 16 genotype with respect to nine characters are presented in the Table 4.1. Trait wise results are presented below:

##### 4.1.1.1 Days to 50% flowering

The days to 50% flowering ranged from 53.00 to 62.00 days with the mean value of 56.81. The genotype viz.: RGC-936 (62.00) followed by RGM-112 (61.67), GST-15-110 (61.33) and RGC-1033 (61.33) with *at par* performance. The genotype viz., GST-15-108 (53.00) followed by RGC-1066 (53.67), M-83 (53.67) and RGM-112 (61.67) were take lowest days for the flowering *i.e.* early flowering .

##### 4.1.1.2 Days to 80% maturity

The days to 80% maturity ranged from 67.33 to 84.33 days with the mean value of 74.48. The genotypes viz.: GST-15-101(84.33) and RGC-1038 (83.33) followed by GST-15-110 (81.67) and GST-15-102 (80.67) with *at par* performance was taken more days for the 80% maturity. The genotype viz., RGC-1066 (67.33) followed by M-83 (67.67), RGC-986 (68.33), RGR-12-1 (68.33) and GST-15-204 (68.67) showed lowest results. However they did not vary among each other.

##### 4.1.1.3 Number of pods/cluster

The number of pods/cluster ranged from 2.33 to 8.33 with the mean value of 4.69. Three genotypes viz: RGC-1038 (8.33), RGC-1055 (8.33) and RGC-1066 (8.33) showed higher number(s) of pods/cluster. The genotype viz. GST-15-101 (2.33) followed by GST-15-108 (3.00), GST-15-110 (3.00) and GST-15-102 (3.33) had minimum counts in this regard.

#### **4.1.1.4 Number of pods/plant**

The number of pods/plant ranged from 27.00 to 165.00 pods/plant with the mean value of 54.56. The genotype GST-15-102 (165.00) followed by RGC-1066 (100.33) and RGC-1055 (70.67) formed pods in higher numbers. However, genotype GST-15-101 (27.00) followed by RGM-112 (30.00) were found inferior for this parameter.

#### **4.1.1.5 Pod length (cm)**

The pod length ranged from 3.63 to 6.333 with the mean value of 4.76. The genotype viz., GST-15-102 (165.00) followed by RGC-1055 (6.33), GST-15-101 (6.07) RGC-1038 (5.63) showed highly significant. The genotype viz., M-83 (3.63) followed by RGR-12-1 (3.97) were less significant.

#### **4.1.1.6 Seeds/pod**

The data for seeds/pod revealed that it's ranged from 4.33 to 9.33 with the mean value of 6.08. The genotype viz., RGC-1055 (9.33) followed by GST-15-204 (7.67), RGC-1038 (7.33) and GST-15-101 (7.33) showed highly significant. The genotype viz., GST-15-102 (4.33) followed by GST-15-202 (4.33), GST-15-108 (4.67) and GST-15-110 (4.67) were less significant.

#### **4.1.1.7 Plant height (cm)**

The plant height varying in range of 35.00 to 104.67 with the mean value of 58.50. The genotype RGC-1055 (104.67) followed by genotypes RGC-1066 (96.67) and RGC-1033(77.67) were proved superior. The genotype RGM-112 (35.00) followed by RGC-986 (37.67) and GST-15-101 (48.00) were proved inferior for this attributes.

#### **4.1.1.8 Canopy temperature (°C)**

The canopy temperature ranged from 33.77 to 45.30 with the mean value of 39.89. The genotype RGM-112 (45.30) followed by RGC-936 (44.17) and M-83 (42.63) showed higher canopy temperature. The genotype viz., RGC-1055 (33.77) followed by RGC-197 (36.27) and RGC-1033 (36.33) were proved inferior in this regard.

#### 4.1.1.9 100 Seed weight (gm)

The 100 seed weight (gm) ranged from 2.59 to 3.65 with the mean value of 3.04. The genotype RGC-936 (3.65) followed by RGC-986 (3.48), RGM-112(3.11) and RGR-12-1 (3.11) were proved superior. The genotype RGC-1033 (2.59) followed by GST-15-108 (2.75) and GST-15-102 (2.79) had showed inferior result.

**Table 4.1: Mean performance of 16 genotypes for nine characters.**

S. No	Genotypes	Days to 50% flowering	Days to maturity	No of Pods / cluster	No of Pods /plant	Pod Length (cm)	Seeds / pod	Plant Height	Canopy Temp.	100 Seed Weight (gm)
1.	GST-15-101	57.67	84.33	2.33	27.00	6.07	7.33	48.00	42.31	3.10
2.	GST-15-102	55.00	80.67	3.33	165.00	4.73	4.33	58.00	40.63	2.79
3.	GST-15-108	53.00	75.00	3.00	37.67	4.20	4.67	54.00	39.17	2.75
4.	GST-15-110	61.33	81.67	3.00	42.67	4.37	4.67	51.33	39.51	2.80
5.	GST-15-202	57.67	75.33	3.33	49.33	4.53	4.33	62.67	37.23	3.28
6.	GST-15-204	54.33	68.67	6.33	35.00	4.57	7.67	49.67	41.00	3.07
7.	M-83	53.67	69.67	4.33	48.33	3.63	5.33	62.67	42.63	3.05
8.	RGM-112	61.67	74.67	3.67	30.00	4.83	6.33	35.00	45.30	3.11
9.	RGR-12-1	54.00	68.33	3.33	47.00	3.97	5.33	40.67	39.70	3.11
10.	RGC-197	60.33	72.33	4.00	36.33	4.17	5.67	41.67	36.27	2.92
11.	RGC-936	62.00	81.00	3.33	46.33	4.93	6.67	48.00	44.17	3.65
12.	RGC-986	53.00	68.33	5.33	36.00	4.13	5.33	37.67	40.30	3.48
13.	RGC-1033	61.33	73.67	4.67	53.33	4.90	6.33	77.67	36.33	2.59
14.	RGC-1038	56.33	83.00	8.33	48.00	5.63	7.33	67.67	40.22	2.95
15.	RGC-1055	54.00	67.67	8.33	70.67	6.63	9.33	104.67	33.77	2.91
16.	RGC-1066	53.67	67.33	8.33	100.33	4.87	6.67	96.67	39.77	3.03
	<b>Mean</b>	<b>56.81</b>	<b>74.48</b>	<b>4.69</b>	<b>54.56</b>	<b>4.76</b>	<b>6.08</b>	<b>58.50</b>	<b>39.89</b>	<b>3.04</b>
	<b>SE(m)</b>	<b>0.23</b>	<b>0.39</b>	<b>0.10</b>	<b>1.01</b>	<b>0.12</b>	<b>0.17</b>	<b>1.33</b>	<b>0.98</b>	<b>0.20</b>
	<b>Cd5%</b>	<b>0.66</b>	<b>1.13</b>	<b>0.29</b>	<b>2.91</b>	<b>0.33</b>	<b>0.48</b>	<b>3.82</b>	<b>2.82</b>	<b>0.57</b>
	<b>CV%</b>	<b>2.29</b>	<b>3.39</b>	<b>3.52</b>	<b>10.25</b>	<b>3.96</b>	<b>5.11</b>	<b>13.00</b>	<b>11.59</b>	<b>8.56</b>

## 4.2 Evaluation of mutagenic effects of gamma rays in M<sub>1</sub> generation

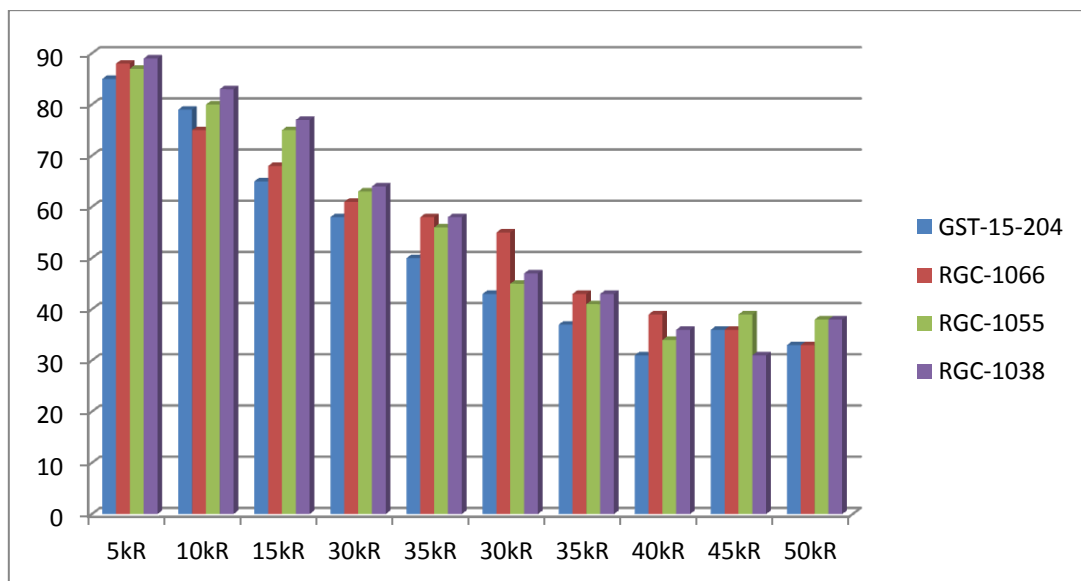
This section gives description and comparison of different doses, regarding germination %, plant survival at maturity, pollen sterility and mortality.

### 4.2.1 Germination% (field condition)

The effect of radio-sensitivity in germinated seeds of M<sub>1</sub> generation revealed that 5kR dose showed the maximum germination (87.35%) and 50kR showed minimum germination (35.35%) (Table 4.2). Genotype RGC-1038 (89%) at 5kR dose showed maximum germination % and genotype RGC-1066 (33%) at 50 kR dose showed minimum germination % as compared to other genotypes (Fig 4.1). Germination was reduced with increased doses.

**Table 4.2: Germination% in M<sub>1</sub> generation**

S.No	Doses	GST-15-204	RGC-1066	RGC-1055	RGC-1038	Mean
1	5kR	85	88	87	89	87.35
2	10kR	79	75	80	83	79.00
3	15kR	65	68	75	77	71.35
4	30kR	58	61	63	64	61.35
5	35kR	50	58	56	58	55.50
6	30kR	43	55	45	47	47.50
7	35kR	37	43	41	43	41.00
8	40kR	31	39	34	36	35.00
9	45kR	36	36	39	31	38.00
10	50kR	33	33	38	38	35.35



**Fig 4.1: Germination% in M<sub>1</sub> generation.**

#### 4.2.2 Pollen sterility %

The sterility was ranging from 5.36% to 59.09%, maximum pollen sterility was recorded with 50kR dose in genotypes: GST-15-204 (59.09%), RGC-1055 (43.53%), RGC1066 (40.36%), RGC-1038(41.76%) and minimum was recorded with 5 KR with genotypes GST-15-204(6.63%), RGC-1055 (7.335%), RGC-1066 (5.89%) and RGC-1038 (5.36%). Pollen sterility was varied from genotype to genotype. The maximum pollen sterility was found in genotype GST-15-304 (59.09%) and minimum in genotype RGC-1066 (40.36). Mean performance of the genotypes showed that maximum sterility was recorded at 50kR (45.38%) dose and minimum at 5kR (6.67). Therefore, it may be concluded that the pollen sterility has been found to increase with increase in the doses of gamma rays (Fig. 4.3).

**Table 4.3: Pollen sterility% in M<sub>1</sub> generation**

S.No	Doses	Genotypes				Mean
		GST-15-204	RGC-1066	RGC-1055	RGC-1038	
		Pollen sterility%	Pollen sterility%	Pollen sterility%	Pollen sterility%	
1.	5kR	5.36	8.33	7.33	5.89	6.67
2.	10kR	9.09	9.07	8.36	8.37	8.73
3.	15kR	10.71	11.34	9.67	10.03	10.41
4.	30kR	13.50	13.03	13.61	11.48	13.65
5.	35kR	15.30	15.31	13.43	14.36	14.30
6.	30kR	17.64	16.33	15.11	17.31	16.54
7.	35kR	33.07	33.34	19.50	30.13	31.36
8.	40kR	30.76	38.08	36.36	34.07	37.31
9.	45kR	40.90	31.35	35.65	33.03	35.30
10.	50kR	59.09	38.36	43.53	40.36	45.38

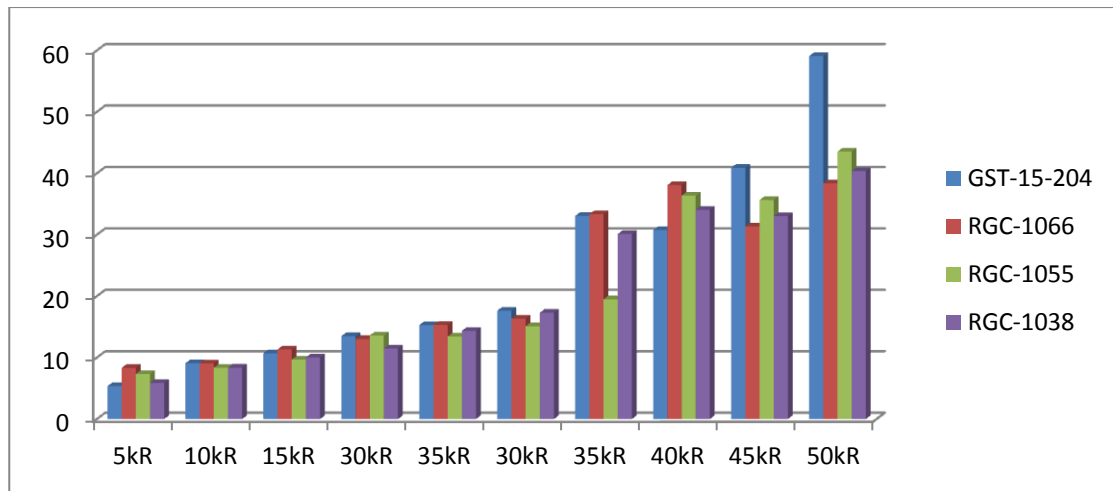


Fig 4.2: Showing pollen sterility% in M1 generation

#### 4.2.3 Mortality

Higher mortality was recorded at 50 kR dose with genotype GST-15-304 (77%) followed by RGC-1066 (74%), RGC-1055 (73%) and RGC-1038 (71%) and lower lethality at 5 KR dose with genotypes GST-15-304 (15%) followed by RGC-1055 (13%), RGC1066 (13%) and RGC-1038 (7%). Maximum Mortality was found in genotype viz., RGC-1066(74%) and minimum in genotype viz., RGC-1038 (7%).

Table 4.4: Mortality in M<sub>1</sub> generation

S.No.	Doses	Genotypes				Mean
		GST-15-204	RGC-1066	RGC-1055	RGC-1038	
		Mortality	Mortality	Mortality	Mortality	
1.	5kR	15	13	13	7	13.75
2.	10kR	31	35	30	18	31.00
3.	15kR	35	33	35	33	38.75
4.	30kR	43	39	38	36	38.75
5.	35kR	50	43	44	43	44.50
6.	30kR	57	45	55	53	53.5.
7.	35kR	63	57	59	57	59.00
8.	40kR	69	61	66	64	65.00
9.	45kR	74	74	71	69	73.00
10.	50kR	77	74	73	73	74.75

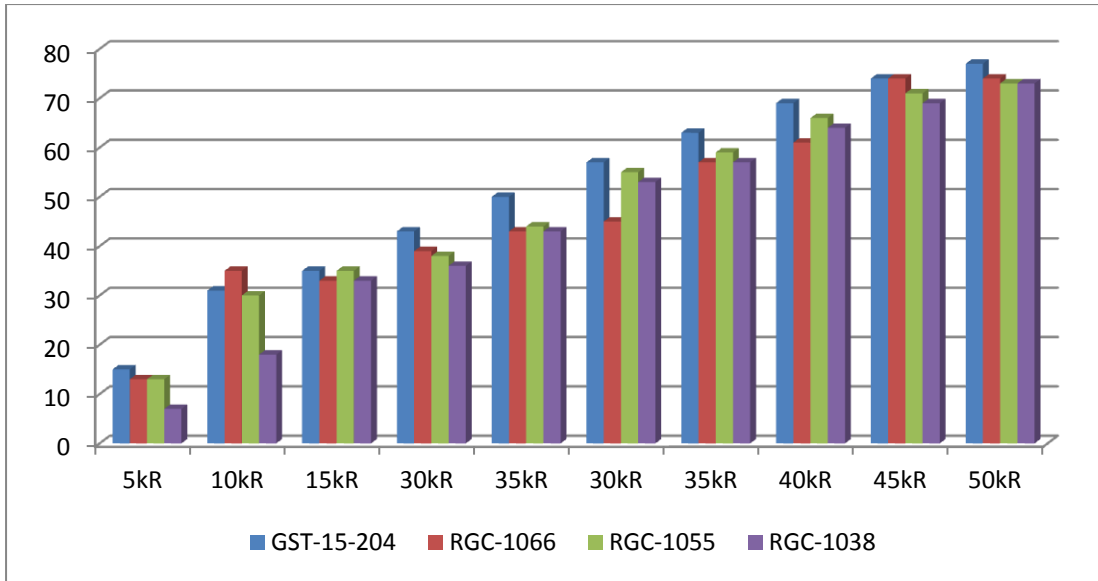


Fig. 4.3: Showing mortality in M<sub>1</sub> generation.

#### 4.2.4 Survival of plant at maturity

Survival of plants at maturity was decreased with increased dose of gamma rays. On the basis of mean performance maximum survival of plants at maturity were recorded at 5kR (71.35) and minimum at 50kR (9.35).

Table 4.5: Survival of plant at maturity in M<sub>1</sub> generation

S.No.	Doses	Genotypes				Mean
		GST-15-204	RGC-1066	RGC-1055	RGC-1038	
		Survival of plant at maturity	Survival of plant at maturity	Survival of plant at maturity	Survival of plant at maturity	
1.	5kR	69	73	71	73	71.35
2.	10kR	63	59	64	66	63
3.	15kR	49	53	59	61	55.35
4.	30kR	43	45	46	48	45.35
5.	35kR	34	43	40	43	39.5
6.	30kR	37	39	39	31	31.5
7.	35kR	31	37	35	37	35
8.	40kR	15	33	18	30	19
9.	45kR	10	10	13	15	13
10.	50kR	7	6	13	13	9.25

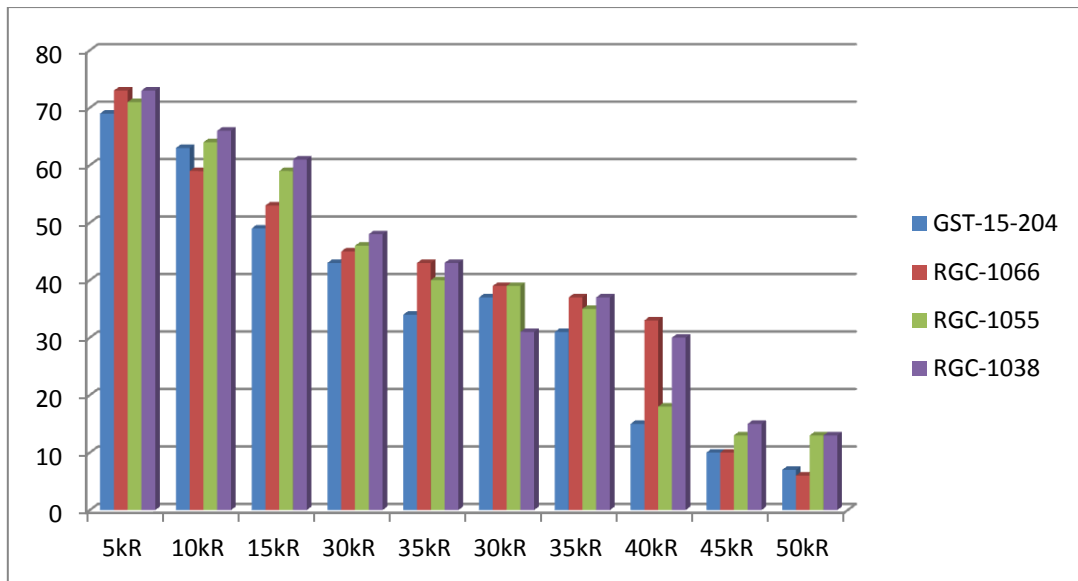


Fig 4.4 Showing survival of plant at maturity M<sub>1</sub> generation

### **4.3 Evaluation of selected mutant lines and effects of gamma rays in M<sub>2</sub> generation**

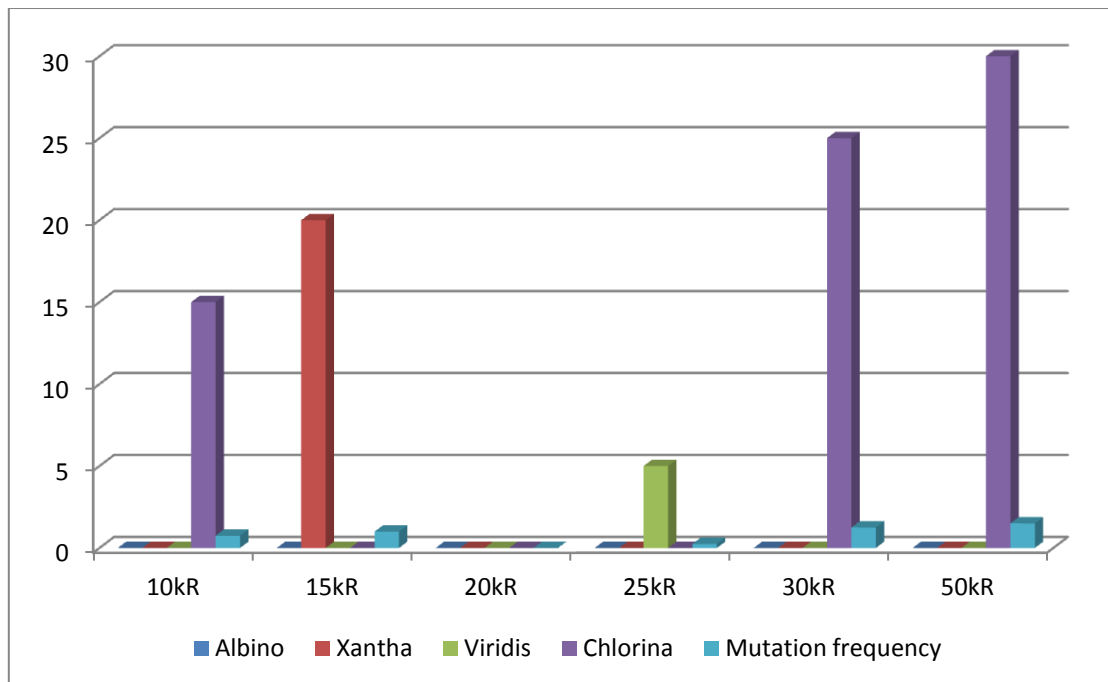
#### **4.3.1 Macro mutation (qualitative genetic changes)**

##### **4.3.1.1 Spectrum and frequency of induced chlorophyll mutations**

Highest mutation frequency was recorded in two genotypes viz., GST-15-204 and RGC-1066 but mutation frequency decreased with increased doses of gamma rays in two other genotypes as well viz., RGC-1055 and RGC-1038. Chlorophyll mutants were found in almost all the mutagenic doses of gamma rays except some doses viz., 25kR, 35kR and 45kR in genotype GST-15-204, 20kR in genotype RGC-1066 and 35kR in genotype RGC-1038 and 10kR in genotype RGC-1055. Chlorophyll mutation was not recorded with 35kR treatment of gamma rays in all studied genotypes. The highest chlorophyll mutation frequency 1.5 was recorded with 50kR while the lowest 0.5 recorded with 30kR treatments respectively. The chlorophyll mutation frequency was increased from 5kR (0.75) to 20kR (1.5) but it decreased with 30kR. however, frequency of 50kR (0.75) was found similar as 5kR (0.75) in genotype GST-15-204, in RGC-1055, chlorophyll mutation frequency was increased from 10kR (0.75) to 50kR (1.5). The chlorophyll mutation frequency was decreased from 5kR to 45kR in two genotypes *namely*: RGC-1055 and RGC-1038. In the segregating M<sub>2</sub> generation, spectrum of chlorophyll mutations indicated the presence of four types of chlorophyll mutant's viz., albina, xantha, viridis, chlorina. Viridis and chlorina were observed with 5, 10, 15, 20, 25, 30, 40 and 50 kR doses while Albino was observed with only 10kR and Xantha with only 15 and 50kR doses. Chlorina was observed with most of the doses. The highest frequency of chlorina mutant was recorded 1.75% with 5 kR and lowest with 20 kR treatments (Table-4.6 to 4.9 and Fig. 4.5 to 4.8).

**Table 4.6: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype GST-15-204**

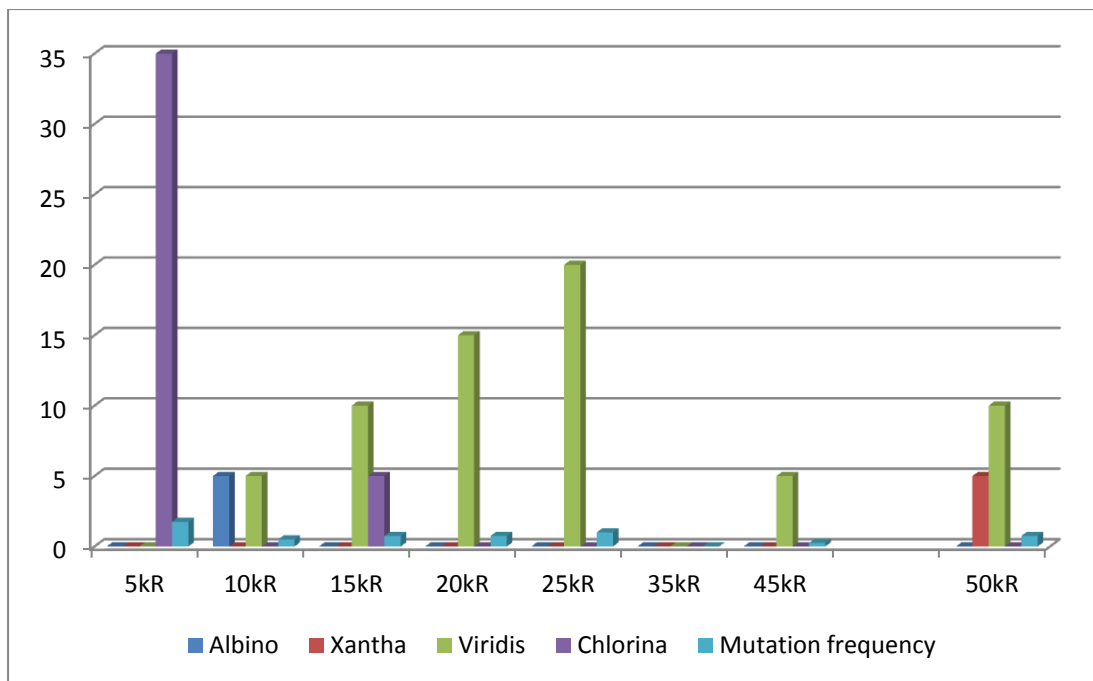
Mutagens Gamma rays (kR)	Albino	Xantha	Viridis	Chlorina	Mutation frequency
10kR	0	0	0	15	0.75
15kR	0	20	0	0	1.00
20kR	0	0	0	0	0.00
25kR	0	0	5	0	0.25
30kR	0	0	0	25	1.25
50kR	0	0	0	30	1.50



**Fig 4.5: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., GST-15-204.**

**Table 4.7: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1066**

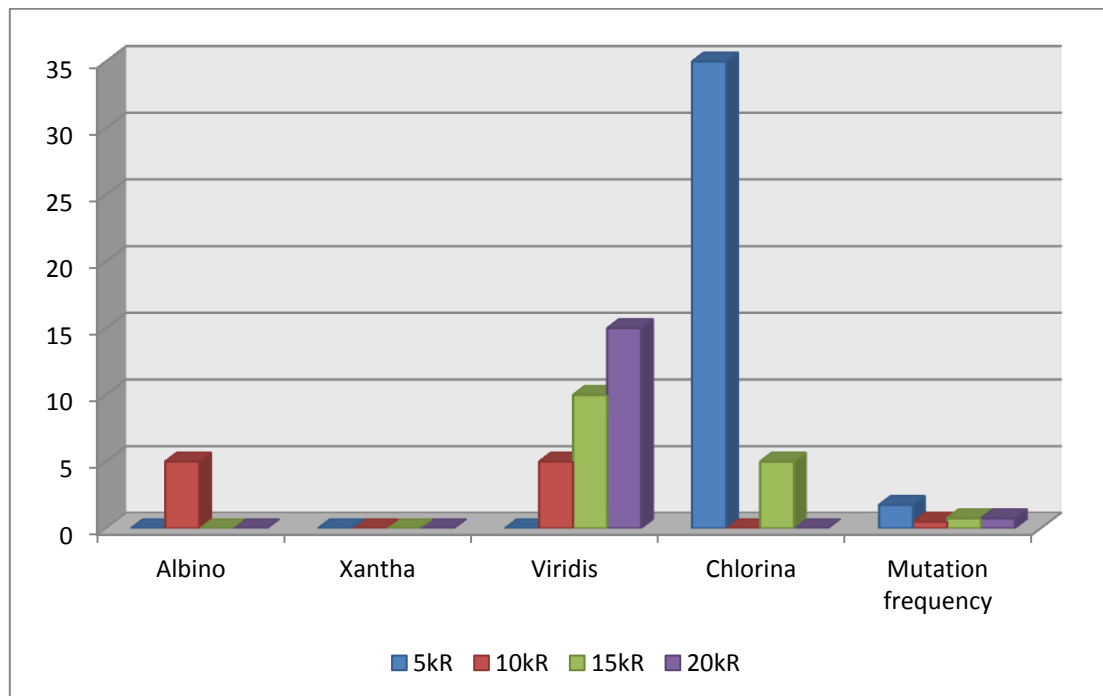
Mutagens Gamma rays (kR)	Albino	Xantha	Viridis	Chlorina	Mutation frequency
5kR	0	0	0	15	0.75
10kR	0	0	0	25	1.25
15kR	0	0	20	0	1.00
20kR	0	0	30	0	1.50
25kR	0	0	0	0	0.00
30kR	0	0	0	10	0.50
35kR	0	0	0	0	0.00
45kR	0	0	0	0	0.00
50kR	0	5	10	0	0.75



**Fig 4.6: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1066**

**Table 4.8: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1055**

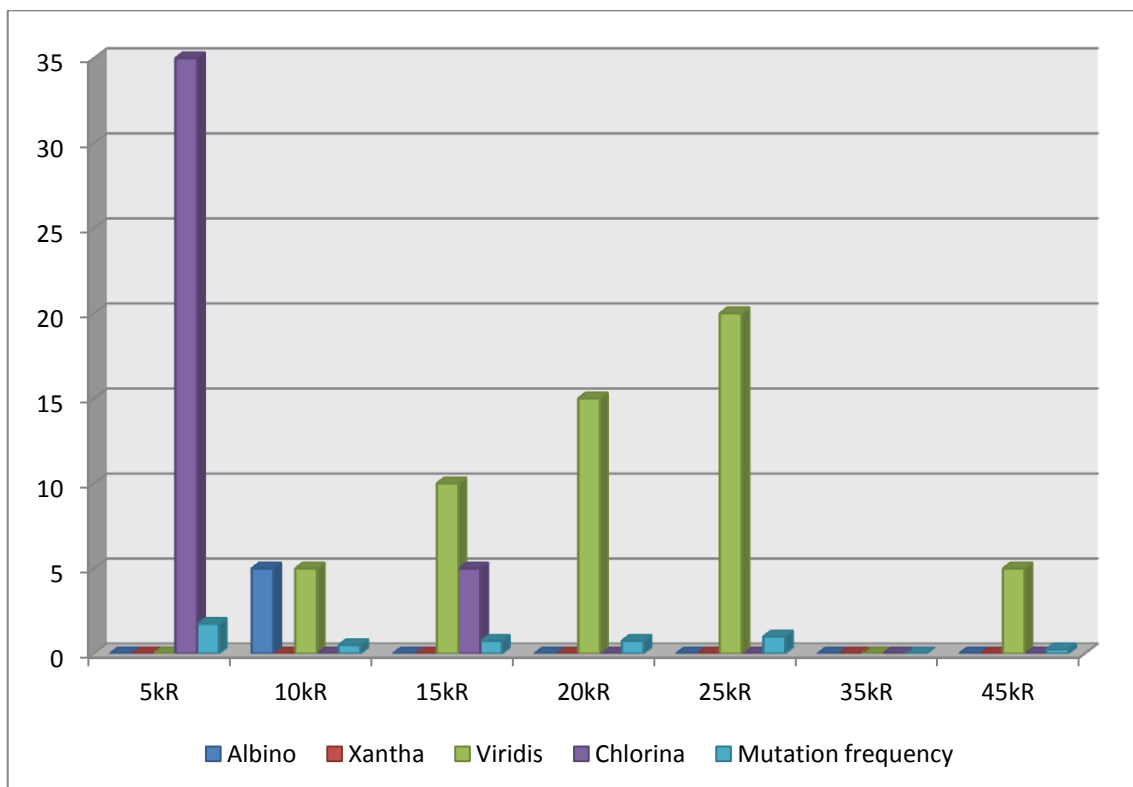
Mutagens Gamma rays (kR)	Albino	Xantha	Viridis	Chlorina	Mutation frequency
5kR	0	0	0	30	1.50
10kR	0	0	0	0	0.00
20kR	0	0	0	0	0.00
25kR	0	0	15	0	0.75



**Fig 4.7: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1055**

**Table-4.9: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1038**

Mutagens Gamma rays (kR)	Albino	Xantha	Viridis	Chlorina	Mutation frequency
5kR	0	0	0	35	1.75
10kR	5	0	5	0	0.50
15kR	0	0	10	5	0.75
20kR	0	0	15	0	0.75
25kR	0	0	20	0	1.00
35kR	0	0	0	0	0.00
45kR	0	0	5	0	0.25



**Fig-4.8: Effect of gamma rays on the frequency of the chlorophyll mutation in M<sub>2</sub> generation of genotype viz., RGC-1038**



Plate 4.1 Shows chlorophyll mutants plant -Xantha (completely yellow)



Plate 4.2 Shows chlorophyll mutants plant -viridis (light green)



Plate 4.3 Shows chlorophyll mutants plant - **Chlorina** (pale green)

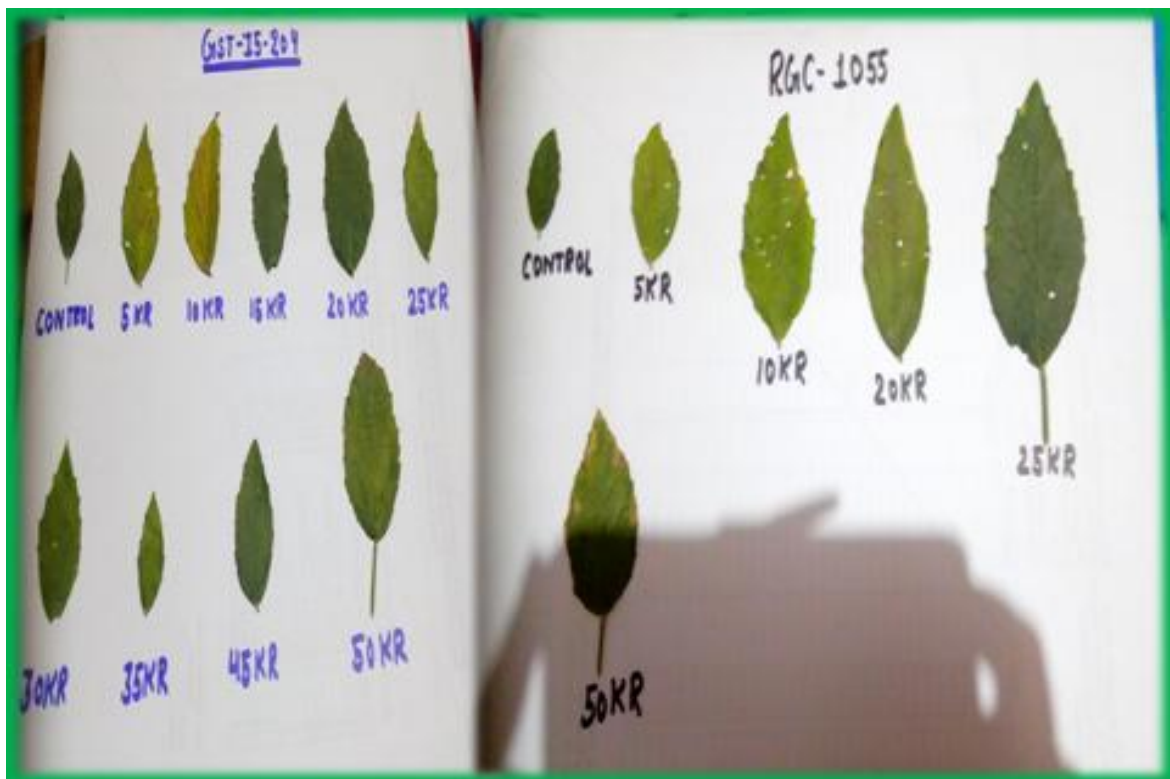


Plate 4.4 Variation in leaf size

#### 4.3.1.2 Spectrum and frequency of induced viable mutations:

Dwarf mutants were observed in genotype RGC-1066 with 5kR and 10kR doses, in genotype RGC-1055 with 35 kR and in genotype RGC-1038 with 15kR. Tall mutants were evidenced in genotype RGC-1066 with 5kR, 20kR, 45kR and 50kR; RGC-1055 with 20kR, 35kR and 45kR doses; genotype GST-15-204 with 20kR, 45kR and 50kR doses. Spreading type mutants were found in genotype RGC-1066 with 5kR application, in genotype RGC-1055 with 15kR, 20kR, 25kR and 45 kR doses, in genotype RGC-1038 with 20kR and in genotype GST-15-204 at 50kR. Genotypes RGC-1066 with 5kR, 15kR, 25kR and 45kR, in genotype RGC-1055 with 5kR, 10kR, 20kR and 25kR; in genotype RGC-1038 with 25kR doses were found performer for early maturity and for late maturity genotype RGC-1066 with 10kR and 20kR doses found suitable. One apical bearing type mutant was found in genotype RGC-1066 with 45kR (Plate 4.1 to 4.4). Data of visible type mutant plants has been given in Table 4.10 to 4.13.

**Table 4.10: Spectrum and frequency of induced viable mutations in M<sub>2</sub> generation of genotype viz., RGC-1066**

Doses	RGC-1066							
	Plant type mutants					Pod bearing Mutant	Total	
	Dwarf	Tall	Spreading	Early	Late	Apical bearing	Number	Type
5kR	1	4	1	1	0	0	7	4
10kR	1	0	0	0	2	0	3	2
15kR	0	0	0	2	0	0	2	1
20kR	0	1	0	0	4	0	5	2
25kR	0	0	0	1	0	0	1	1
30kR	0	0	0	0	0	0	0	0
35kR	0	0	0	0	0	0	0	0
45kR	0	2	0	1	0	1	4	3
50kR	0	1	0	0	0	0	1	1



Table 4.13: Spectrum and frequency of induced viable mutations in M<sub>2</sub> generation of genotype viz., GST-15-204

Doses	GST-15-204							
	Plant type mutants					Pod bearing Mutant	Total	
	Dwarf	Tall	Spreading	Early	Late	Apical bearing	Number	Type
5kR	0	0	0	0	0	0	0	0
10kR	0	0	0	0	0	0	0	1
15kR	0	0	0	0	0	0	1	1
20kR	0	2	0	0	0	0	2	1
25kR	0	0	0	0	0	0	0	0
30kR	0	0	0	0	0	0	0	0
35kR	0	0	0	0	0	0	0	0
45kR	0	3	0	0	0	0	3	1
50kR	0	1	3	0	0	0	4	2

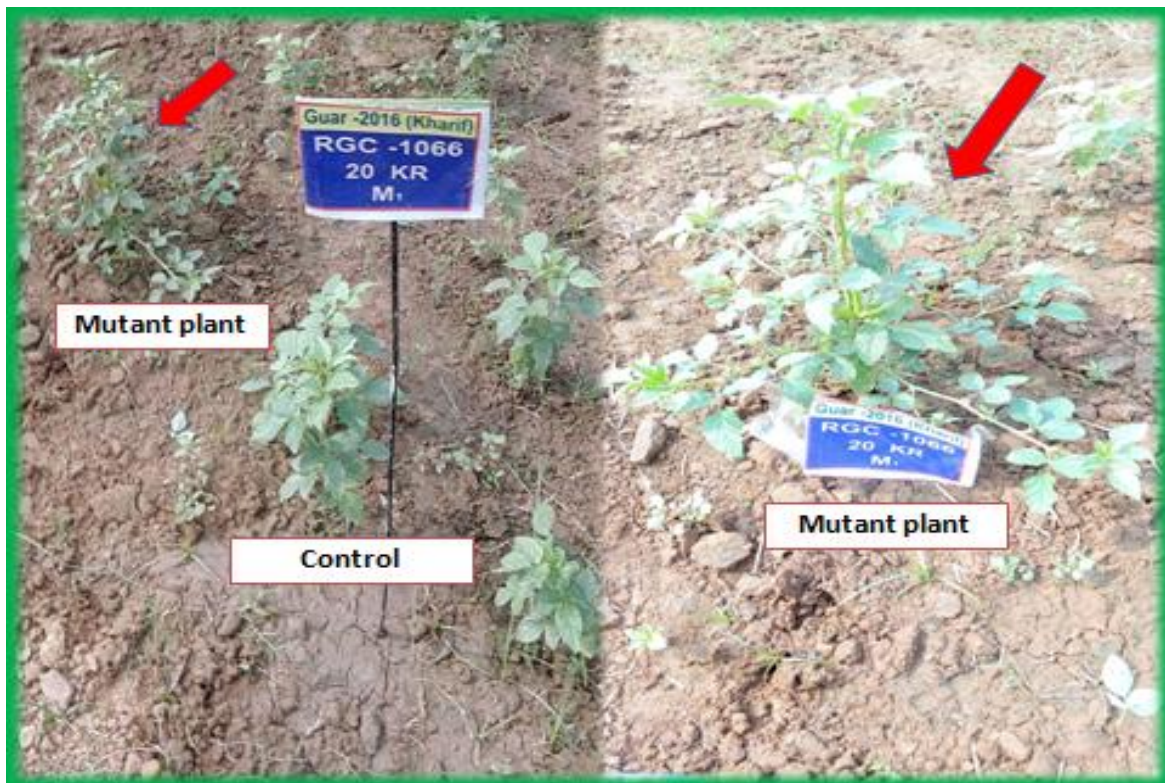


Plate-4.5 Shows spreading type mutant plant in genotype RGC-1066 at dose 20kR



Plate 4.6: Shows spreading type mutant plant in genotype GST-15-204 at dose 50kR



Plate 4.7 Shows taller mutants plant



Plate 4.8 Shows early maturity mutant plant



Plate 4.9 Shows apical bearing mutant plant

**4.3.1.3 Effectiveness and efficiency of mutagens**

**4.3.1.3.1 Mutagenic Effectiveness:**

The mutagenic effectiveness is a measure of factor mutations induced by a unit dose of mutagen. In M<sub>2</sub> generation after Gamma rays treatment, the numerical value of effectiveness gradually decreased with increased dose of the mutagen in all the genotypes. The range for Gamma rays treatment was 5 kR to 50kR. The highest value of mutagenic effectiveness 0.15 was recorded with 5KR treatment and lowest 0.01 with 50KR treatment in genotype GST-15-204. In genotype RGC-1066, the highest value was 0.07(10kR) and the lowest was 0.03(50kR), in genotype RGC-1055 the highest value was 0.3(5kR) & the lowest was 0.03(25kR), in genotype RGC-1038 the highest value was 0.35(5kR) and the lowest was 0.005(45kR). 0.35 was the highest value of efficiency which was found in genotype RGC-1038 with 5kR dose. Thus the lower doses of gamma rays were found most effective (Table-4.14 to 4.17).

**Table-4.14:** Mutagenic effectiveness of gamma rays in M<sub>2</sub> generation genotype GST-15-204

**Table-4.15:** Mutagenic effectiveness of gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RGC-1066

<b>Doses</b>	<b>Frequency of % chlorophyll mutation (MF)</b>	<b>Effectiveness (MF/doses)</b>
5kR	0.75	0.15
10kR	1.25	0.12
15kR	1	0.06
20kR	1.5	0.07
25kR	0	0
30kR	0	0
35kR	0	0
45kR	0	0
50kR	0.75	0.01

Doses	Frequency of % chlorophyll mutation (MF)	Effectiveness (MF/doses)
10kR	0.75	0.07
15kR	1	0.06
20kR	0	0
25kR	0.25	0.01
30kR	1.25	0.04
50kR	1.5	0.03

**Table-4.16:** Mutagenic effectiveness of gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RGC-1055

Doses	Frequency of % chlorophyll mutation (MF)	Effectiveness (MF/doses)
5kR	1.5	0.3
10kR	0	0
20kR	0	0
25kR	0.75	0.03

**Table4.17:** Mutagenic effectiveness of gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RGC1038

Doses	Frequency of % chlorophyll mutation (MF)	Effectiveness (MF/doses)
5kR	1.75	0.35
10kR	0.5	0.05
15kR	0.75	0.05
20kR	0.75	0.0375
25kR	1	0.04
35kR	0	0
45kR	0.25	0.005

#### 4.3.1.3.2 Mutagenic Efficiency

The mutagenic efficiency is the ratio of chlorophyll mutations induced in the M<sub>2</sub> generation to the various biological damages induced in M<sub>1</sub> generation such as lethality and pollen sterility.

##### 4.3.1.3.2.1 Efficiency in relation to lethality

In the present study, the mutagenic efficiency decreased with the increasing doses of gamma rays with respect to lethality (L). Highest value of mutagenic efficiency was recorded 0.05 (GST-15-204), 0.08 (RGC-1055), 0.15 (RGC-1038) and 0.06 (RGC-1066) with 5kR, 10kR doses and the lowest 0.009 (GST-15-204), 0.02 (RGC-1066), 0.01(RGC-1055) and 0.003 (RGC-1038) with 50, 25 and 45kR doses of mutagen.

##### 4.3.1.3.2.3 Efficiency in relation to Pollen sterility

The observations in respect to efficiency with reference to pollen sterility demonstrated a doses dependent enhancement in majority of the mutagenic treatments in M<sub>2</sub> generation. The value of efficiency decreased with increased doses of Gamma rays. It was ranged from 0.01 to 0.29. The highest value of mutagenic efficiency was recorded 0.14 (GST-15-204), 0.20 (RGC-1055), 0.15 (RGC-1038) and 0.29 (RGC-1066) with 5kR and 10kR and the lowest 0.01 (GST-15-204), 0.04 (RGC-1066), 0.06 (RGC-1055) and RGC-1038(0.05) with 50, 25 and 45Kr doses of mutagen.

On the basis of mean values, the highest mutagenic efficiency was recorded 0.0610 in relation to pollen sterility and lowest 0.0249 in relation to lethality (Table 4.17 to 4.21).

**Table-4.18:** Mutagenic efficiency of Gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., GST-15-204

Dose	%Chlorophyll Mutation (MF)	% Lethality (L)	Efficiency (MF/L)	Pollen Sterility (S)	Efficiency (MF/S)
5kR	0.75	15	0.05	5.26	0.14
10kR	1.25	21	0.05	9.09	0.13
15kR	1	35	0.02	10.71	0.09
20kR	1.5	42	0.03	12.5	0.12
25kR	0	50	0	15.2	0
30kR	0	57	0	17.64	0
35kR	0	63	0	23.07	0
45kR	0	74	0	40.9	0
50kR	0.75	76	0.009	59.09	0.01

**Table-4.19:** Mutagenic efficiency of Gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RCG-1066

Dose	%Chlorophyll Mutation (MF)	% Lethality (L)	Efficiency (MF/L)	Pollen Sterility (S)	Efficiency (MF/S)
10kR	0.75	12	0.06	8.37	0.08
15kR	1	25	0.04	10.02	0.09
20kR	0	32	0	11.48	0
25kR	0.25	39	0.0064	14.26	0.01
30kR	1.25	42	0.0297	17.21	0.07
50kR	1.5	61	0.02	33.03	0.04

**Table 4.20:** Mutagenic efficiency of Gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RGC-1055

Dose	%Chlorophyll Mutation (MF)	% Lethality (L)	Efficiency (MF/L)	Pollen Sterility (S)	Efficiency (MF/S)
5kR	1.5	18	0.08	7.22	0.20
10kR	0	20	0	8.36	0
20kR	0	38	0	13.61	0
25kR	0.75	44	0.01	12.43	0.06

**Table-4.21:** Mutagenic efficiency of Gamma rays in M<sub>2</sub> generation of clusterbean genotype viz., RGC-1038

Dose	%Chlorophyll Mutation (MF)	% Lethality (L)	Efficiency (MF/L)	Pollen Sterility (S)	Efficiency (MF/S)
5kR	1.75	11	0.15	5.89	0.29
10kR	0.5	18	0.02	8.37	0.05
15kR	0.75	23	0.03	10.02	0.07
20kR	0.75	36	0.02	11.48	0.06
25kR	1	42	0.02	14.26	0.07
35kR	0	57	0	20.13	0
45kR	0.25	69	0.003	33.03	0.007

### **4.3.3 Micro mutation (quantitative genetic changes)**

#### **4.3.3.1 ANOVA for compact family block design**

The estimation of variation within the treatments was done as per compact family block design for all the nineteen characters were studied in  $M_2$  generation are presented in Table 4.22.

Analyses of variance for between families (lines) of induced mutants derived from cluster bean genotypes for different polygenic characters indicated that the mean sum of squares due to between families (lines) for all the characters were highly significant except number of primary branch/plant and number of seeds/pod and 100 seed weight in  $M_2$  generation indicating the induction of genetic variability through irradiation of gamma rays and within progeny the mean sum of square due to treatments almost found to be significant for all the characters in  $M_2$  generation. However, the mean sum of square due to treatment under 45kR (within progeny) for germination%, control and 40 kR for days to 50% flowering, 20, 25 and 35 kR for canopy temperature (at vegetative stage), 0 to 50 kR except 35 kR for number of primary branch/plant, 45kR for days to maturity, control and 45 kR for number of pods/plant, control for number of cluster/plant, 50kR for seed yield/plant , control and 5 kR for 100 seed weight, 40 and 50 kR for relative water content and control and 45 kR for number of seeds/pod were found non-significant in  $M_2$  generation.

**Table 4.22:** Analysis of variance for 19 characters in mutant population of clusterbean

S.No	Characters	Mean sum of square			
		Replication	Lines	Doses	Error
1	Germination%	721.80**	982.46**	11600.61**	15.73
2	Days to 50 %Flowering	8.10**	26.55**	49.73**	0.72
3	Canopy temp (at Vegetative stage)	74.90**	14.25**	14.50**	6.71
4	Canopy temp (at Reproductive stage)	27.08**	17.60	32.98	2.66
5	Number of primary branches/plant	0.24	0.28	0.22	0.21
6	Days to 80% Maturity	36.89**	23.99**	45.73**	1.59
7	Plant height (cm)	945.64**	419.55	675.61**	17.62
8	Pod length (cm)	7.07**	1.00**	1.89**	0.09
9	Number of pods/plant	976.17**	1209.11**	2991.62**	52.14
10	Number of pods/cluster	6.06**	1.55*	2.95*	0.42
11	Number of cluster/plant	745.51**	70.21**	166.20**	6.34
12	Leaf area index	2.92*	34.94**	80.18**	1.89
13	Seed yield/Plant (gm)	0.44*	2.77**	20.75**	0.07
14	100 seed weight(gm)	0.17	0.30*	0.96*	0.05
15	RWC(Irrigated Condition)	13.93**	347.22**	1135.98**	125.13
16	RWC(Non-Irrigated Condition)	0.35	342.80**	820.09**	4.75
17	Gum Content	0.80	35.38**	232.93**	1.98
18	Proline content	113.53**	4276.94**	64597.05**	1.49
19	Number of seeds/pod	6.90	12.23	9.47	10.58

**Table: 4.23(a)** Analysis of variance for 19 characters in different doses of gamma rays

Doses	Germination %		Days to 50 % Flowering		Canopy temp (1)		Canopy temp (2)	
	Mutant lines	error	Mutant lines	error	Mutant lines	error	Mutant lines	error
0Kr	17.79	5.79	2.79	2.46	17.98	0.18	15.81	2.32
5Kr	84.98*	11.35	27.87**	0.57	17.17**	4.64	23.36**	3.22
10kR	551.80**	21.51	12.38**	0.59	13.39**	4.62	23.83**	2.86
15kR	93.51**	14.38	21.66**	0.88	27.54**	4.36	29.43**	2.77
20kR	570.42**	25.12	17.14**	0.99	6.03	4.45	10.54**	1.32
25kR	802.42**	11.17	12.80**	1.05	4.99	5.10	10.05**	2.72
30kR	406.12**	13.73	8.67**	0.68	35.56**	30.95	10.61**	2.44
35kR	472.84**	14.15	6.23**	0.21	3.46	4.55	8.59**	2.41
40kR	1.75	9.75	0.88	0.48	1.93**	0.53	1.70	0.33
45kR	351.36**	7.85	19.42**	0.57	7.26*	3.12	9.24**	0.68
50kR	459.26**	5.26	194.88**	0.38	6.11**	0.20	8.50**	1.79

Table: 4.23(b) Analysis of variance for 19 characters in different doses of gamma rays

Doses	No of primary branches / plant		Days to 80 % Maturity		Plant height (cm)		Pod length (cm)	
	Mutant lines	error	Mutant lines	error	Mutant lines	error	Mutant lines	error
0Kr	0.13	0.46	16.17**	0.17	270.46**	5.46	2.10**	0.13
5Kr	0.34	0.17	8.16**	1.80	725.98**	5.09	1.11**	0.09
10kR	0.22	0.24	37.47**	1.17	342.39**	2.66	1.10**	0.10
15kR	0.28	0.20	20.86**	1.11	397.63**	101.47	0.89**	0.13
20kR	0.22	0.31	18.78**	1.73	214.06**	12.67	0.38**	0.04
25kR	0.34	0.14	19.67**	1.49	461.82**	0.42	0.96**	0.08
30kR	0.34	0.12	23.98**	3.76	186.71**	12.40	0.82**	0.10
35kR	0.38*	0.11	81.28**	1.14	67.43**	2.03	1.04**	0.06
40kR	0.08	0.48	1.88**	0.28	50.75**	2.08	0.33**	0.01
45kR	0.31	0.22	2.92	1.73	604.05**	9.14	0.74**	0.11
50kR	0.26	0.13	17.56**	1.97	499.31**	0.06	1.55**	0.10

Table: 4.23(c) Analysis of variance for 19 characters in different doses of gamma rays

Doses	Number of pods /plant		Number of pods /cluster		Number of cluster /plant		Leaf area index	
	Mutant lines	error	Mutant lines	error	Mutant lines	error	Mutant lines	error
0Kr	269.50**	66.33	0.79	0.46	7.13	5.13	8.85**	0.31
5Kr	1202.23**	61.05	1.74**	0.56	53.85**	8.13	46.76**	2.48
10kR	922.34**	56.90	1.65**	0.31	68.94**	6.49	23.00**	1.06
15kR	233.27**	45.70	1.53**	0.26	27.01**	4.72	37.47**	1.90
20kR	1280.88**	33.48	1.22**	0.36	69.29**	9.29	22.50**	1.22
25kR	929.30**	48.18	2.51**	0.69	77.75**	9.87	14.16**	1.51
30kR	437.15**	71.75	0.89**	0.34	63.11**	2.67	22.82**	0.86
35kR	915.00**	60.44	0.53**	0.24	99.33**	1.75	26.40**	1.50
40kR	1908.33**	30.73	2.13**	0.40	66.33**	1.13	34.71**	8.30
45kR	2051.78**	33.89	0.98	0.63	25.22**	5.42	64.93**	1.95
50kR	3430.68**	19.63	0.81**	0.25	197.14**	3.81	39.58**	0.78

**Table: 4.23(d)** Analysis of variance for 19 characters in different doses of gamma rays

Doses	Seed yield/ Plant (gm)		100 seed weight (gm)		RWC (1)		RWC (2)	
	Mutant lines	error	Mutant lines	error	Mutant lines	error	Mutant lines	error
0Kr	0.47**	0.01	0.01	0.09	764.51**	147.70	34.84**	2.48
5Kr	0.34**	0.05	0.13	0.07	351.88**	46.87	147.01**	5.11
10kR	0.51**	0.06	0.16**	0.04	378.87**	113.43	189.41**	7.91
15kR	0.21**	0.04	0.50**	0.06	286.77**	223.65	539.04**	4.39
20kR	2.88**	0.04	0.33**	0.02	336.34**	39.42	649.41**	3.14
25kR	7.35**	0.13	0.29**	0.05	408.16**	267.89	95.17**	1.39
30kR	0.45**	0.02	0.31**	0.04	196.56**	78.38	893.71**	4.31
35kR	0.48**	0.06	0.39**	0.06	183.49**	108.10	54.72**	4.21
40kR	0.22**	0.43	0.14**	0.00	29.04	14276.45	29.38**	4.74
45kR	2.55**	0.02	0.27**	0.03	184.33**	37.43	250.49**	1.64
50kR	3.87	11.61	0.31**	0.06	172.82	145.88	502.60**	3.87

**Table: 4.23(e)** Analysis of variance for 19 characters in different doses of gamma rays

Doses	Gum Content		Proline content		Number of seeds/ pod	
	Mutant lines	error	Mutant lines	error	Mutant lines	error
0Kr	7.93**	2.37	740.84**	0.05	0.50	0.50
5Kr	11.13**	2.28	944.64**	2.06	1.53**	0.25
10kR	37.09**	2.21	1315.63**	1.18	1.59**	0.23
15kR	15.42**	2.27	845.83**	0.94	2.80**	0.42
20kR	30.22**	1.16	327.46**	1.01	2.06**	0.04
25kR	16.93**	1.24	608.39**	0.11	3.40**	0.28
30kR	56.82**	1.16	1777.78**	1.33	2.29**	0.26
35kR	33.78**	0.59	676.40**	0.23	0.85**	0.08
40kR	6.46v	0.10	112.78**	7.07	3.28**	0.08
45kR	17.77**	2.23	237.65**	0.08	126.71	120.24
50kR	17.81**	1.92	126.51**	2.86	1.89**	0.39

#### **4.3.3.2 Mean performance of mutant lines for 19 characters in M<sub>2</sub> Generation**

The mean values of 163 mutant lines and 4 controls with respect to 19 characters are presented in the Table 4.24(a) to 4.24(c). The details of mean performance for all 9 characters are given below:

##### **4.3.3.2.1 Germination (%)**

The germination (%) ranged from 7.00 to 91.00 with the mean value of 52.17. The mutant lines 46-10-RGC-1038 (91.00) significantly higher germination% followed by 42-10-RGC-1038 (88.50), 100-25-RGC1038 (86.50), 40-10-RGC-1038 (86.00) and 46-10-RGC-1038 (85.60) and the mutant line 166-50-GST-15-204 (7.00) followed by 165-50-GST-15-204 (8.00), 163-50-RGC-1055 (8.50), 152-45-GST-15-204 (9.00), 154-45-GST-15-204 (9.50), 158-45-GST-15-204 (9.50), 167-50-GST-15-204 (10.00) and 151-45-GST-15-204 (10.00) were proved to be lowest performer in this regard.

##### **4.3.3.2.2 Days to 50% flowering**

The days to 50% flowering ranged from 47.50 to 84.50 days with the mean value of 56.28. The mutant lines viz., 11-5-RGC-1066 (47.50) followed by 64-15-RGC-1066 (48.00), 9-5-RGC-1066 (48.50) and 70-15-RGC-1038 (50.00) were proved significantly earlier than the two best controls namely: RGC-1066 (53.50) and RGC-1055 (53.50).

##### **4.3.3.2.3 Canopy temperature °C (at vegetative stage)**

The canopy temperature °C (at vegetative stage) ranged from 22.80 to 33.90 with the mean value of 28.03. The mutant lines viz., 31-5-GST-15-204 (22.80), 58-10-GST-15-204 (22.80), 78-15-GST-15-204(22.80), 27-5-GST-15-204 (22.90), 147-45-RGC-1066, (23.25), 59-10-GST-15-204 (23.40), 75-15-GST-15-204 (23.50), 79-15-GST-15-204(23.60), 74-15-GST-15-204 (23.80), 77-15-GST-15-204 (23.80), 30-5-GST-15-204 (23.90), 55-10-GST-15-204 (23.90), 57- 10-GST-15-204 (23.90)-80-15-GST-15-204 (23.90), 28-5-GST-15-204 (24.10), 56-10-GST-15-204 (24.10), 54-10-GST-15-204 (24.20), 29-5-GST-15-204 (24.30), 73-15-GST-15-204 (24.40), 76-15-GST-15-204 (24.40), 32-5-GST-15-204 (24.50) 97-25-RGC-1066 (24.95), 93-20-GST-15-204 (25.00), 110-25-GST-15-204 (25.10), 109-25-GST-15-204 (25.30), 96-25-RGC-1066 (25.45), 145-45-RGC-1066 (25.45), 146-45-RGC-1066 (25.45), 148-45-RGC-1066 (25.45), 95-25-RGC-1066 (25.75), 14-5-RGC-1038 (26.10), 159-50-RGC-1066 (26.10), 137-35-GST-15-204 (26.20), 114-30-RGC-1066 (26.25) and 90-20-RGC-1055 (26.30) showed significantly lowest canopy temperature from range and best control (26.90).

#### **4.3.3.2.4 Canopy temperature °C (at reproductive stage)**

The canopy temperature °C (at reproductive stage) ranged from 30.60 to 43.30 with the mean value of 28.03. The mutant lines viz., 31-5-GST-15-204 (30.60), 58-10-GST-15-204 (30.60), 78-15-GST-15-204 (30.60), 27-5-GST-15-204 (30.70), 147-45-RGC-1066 (30.90), 59-10-GST-15-204 (31.20), 75-15-GST-15-204 (31.30), 79-15-GST-15-204 (31.40), 74-15-GST-15-204 (31.60), 77-15-GST-15-204 (31.60), 30-5-GST-15-204 (31.70), 55-10-GST-15-204 (31.70), 57-10-GST-15-204 (31.70), 80-15-GST-15-204 (31.70), 28-5-GST-15-204 (31.90), 56-10-GST-15-204 (31.90), 54-10-GST-15-204 (32.00), 29-5-GST-15-204 (32.10), 73-15-GST-15-204 (32.20), 76-15-GST-15-204 (32.20), 32-5-GST-15-204 (32.30) and 93-20-GST-15-204 (32.80) showed significantly lowest temperature than control (38.53).

#### **4.3.3.2.5 Number of primary branch/plant**

The number of primary branch/plant was ranging from 1.00 to 2.00 with the mean value of 1.41. The mutant lines viz 13- 5-RGC-1066 (2.00) followed by 14- 5-RGC-1066 (2.00), 20- 5-RGC-1066 (2.00), 2513- 5-RGC-1066 (2.00) and 39- 10-RGC-1038 (2.00) showed significantly higher number than three best controls namely: RGC-1066 (1.50), RGC-1038 (1.50) and GST-15-204 (1.50).

#### **4.3.3.2.6 Days to 80 % maturity**

The days to 80 % maturity ranged from 75.00 to 92.50 days with the mean value of 84.61days. The mutant lines 132-35-RGC-1038 (75.50) followed by 133-35-RGC-1038 (77.00), 10-RGC-1055 (77.00) and 50-10-RGC-1055 (77.50) were proved significantly earlier over the best control RGC-1055 (81.50).

#### **4.3.3.2.7 Plant height (cm)**

The plant height (cm) ranged from 31.00 to 108.50 cm with the mean value of 65.84cm. The mutant lines viz., 11-5-RGC-1066 (108.50), followed by 106-25-RGC-1055 (103.50), 13-5-RGC-1066 (103.50), 80-15-GST-15-204 (101.50) and 159-50-RGC-10669(100.50) were found significantly superior and the mutant lines viz., 49-10-RGC-1055 (31.50) and 25-5-RGC-1055 (34.50) were proved dwarf over control mean (55.87).

#### **4.3.3.2.8 Pod length (cm)**

The pod length (cm) ranged from 2.70 to 6.65 with the mean value of 4.52. The mutant lines viz., 11- 5-RGC-1066 (5.90) followed by 37-10-RGC-1066 (5.10), 33-10-RGC-1066 (6.05) and 96-25-RGC-1066 (6.00) was proved highly significant superior as compared to the best control RGC-1066 (5.05).

#### **4.3.3.2.9 Number of pods/plant**

The number of pods/plant ranged from 38.50 to 183.00 with the mean value of 82.19. The mutant lines 158-45-GSt-15-204 (183.00) followed by 165- 50-GST-15-204 (180.00) and 164-50-GST-15-204 (174.51) was proved significantly superior over the best control GST-15-204 (86.50).

#### **4.3.3.2.10 Number of pods/cluster**

The number of pods/cluster ranged from 2.00 to 7.50 with the mean value of 3.37. The mutant lines viz., 58-10-GST15-204 (6.50) and 107-25-GST-204 (7.50) was proved significantly superior over the best control RGC-1038 (3.50).

#### **4.3.3.2.11 Number of cluster/plant**

The number of cluster/plant ranged from 5.50 to 40.00 with the mean value of 16.41. The mutant lines viz 164-50-GST-15-204 (40.00) was proved significantly superior over the best control GST-15-204 (18.00).

#### **4.3.3.2.12 Leaf area index**

The leaf area index ranged from 8.40 to 34.10 with the mean value of 15.19. The mutant lines viz., 146-45-RGC-1066 (34.10) was found highly significant superior than the best control RGC-1066 (16.15).

#### **4.3.3.2.13 Seed yield/plant**

The seed yield per plant ranged from 2.95 to 7.04 with the mean value of 3.72. The mutant line viz 101-25-RGC-1055 (7.04) was giving significantly highest yield than the best control GST-15-204 (3.55).

#### **4.3.3.2.14 100 seed weight (gm)**

The seed yield per plant ranged from 0.56 to 3.85 with the mean value of 1.69. The mutant line viz., 70-15-RGC-1038 (3.60) followed by 29-5-GST-15-204 (3.65), 43-10-RGC-1038 (3.67), 73-15-GST-15-204 (3.70), 60-15-RGC-1066 (3.78) and 148-45-RGC-1066 (3.85) were produced significantly higher yield than the best control GST-15-204 (1.62).

#### **4.3.3.2.15 Relative water content (irrigated condition)**

The relative water content (under irrigated condition) ranged from 15.24 to 95.53 with the mean value of 64.92. The mutant lines viz., 73-15-GST-15-204 (80.16), 88-20-RGC-1038 (80.45), 156-45-GST-15-204 (80.82), 117-30-RGC-1038 (81.00), 121-30-RGC-1038 (81.17), 139-40-RGC-1038 (81.45), 116-30-RGC-1038 (81.64), 8-5-RGC-1066 (81.68), 67-15-RGC-1038 (83.11), 46-10-RGC-1038 (83.25), 84-20-RGC-1038 (83.54), 47-10-RGC-1038 (83.69),

69-15-RGC-1038 (84.00), 72-15-RGC-1038 (84.89), 87-20-RGC-1038 (85.03) 45-10-RGC-1038 (86.20), 44-10-RGC-1038-(86.91), 66-15-RGC-1038 (88.33) and 11-5-RGC-1066 (95.53) were proved highly significant superior and the mutant lines viz., 98-25-RGC-1038 (15.24) and 103-25-RGC-1055 (31.32) was proved inferior for this parameter.

#### **4.3.3.2.16 Relative water content (non- irrigated condition)**

The relative water content (under non- irrigated condition) ranged from 2.11 to 78.35 with the mean value of 22.35. The mutant lines viz., 117-30-RGC-1038 (78.35), 116-30-RGC-1038 (67.34), 70-15-RGC-1038 (60.87), 85-20-RGC-1038 (58.54), 88-20-RGC-1038 (58.49), 71-15-RGC-1038(52.59) and 6815-RGC-1038 (49.40) were proved highly significant superior and mutant lines 65-15-RGC-1066 (2.11), 147-45-RGC1066 (2.96), 167-50-GST-15-204 (3.64), 166-50-GST-15-204 (3.85), 36-10-RGC-1066 (4.70) and 94-20-GST-15-204 (4.76) were proved to be lowest performer.

#### **4.3.3.2.17 Gum content**

The gum content ranged from 12.35 to 36.15 with the mean value of 23.44. The mutant lines viz., 42-10-RGC-1038 (36.15) and 133-35-RGC-1038 (34.05) was giving significantly high gum content value than best control RGC-1066 (26.85).

#### **4.3.3.2.18 proline content**

The proline content ranged from 12.65 to 199.50 with the mean value of 90.55. The mutant line viz., 161-50-GST-15-204 (199.50) showed higher proline content and mutant lines 5-5-RGC-1066 (12.65), 8-5-RGC-1066 (12.95), 7-5-RGC-1066 (14.85) showed lowest significant.

#### **4.3.3.2.19 Number of seeds/pod**

The number of seeds/pod ranged from 4.50 to 9.50 with the mean value of 6.99. The mutant line viz., 102-25-RGC-1055 (9.50), 116-30-RGC-1038 (9.50), 163-50-RGC-1055 (9.50) was giving significantly maximum number of seeds/pod than best three control RGC-1066 (7.50), RGC-1038 (7.50), RGC-1055 (7.50).

Table 4.24 (a): Mean performance of 167 mutant lines for 19 characters

S. No.	Mutant lines/Controls	Mean performance					
		Germination %	Days to 50 % Flowering	Canopy temp (1)	Canopy temp (2)	No of primary branches / plant	Days to 80 % Maturity
1	RGC-1066	88.00	53.50	33.80	41.45	1.50	82.00
2	RGC-1038	94.00	54.50	28.90	38.80	1.50	82.00
3	RGC-1055	89.00	53.50	26.90	34.70	1.00	81.50
4	GST-15-204	87.50	56.00	31.40	39.20	1.50	87.50
5	5-5kR-RGC-1066	59.50	55.50	30.88	38.40	1.00	84.00
6	6-5kR-RGC-1066	66.00	59.00	30.85	38.20	1.50	83.50
7	7-5kR-RGC-1066	69.50	59.00	32.87	41.50	1.00	85.50
8	8-5kR-RGC-1066	71.00	60.50	30.50	40.10	1.50	86.50
9	9-5kR-RGC-1066	70.00	48.50	30.70	41.10	1.00	88.00
10	10-5kR- RGC-1066	63.50	58.00	31.50	40.20	1.50	81.00
11	11-5kR-RGC-1066	70.50	47.50	30.60	41.10	1.00	82.50
12	12-5kR-RGC-1066	61.50	55.00	31.10	40.30	1.00	84.50
13	13-5kR-RGC-1066	66.50	52.50	31.90	41.50	2.00	85.50
14	14-5kR-RGC-1038	72.50	56.50	26.10	33.75	2.00	84.50
15	15-5kR-RGC-1038	72.00	57.00	26.40	34.05	1.00	83.00
16	16-5kR-RGC-1038	76.00	54.50	29.80	37.45	1.00	83.50
17	17-5kR-RGC-1038	79.50	52.50	27.90	35.55	2.00	79.00
18	18-5kR-RGC-1038	77.50	50.50	28.40	36.05	1.00	82.50
19	19-5kR-RGC-1038	75.00	55.00	30.80	38.45	1.50	84.50
20	20-5kR-RGC-1055	52.50	52.50	27.70	37.60	2.00	83.50
21	21-5kR-RGC-1055	58.50	51.50	28.10	38.00	1.50	84.00
22	22-5kR-RGC-1055	63.50	55.50	27.40	37.30	2.00	83.00
23	23-5kR-RGC-1055	65.50	52.50	26.80	36.70	1.50	83.50
24	24-5kR-RGC-1055	71.50	52.00	26.70	36.60	1.50	84.50
25	25-5kR-RGC-1055	76.50	56.00	26.80	36.70	2.00	83.50
26	26-5kR-GST-15-204	60.50	61.00	27.10	34.90	1.00	81.00
27	27-5kR-GST-15-204	70.00	60.00	22.90	30.70	1.00	86.50
28	28-5kR-GST-15-204	65.00	58.50	24.10	31.90	1.00	87.00
29	29-5kR-GST-15-204	60.50	60.50	24.30	32.10	1.50	85.50
30	30-5kR-GST-15-204	70.00	59.50	23.90	31.70	1.50	85.00
31	31-5kR-GST-15-204	69.50	57.50	22.80	30.60	1.00	87.50
32	32-5kR-GST-15-204	61.50	58.50	24.50	32.30	2.00	85.50
33	33-10kR-RGC-1066	54.00	55.50	28.00	40.10	1.00	85.50
34	34-10kR-RGC-1066	57.00	55.00	28.10	42.30	1.00	85.00
35	35-10kR-RGC-1066	62.00	53.00	29.60	41.00	1.50	83.00
36	36-10kR-RGC-1066	62.00	53.50	32.10	39.00	1.50	87.00
37	37-10kR-RGC-1066	65.50	55.00	32.10	43.30	1.50	85.00
38	38-10kR-RGC-1066	56.00	52.00	31.80	39.20	1.00	89.00
39	39-10kR-RGC-1038	83.00	53.00	29.10	36.75	2.00	84.50
40	40-10kR-RGC-1038	86.00	53.50	27.80	35.45	1.50	87.50
41	41-10kR-RGC-1038	83.50	56.50	28.80	36.45	1.50	87.00
42	42-10kR-RGC-1038	88.50	57.50	27.20	34.85	1.00	81.50
43	43-10kR-RGC-1038	85.00	58.50	29.20	36.85	1.50	82.50

S. No.	Mutant lines/Controls	Mean performance					
		Germination %	Days to 50 % Flowering	Canopy temp (1)	Canopy temp (2)	No of primary branches / plant	Days to 80 % Maturity
44	44-10kR-RGC-1038	84.50	59.00	28.90	38.80	1.00	84.50
45	45-10kR-RGC-1038	85.50	53.50	28.50	38.40	1.00	86.50
46	46-10kR-RGC-1038	91.00	58.50	29.40	39.30	1.00	84.50
47	47-10kR-RGC-1038	84.50	60.50	29.30	39.20	1.00	83.50
48	48-10kR-RGC-1038	82.00	60.00	29.00	38.90	1.00	83.50
49	49-10kR-RGC-1055	37.50	57.00	26.90	36.80	1.50	84.00
50	50-10kR-RGC-1055	45.00	56.00	26.70	36.60	1.50	77.50
51	51-10kR-RGC-1055	45.50	53.50	26.70	36.60	1.50	77.00
52	52-10kR-RGC-1055	44.00	57.50	26.90	36.80	1.50	78.00
53	53-10kR-RGC-1055	45.00	58.50	27.60	37.50	1.50	78.50
54	54-10kR-GST-15-204	279.00	60.50	24.20	32.00	1.50	91.00
55	55-10kR-GST-15-204	77.00	58.50	23.90	31.70	2.00	92.00
56	56-10kR-GST-15-204	84.50	54.50	24.10	31.90	1.00	91.00
57	57-10kR-GST-15-204	76.00	56.50	23.90	31.70	1.50	90.00
58	58-10kR-GST-15-204	75.00	58.00	22.80	30.60	2.00	89.50
59	59-10kR-GST-15-204	69.50	56.50	23.40	31.20	1.50	92.00
60	60-15kR-RGC-1066	46.50	60.00	33.90	39.50	2.00	85.50
61	61-15kR-RGC-1066	51.50	53.50	31.90	40.30	1.00	84.00
62	62-15kR-RGC-1066	47.50	55.50	30.60	40.00	1.00	83.00
63	63-15kR-RGC-1066	54.50	50.50	33.30	39.30	1.50	89.00
64	64-15kR-RGC-1066	61.50	48.00	33.05	40.90	1.50	85.00
65	65-15kR-RGC-1066	56.00	57.00	32.05	40.00	1.00	80.50
66	66-15kR-RGC-1038	47.50	54.50	29.10	39.00	2.00	87.00
67	67-15kR-RGC-1038	55.00	55.50	27.50	37.40	1.50	85.00
68	68-15kR-RGC-1038	57.50	51.00	29.20	39.10	2.00	89.50
69	69-15kR-RGC-1038	62.50	54.00	29.30	39.20	1.50	85.00
70	70-15kR-RGC-1038	67.00	50.00	27.90	37.80	2.00	86.00
71	71-15kR-RGC-1038	54.00	56.50	27.40	37.30	1.00	82.50
72	72-15kR-RGC-1038	56.00	54.50	27.90	37.80	1.50	90.50
73	73-15kR-GST-15-204	46.50	53.00	24.40	32.20	1.50	92.00
74	74-15kR-GST-15-204	55.00	58.50	23.80	31.60	1.50	90.00
75	75-15kR-GST-15-204	62.50	59.00	23.50	31.30	1.50	91.00
76	76-15kR-GST-15-204	65.00	59.00	24.40	32.20	1.00	88.00
77	77-15kR-GST-15-204	66.00	57.50	23.80	31.60	1.00	83.00
78	78-15kR-GST-15-204	67.50	54.50	22.80	30.60	1.00	83.00
79	89-15kR-GST-15-204	53.50	55.50	23.60	31.40	1.50	84.50
80	80-15kR-GST-15-204	62.50	59.00	23.90	31.70	1.00	83.50
81	81-20kR-RGC-1066	34.00	59.50	31.75	40.40	1.50	83.50
82	82-20kR-RGC-1066	35.50	54.00	27.85	40.80	1.50	83.00
83	83-20kR-RGC-1038	55.50	54.00	29.00	38.90	2.00	86.50
84	84-20kR-RGC-1038	60.00	52.50	27.60	37.50	1.00	82.00
85	85-20kR-RGC-1038	62.50	57.50	28.50	38.40	1.50	83.00
86	86-20kR-RGC-1038	64.50	58.50	30.70	40.60	1.00	84.00
87	87-20kR-RGC-1038	71.00	59.50	28.80	38.70	1.50	87.50
88	88-20kR-RGC-1038	71.00	60.00	28.60	38.50	1.00	88.50

S. No.	Mutant lines/Controls	Mean performance					
		Germination %	Days to 50 % Flowering	Canopy temp (1)	Canopy temp (2)	No of primary branches / plant	Days to 80 % Maturity
89	89-20kR-RGC-1055	31.50	57.50	27.50	37.40	1.50	79.50
90	90-20kR-RGC-1055	42.00	59.00	26.30	36.20	2.00	81.50
91	91-20kR-RGC-1055	40.00	59.50	27.70	37.60	1.50	78.50
92	92-20kR-RGC-1055	46.50	60.50	29.10	39.00	1.50	78.50
93	93-20kR-GST-15-204	14.50	54.50	25.00	32.80	1.50	83.00
94	94-20kR-GST-15-204	37.00	52.50	26.40	34.20	1.00	84.50
95	95-25kR-RGC-1066	31.00	55.50	25.75	39.90	1.00	87.50
96	96-25kR-RGC-1066	26.50	53.00	25.45	39.60	1.00	88.00
97	97-25kR-RGC-1066	33.50	54.50	24.95	39.60	2.00	91.00
98	98-25kR-RGC-1038	74.00	55.50	27.40	37.30	1.50	89.50
99	99-25kR-RGC-1038	76.00	53.50	29.50	39.40	2.00	85.50
100	100-25kR-RGC-1038	86.50	53.50	28.30	38.20	2.00	83.50
101	101-25kR-RGC-1055	33.00	60.00	27.00	36.90	1.50	81.50
102	102-25kR-RGC-1055	35.50	60.50	29.10	39.00	1.00	81.50
103	103-25kR-RGC-1055	39.50	53.50	30.40	40.30	1.00	81.00
104	104-25kR-RGC-1055	32.50	54.00	27.20	37.10	2.00	82.50
105	105-25kR-RGC-1055	34.50	58.50	28.90	36.70	1.50	81.50
106	106-25kR-RGC-1055	36.50	55.00	27.10	34.90	1.00	81.00
107	107-25kR-GST-15-204	24.00	52.50	27.60	35.40	1.50	83.50
108	108-25kR-GST-15-204	19.50	56.00	28.60	36.40	1.00	86.50
109	109-25kR-GST-15-204	19.50	54.00	25.30	33.10	1.00	87.50
110	110-25kR-GST-15-204	23.00	52.50	25.10	32.90	1.00	85.50
111	111-25kR-GST-15-204	27.00	55.00	28.40	36.20	1.50	87.00
112	112-25kR-GST-15-204	18.00	58.00	27.00	34.80	1.00	82.50
113	113-25kR-GST-15-204	21.50	59.00	28.00	35.80	1.00	82.00
114	114-30kR-RGC-1066	25.00	56.50	26.25	39.35	1.00	85.50
115	115-30kR-RGC-1066	22.50	57.00	26.45	34.10	2.00	88.00
116	116-30kR-RGC-1038	56.50	58.50	30.40	40.30	2.00	82.50
117	117-30kR-RGC-1038	62.00	58.50	30.50	40.40	1.50	86.50
118	118-30kR-RGC-1038	62.00	56.50	29.90	39.80	1.50	85.00
119	119-30kR-RGC-1038	67.00	54.50	28.60	38.50	1.00	83.50
120	120-30kR-RGC-1038	65.00	58.00	31.10	41.00	1.00	85.50
121	121-30kR-RGC-1038	62.00	53.50	30.00	39.90	1.00	90.50
122	122-30kR-RGC-1038	61.50	58.50	30.00	39.90	1.50	83.00
123	123-30kR-RGC-1038	67.00	54.50	27.30	37.20	1.00	81.00
124	124-30kR-GST-15-204	47.50	53.50	28.30	36.10	2.00	85.00
125	125-30kR-GST-15-204	51.00	53.00	28.00	35.80	1.50	82.00
126	126-30kR-GST-15-204	48.00	57.00	27.20	35.00	2.00	92.00
127	127-30kR-GST-15-204	56.50	58.50	28.40	36.20	1.50	91.00
128	128-35kR-RGC-1038	64.00	57.00	29.90	39.80	1.00	88.50
129	129-35kR-RGC-1038	66.00	54.50	30.00	39.90	2.00	83.00
130	130-35kR-RGC-1038	63.00	55.50	29.50	39.40	1.00	84.50
131	131-35kR-RGC-1038	62.50	53.00	28.80	38.70	1.50	78.50
132	132-35kR-RGC-1038	64.50	57.00	28.60	38.50	2.00	75.50
133	133-35kR-RGC-1038	62.50	57.50	29.30	39.20	1.00	77.00

S. No.	Mutant lines/Controls	Mean performance					
		Germination %	Days to 50 % Flowering	Canopy temp (1)	Canopy temp (2)	No of primary branches / plant	Days to 80 % Maturity
134	134-35kR-GST-15-204	32.50	57.00	27.00	34.80	2.00	92.50
135	135-35kR-GST-15-204	34.50	58.00	29.20	37.00	1.50	92.00
136	136-35kR-GST-15-204	27.50	56.50	27.90	35.70	2.00	92.00
137	137-35kR-GST-15-204	42.00	59.00	26.20	34.00	2.00	90.50
138	138-35kR-GST-15-204	39.50	58.50	30.50	38.30	1.50	82.00
139	139-40kR-RGC-1038	44.50	57.50	27.84	38.00	1.50	81.00
140	140-40kR-RGC-1038	47.00	58.50	30.80	40.70	1.50	83.50
141	141-40kR-RGC-1038	45.00	59.50	28.70	38.60	1.50	82.00
142	142-40kR-RGC-1038	45.50	58.50	29.20	39.10	1.00	81.50
143	143-40kR-RGC-1038	45.00	58.00	28.70	38.60	1.50	82.50
144	144-40kR-RGC-1038	44.50	58.50	28.90	38.80	1.50	81.00
145	145-45kR-RGC-1066	22.50	60.00	25.45	33.10	1.50	82.00
146	146-45kR-RGC-1066	23.50	53.00	25.45	33.10	2.00	84.00
147	147-45kR-RGC-1066	18.00	53.50	23.25	30.90	2.00	85.00
148	148-45kR-RGC-1066	25.00	54.50	25.45	33.10	1.00	82.50
149	149-45kR-RGC-1066	20.00	56.50	26.65	34.30	1.50	83.50
150	150-45kR-RGC-1038	61.50	53.50	28.40	38.30	2.00	81.00
151	151-45kR-GST-15-204	11.50	60.50	26.40	34.20	1.50	83.00
152	152-45kR-GST-15-204	9.00	61.00	26.70	34.50	1.50	82.00
153	153-45kR-GST-15-204	16.00	60.50	27.50	35.30	1.00	82.00
154	154-45kR-GST-15-204	9.50	58.50	27.20	35.00	1.50	82.50
155	155-45kR--GST-15-204	16.50	52.00	26.50	34.30	1.00	82.00
156	156-45kR--GST-15-204	13.00	57.00	30.20	38.00	1.50	83.50
157	157-45kR--GST-15-204	14.50	57.50	29.30	37.10	1.00	84.00
158	158-45kR-GST-15-204	9.50	55.00	29.70	37.50	2.00	85.00
159	159-50kR-RGC-1066	13.00	51.00	26.10	33.75	1.50	89.00
160	160-50kR-RGC-1066	16.50	53.00	26.40	34.05	1.00	81.00
161	161-50kR-RGC-1038	44.00	56.00	29.40	39.30	1.00	82.50
162	162-50kR-RGC-1038	45.00	54.50	28.40	38.30	2.00	84.00
163	163-50kR-RGC-1055	8.50	84.50	31.80	39.60	1.00	82.50
164	164-50kR-GST-15-204	12.50	58.50	30.10	37.90	1.00	87.50
165	165-50kR-GST-15-204	8.00	60.00	29.20	37.00	1.50	88.00
166	166-50kR-GST-15-204	7.00	60.00	28.90	36.70	1.00	86.50
167	167-50kR-GST-15-204	10.00	61.00	28.90	36.70	1.00	88.00
	<b>Mean</b>	<b>52.17</b>	<b>56.28</b>	<b>28.03</b>	<b>36.96</b>	<b>1.41</b>	<b>84.61</b>
	<b>SE(m)</b>	<b>1.98</b>	<b>0.42</b>	<b>1.30</b>	<b>0.82</b>	<b>0.23</b>	<b>0.63</b>
	<b>CD 5%</b>	<b>5.50</b>	<b>1.18</b>	<b>3.59</b>	<b>2.26</b>	<b>0.63</b>	<b>1.75</b>
	<b>CV%</b>	<b>5.49</b>	<b>1.13</b>	<b>4.89</b>	<b>2.68</b>	<b>3.83</b>	<b>1.37</b>

Canopy-1= Canopy temperature at vegetative stage

Canopy-2= Canopy temperature at reproductive stage

Table 4.24 b: Mean performance of 167 mutant lines for 19 characters

S. No	Mutant lines/Controls	Mean performance					
		Plant height (cm)	Pod length (cm)	Number of pods / plant	Number of pods/ cluster	Number of cluster / plant	Leaf area index
1	RGC-1066	39.00	5.05	68.50	3.00	13.50	16.15
2	RGC-1038	57.50	4.90	61.00	3.50	15.00	12.10
3	RGC-1055	62.50	3.85	81.00	3.00	16.00	11.95
4	GST-15-204	64.50	2.85	86.50	2.00	18.00	15.00
5	5-5kR-RGC-1066	81.50	4.60	88.00	4.00	22.00	26.60
6	6-5kR-RGC-1066	96.50	5.90	93.00	5.50	12.50	19.85
7	7-5kR-RGC-1066	94.50	4.95	49.00	3.00	6.00	29.25
8	8-5kR-RGC-1066	96.50	5.15	104.00	5.00	12.00	26.60
9	9-5kR-RGC-1066	74.50	5.20	59.50	3.50	9.00	19.95
10	10-5kR- RGC-1066	73.50	5.90	96.00	4.50	16.50	15.30
11	11-5kR-RGC-1066	108.50	6.65	81.00	2.50	20.50	16.35
12	12-5kR-RGC-1066	65.50	5.55	119.00	4.50	27.50	15.45
13	13-5kR-RGC-1066	103.50	4.90	112.00	5.50	22.50	8.95
14	14-5kR-RGC-1038	42.00	4.25	46.50	2.00	9.00	17.35
15	15-5kR-RGC-1038	49.00	4.20	53.00	3.00	16.00	17.85
16	16-5kR-RGC-1038	57.50	3.25	79.50	3.50	18.50	19.85
17	17-5kR-RGC-1038	72.50	4.65	58.50	2.50	14.50	17.25
18	18-5kR-RGC-1038	57.00	4.75	144.50	4.50	26.50	16.65
19	19-5kR-RGC-1038	65.50	5.25	62.00	3.00	12.50	11.20
20	20-5kR-RGC-1055	62.50	4.65	57.00	3.50	13.50	14.50
21	21-5kR-RGC-1055	60.50	4.35	64.00	2.50	15.00	13.80
22	22-5kR-RGC-1055	37.50	4.95	66.50	3.00	15.00	12.15
23	23-5kR-RGC-1055	56.50	4.80	79.00	2.50	18.00	12.80
24	24-5kR-RGC-1055	59.50	4.65	90.50	3.50	16.50	13.05
25	25-5kR-RGC-1055	34.50	4.80	91.50	2.50	11.50	10.15
26	26-5kR-GST-15-204	51.50	2.90	101.00	3.50	16.00	13.95
27	27-5kR-GST-15-204	61.50	4.40	117.50	3.00	25.50	14.60
28	28-5kR-GST-15-204	67.50	4.60	77.00	4.00	17.50	12.95
29	29-5kR-GST-15-204	54.50	5.05	88.00	3.50	19.50	13.85
30	30-5kR-GST-15-204	71.50	4.60	69.50	4.00	18.50	14.00
31	31-5kR-GST-15-204	62.50	3.90	90.50	3.50	15.00	13.45
32	32-5kR-GST-15-204	55.00	4.70	46.00	2.50	15.00	15.55
33	33-10kR-RGC-1066	93.00	6.05	58.00	4.00	10.00	8.89
34	34-10kR-RGC-1066	77.50	4.55	81.00	4.50	12.50	14.40
35	35-10kR-RGC-1066	63.50	5.10	58.50	3.00	8.00	8.70
36	36-10kR-RGC-1066	67.50	5.55	70.50	3.00	11.50	11.95
37	37-10kR-RGC-1066	56.50	6.15	93.00	4.00	15.50	11.40
38	38-10kR-RGC-1066	77.50	5.30	96.00	4.00	25.50	18.40
39	39-10kR-RGC-1038	65.00	4.25	105.00	2.50	21.50	12.10
40	40-10kR-RGC-1038	56.00	4.40	80.00	3.00	16.50	14.00
41	41-10kR-RGC-1038	58.00	3.95	139.50	2.50	17.50	9.75
42	42-10kR-RGC-1038	57.00	3.35	75.50	4.50	27.50	10.35
43	43-10kR-RGC-1038	59.00	3.85	56.50	2.50	10.00	12.75
44	44-10kR-RGC-1038	59.50	2.95	68.50	4.00	12.00	14.50

S. No	Mutant lines/Controls	Mean performance					
		Plant height (cm)	Pod length (cm)	Number of pods / plant	Number of pods/ cluster	Number of cluster / plant	Leaf area index
45	45-10kR-RGC-1038	70.50	4.60	63.00	3.00	8.50	13.10
46	46-10kR-RGC-1038	61.00	5.30	84.00	2.50	16.00	12.45
47	47-10kR-RGC-1038	60.50	4.41	97.00	3.50	19.00	17.30
48	48-10kR-RGC-1038	68.50	4.45	90.00	2.50	24.50	21.15
49	49-10kR-RGC-1055	31.50	5.20	67.00	3.50	8.50	8.80
50	50-10kR-RGC-1055	40.50	4.85	75.50	3.00	11.50	8.70
51	51-10kR-RGC-1055	57.50	4.60	60.00	3.00	10.50	11.50
52	52-10kR-RGC-1055	55.50	4.90	62.50	3.00	18.50	11.80
53	53-10kR-RGC-1055	53.50	4.85	89.50	3.50	24.50	12.60
54	54-10kR-GST-15-204	70.50	4.80	56.50	3.00	9.50	17.70
55	55-10kR-GST-15-204	79.50	4.95	73.00	3.00	13.50	15.80
56	56-10kR-GST-15-204	53.50	5.05	132.00	3.00	10.50	14.15
57	57-10kR-GST-15-204	73.50	5.60	58.50	4.00	16.50	16.55
58	58-10kR-GST-15-204	69.50	3.90	66.50	6.50	11.00	17.35
59	59-10kR-GST-15-204	87.50	4.35	72.00	2.00	7.50	18.05
60	60-15kR-RGC-1066	82.50	5.20	58.50	2.00	11.00	10.91
61	61-15kR-RGC-1066	60.50	5.25	69.00	3.00	8.50	8.40
62	62-15kR-RGC-1066	79.50	5.10	82.00	5.00	8.50	12.00
63	63-15kR-RGC-1066	67.50	4.10	86.00	4.00	12.00	13.80
64	64-15kR-RGC-1066	74.50	4.40	66.00	3.00	13.50	13.60
65	65-15kR-RGC-1066	58.50	4.35	81.50	3.50	13.50	16.80
66	66-15kR-RGC-1038	69.50	4.10	75.50	3.00	15.00	24.40
67	67-15kR-RGC-1038	58.50	4.60	83.00	3.00	18.00	20.85
68	68-15kR-RGC-1038	57.00	3.90	62.00	4.50	12.50	20.55
69	69-15kR-RGC-1038	55.50	3.65	79.50	5.00	20.00	16.00
70	70-15kR-RGC-1038	54.50	4.90	72.50	4.00	13.50	14.25
71	71-15kR-RGC-1038	54.50	3.95	69.50	4.50	14.50	12.50
72	72-15kR-RGC-1038	49.50	4.85	57.50	4.50	19.50	12.10
73	73-15kR-GST-15-204	60.50	2.70	89.50	4.00	14.50	19.25
74	74-15kR-GST-15-204	36.50	3.90	50.50	5.00	7.50	16.65
75	75-15kR-GST-15-204	75.50	3.75	61.50	3.00	15.00	11.25
76	76-15kR-GST-15-204	60.00	3.60	74.00	2.50	13.50	12.50
77	77-15kR-GST-15-204	65.50	4.25	72.50	3.00	14.50	15.55
78	78-15kR-GST-15-204	69.50	4.90	88.00	3.50	15.50	14.00
79	89-15kR-GST-15-204	82.50	5.35	77.50	4.00	5.50	14.80
80	80-15kR-GST-15-204	101.50	4.25	80.50	4.50	14.50	24.55
81	81-20kR-RGC-1066	57.50	4.25	79.00	4.50	7.50	21.00
82	82-20kR-RGC-1066	54.50	4.20	58.00	2.00	7.50	15.75
83	83-20kR-RGC-1038	47.50	3.95	58.50	2.50	17.50	15.05
84	84-20kR-RGC-1038	73.00	3.90	68.50	2.50	12.50	13.05
85	85-20kR-RGC-1038	55.50	4.85	72.50	2.50	17.50	18.05
86	86-20kR-RGC-1038	64.50	3.90	57.50	3.50	17.00	13.00
87	87-20kR-RGC-1038	64.00	4.25	78.00	2.50	15.00	12.50
88	88-20kR-RGC-1038	61.50	4.00	86.00	3.00	14.50	9.90
89	89-20kR-RGC-1055	62.00	5.05	82.50	3.00	24.50	14.55
90	90-20kR-RGC-1055	57.00	3.75	137.00	4.00	26.50	14.30

S. No	Mutant lines/Controls	Mean performance					
		Plant height (cm)	Pod length (cm)	Number of pods / plant	Number of pods/ cluster	Number of cluster / plant	Leaf area index
91	91-20kR-RGC-1055	60.00	4.35	78.50	2.50	22.00	12.05
92	92-20kR-RGC-1055	77.50	4.90	82.00	4.50	22.50	15.90
93	93-20kR-GST-15-204	51.50	4.85	138.00	3.00	18.50	22.10
94	94-20kR-GST-15-204	85.50	4.65	71.50	3.00	11.00	15.40
95	95-25kR-RGC-1066	53.50	5.40	82.50	3.00	10.50	13.00
96	96-25kR-RGC-1066	51.50	6.00	101.00	4.50	24.50	15.95
97	97-25kR-RGC-1066	81.50	5.90	77.00	3.00	15.50	17.00
98	98-25kR-RGC-1038	47.50	5.25	79.00	3.50	17.00	9.15
99	99-25kR-RGC-1038	58.50	5.00	57.50	2.50	14.00	11.25
100	100-25kR-RGC-1038	75.50	5.25	38.50	3.50	7.50	22.25
101	101-25kR-RGC-1055	70.50	3.50	111.50	4.50	25.00	14.70
102	102-25kR-RGC-1055	93.50	5.20	119.00	4.50	25.50	13.85
103	103-25kR-RGC-1055	86.50	4.10	123.00	3.50	21.00	16.00
104	104-25kR-RGC-1055	76.50	4.25	103.50	3.50	19.50	15.30
105	105-25kR-RGC-1055	74.50	3.90	104.50	4.00	22.50	14.25
106	106-25kR-RGC-1055	103.50	4.50	96.00	3.50	14.00	12.90
107	107-25kR-GST-15-204	55.50	5.10	82.50	7.50	16.00	15.90
108	108-25kR-GST-15-204	56.50	4.85	108.00	2.50	26.50	13.05
109	109-25kR-GST-15-204	60.50	4.10	88.50	2.50	28.50	14.95
110	110-25kR-GST-15-204	66.50	4.40	109.50	3.50	31.50	13.65
111	111-25kR-GST-15-204	55.50	4.60	68.00	4.00	19.50	12.15
112	112-25kR-GST-15-204	61.50	5.05	81.50	3.50	21.50	13.45
113	113-25kR-GST-15-204	65.50	3.90	83.00	3.00	22.00	14.95
114	114-30kR-RGC-1066	72.50	5.90	50.50	2.00	14.50	16.45
115	115-30kR-RGC-1066	60.00	4.40	80.00	4.00	18.50	20.10
116	116-30kR-RGC-1038	72.00	3.90	49.00	3.00	26.00	20.25
117	117-30kR-RGC-1038	66.50	4.95	71.00	2.50	15.00	23.15
118	118-30kR-RGC-1038	61.50	3.40	63.50	2.00	22.50	20.45
119	119-30kR-RGC-1038	51.50	3.75	52.50	2.00	16.50	18.95
120	120-30kR-RGC-1038	62.50	3.70	57.00	2.50	15.00	16.00
121	121-30kR-RGC-1038	57.50	4.30	87.50	2.00	11.50	12.65
122	122-30kR-RGC-1038	71.50	4.60	77.00	3.00	6.00	15.50
123	123-30kR-RGC-1038	67.50	3.95	80.50	3.50	25.00	11.30
124	124-30kR-GST-15-204	60.50	3.65	89.00	3.50	19.50	16.35
125	125-30kR-GST-15-204	64.00	3.85	79.50	3.50	23.00	14.10
126	126-30kR-GST-15-204	50.50	4.20	87.00	3.00	13.00	13.75
127	127-30kR-GST-15-204	37.50	4.10	56.00	3.00	14.00	16.05
128	128-35kR-RGC-1038	69.50	3.65	122.00	4.00	17.50	8.90
129	129-35kR-RGC-1038	72.50	4.85	90.00	4.00	21.50	11.00
130	130-35kR-RGC-1038	76.00	4.95	112.00	3.50	27.50	10.85
131	131-35kR-RGC-1038	80.50	5.20	102.00	3.00	25.00	11.80
132	132-35kR-RGC-1038	77.50	3.90	92.00	2.50	23.00	9.55
133	133-35kR-RGC-1038	74.50	4.60	90.50	3.00	20.50	14.25
134	134-35kR-GST-15-204	60.50	4.65	58.00	3.00	9.50	13.10
135	135-35kR-GST-15-204	66.50	5.40	54.50	4.00	11.50	16.70
136	136-35kR-GST-15-204	71.50	3.75	70.50	3.50	8.00	17.40

S. No	Mutant lines/Controls	Mean performance						
		Plant height (cm)	Pod length (cm)	Number of pods / plant	Number of pods/ cluster	Number of cluster / plant	Leaf area index	
137	137-35kR-GST-15-204	66.50	3.10	84.50	3.00	11.50	14.85	
138	138-35kR-GST-15-204	67.50	4.25	70.00	3.00	9.50	20.65	
139	139-40kR-RGC-1038	50.50	4.25	81.50	2.50	12.00	14.05	
140	140-40kR-RGC-1038	59.00	3.95	53.00	2.50	16.00	13.35	
141	141-40kR-RGC-1038	62.50	4.35	61.00	3.50	18.00	11.15	
142	142-40kR-RGC-1038	52.50	4.95	84.50	4.00	14.00	9.60	
143	143-40kR-RGC-1038	56.50	3.80	117.50	4.50	22.50	11.20	
144	144-40kR-RGC-1038	62.50	4.45	131.50	5.00	27.50	17.25	
145	145-45kR-RGC-1066	59.50	5.20	59.50	2.50	10.00	19.45	
146	146-45kR-RGC-1066	92.50	4.65	51.50	3.00	8.50	34.10	
147	147-45kR-RGC-1066	90.00	4.30	77.00	4.50	9.50	15.00	
148	148-45kR-RGC-1066	94.00	5.95	60.00	2.50	17.50	17.30	
149	149-45kR-RGC-1066	93.50	3.60	79.00	3.00	15.00	24.55	
150	150-45kR-RGC-1038	48.50	4.00	88.50	4.50	15.00	14.90	
151	151-45kR-GST-15-204	60.50	4.40	68.50	3.00	14.50	15.80	
152	152-45kR-GST-15-204	65.50	4.90	73.50	3.50	16.00	15.25	
153	153-45kR-GST-15-204	47.50	4.35	101.00	3.00	12.50	14.95	
154	154-45kR-GST-15-204	64.50	4.20	93.00	3.50	12.50	22.45	
155	155-45kR--GST-15-204	73.50	5.20	68.50	2.50	17.50	13.10	
156	156-45kR--GST-15-204	97.50	5.10	91.00	3.50	19.50	16.10	
157	157-45kR--GST-15-204	83.50	4.45	69.50	2.50	16.50	14.15	
158	158-45kR-GST-15-204	76.50	5.10	183.00	4.00	19.50	14.15	
159	159-50kR-RGC-1066	100.50	4.35	70.50	2.50	16.50	16.15	
160	160-50kR-RGC-1066	83.00	3.95	88.00	3.50	17.00	25.80	
161	161-50kR-RGC-1038	57.50	3.55	101.50	3.00	12.50	15.30	
162	162-50kR-RGC-1038	56.50	3.86	89.00	2.00	14.50	14.65	
163	163-50kR-RGC-1055	62.50	5.65	71.50	3.50	10.50	9.15	
164	164-50kR-GST-15-204	74.50	5.50	174.00	4.00	40.00	13.20	
165	165-50kR-GST-15-204	55.50	3.90	180.00	3.50	16.00	13.75	
166	166-50kR-GST-15-204	52.50	4.35	131.00	2.50	33.00	13.85	
167	167-50kR-GST-15-204	65.50	2.90	94.00	3.00	22.50	15.75	
	<b>Total mean</b>	<b>65.84</b>	<b>4.52</b>	<b>82.19</b>	<b>3.37</b>	<b>16.41</b>	<b>15.19</b>	
	<b>Range</b>	<b>Max</b>	<b>108.50</b>	<b>6.65</b>	<b>183.00</b>	<b>7.50</b>	<b>40.00</b>	<b>34.10</b>
		<b>Min</b>	<b>31.50</b>	<b>2.70</b>	<b>38.50</b>	<b>2.00</b>	<b>5.50</b>	<b>8.40</b>
	<b>SE(m)</b>	<b>67.56</b>	<b>4.22</b>	<b>111.06</b>	<b>3.06</b>	<b>20.28</b>	<b>15.29</b>	
	<b>CD 5%</b>	<b>2.10</b>	<b>0.15</b>	<b>3.61</b>	<b>0.33</b>	<b>1.26</b>	<b>0.69</b>	
	<b>CV%</b>	<b>5.82</b>	<b>0.42</b>	<b>10.01</b>	<b>0.90</b>	<b>3.49</b>	<b>1.91</b>	

Table 4.24 c: Mean performance of 167 mutant lines for 19 characters

S. No.	Mutant lines/Controls	Mean performance						
		Seed yield/ Plant (gm)	100 seed weight(gm)	RWC(1)	RWC(2)	Gum Content	Proline content	Number of seeds / pod
1	RGC-1066	3.45	1.34	67.57	18.09	26.85	94.55	7.50
2	RGC-1038	3.50	0.71	38.80	15.89	23.65	119.50	7.50
3	RGC-1055	3.40	0.62	39.23	19.17	24.55	82.00	7.50
4	GST-15-204	3.55	1.62	76.89	9.83	27.95	76.10	6.50
5	5-5kR-RGC-1066	3.20	1.47	79.16	19.60	22.65	12.65	7.50
6	6-5kR-RGC-1066	3.10	2.44	62.50	18.10	22.95	16.75	6.50
7	7-5kR-RGC-1066	3.45	1.37	73.48	7.70	21.95	14.85	7.50
8	8-5kR-RGC-1066	3.70	1.58	81.68	15.30	22.65	12.95	8.50
9	9-5kR-RGC-1066	3.20	1.44	66.44	17.20	21.25	15.65	8.50
10	10-5kR- RGC-1066	3.55	1.61	75.20	18.50	22.65	17.65	8.50
11	11-5kR-RGC-1066	3.75	1.23	95.53	20.50	21.65	15.45	7.50
12	12-5kR-RGC-1066	3.15	1.56	70.23	20.00	22.85	16.35	7.50
13	13-5kR-RGC-1066	3.65	1.23	70.55	20.40	23.95	15.05	7.50
14	14-5kR-RGC-1038	3.45	1.76	65.86	40.40	27.75	70.70	6.50
15	15-5kR-RGC-1038	3.40	1.35	63.20	40.80	26.95	66.00	6.50
16	16-5kR-RGC-1038	3.50	0.93	51.59	30.02	27.75	63.70	6.50
17	17-5kR-RGC-1038	3.05	1.42	58.18	28.68	27.75	68.90	6.50
18	18-5kR-RGC-1038	3.30	1.23	62.79	17.26	20.75	68.00	7.50
19	19-5kR-RGC-1038	3.95	1.73	65.36	34.72	22.85	69.90	6.50
20	20-5kR-RGC-1055	3.55	1.42	71.53	22.66	25.45	47.65	7.50
21	21-5kR-RGC-1055	3.35	1.28	75.51	14.01	24.75	40.25	6.50
22	22-5kR-RGC-1055	3.35	1.82	67.66	10.41	25.35	39.25	4.50
23	23-5kR-RGC-1055	3.45	0.61	77.28	8.89	24.15	45.25	6.50
24	24-5kR-RGC-1055	3.25	0.76	39.95	14.07	25.45	43.25	6.50
25	25-5kR-RGC-1055	3.45	0.67	74.96	19.07	23.85	63.20	6.50
26	26-5kR-GST-15-204	3.60	1.70	50.20	11.09	26.55	58.65	7.50
27	27-5kR-GST-15-204	3.55	1.48	51.79	27.24	26.55	55.95	6.50
28	28-5kR-GST-15-204	3.15	0.72	42.31	17.09	27.55	60.75	8.50
29	29-5kR-GST-15-204	3.30	1.67	58.61	11.72	28.25	53.95	6.50
30	30-5kR-GST-15-204	3.45	0.73	52.69	15.09	27.55	62.05	7.50
31	31-5kR-GST-15-204	3.30	1.33	43.80	15.44	26.75	55.55	7.50
32	32-5kR-GST-15-204	4.20	1.48	47.83	20.69	27.55	27.55	7.50
33	33-10kR-RGC-1066	3.45	2.29	48.14	26.20	21.95	18.95	7.50
34	34-10kR-RGC-1066	2.95	1.77	50.19	29.40	22.85	23.65	7.50
35	35-10kR-RGC-1066	3.30	1.23	59.30	32.80	23.45	19.85	7.50
36	36-10kR-RGC-1066	3.35	0.94	76.98	4.70	22.25	25.65	7.50
37	37-10kR-RGC-1066	3.55	1.70	49.61	25.18	23.55	28.45	8.50
38	38-10kR-RGC-1066	3.30	1.50	46.37	25.15	21.95	32.65	8.50
39	39-10kR-RGC-1038	3.35	2.40	71.69	24.96	26.65	95.50	7.50
40	40-10kR-RGC-1038	3.25	1.84	71.88	23.68	24.45	85.10	7.50
41	41-10kR-RGC-1038	3.90	2.19	75.78	23.12	24.45	91.20	5.50
42	42-10kR-RGC-1038	3.10	1.56	77.79	35.06	36.15	87.10	5.50
43	43-10kR-RGC-1038	3.25	1.45	64.40	42.40	33.35	89.20	6.50
44	44-10kR-RGC-1038	3.60	2.29	86.91	36.83	32.35	90.40	6.50

S. No.	Mutant lines/Controls	Mean performance						
		Seed yield/ Plant (gm)	100 seed weight(gm)	RWC(1)	RWC(2)	Gum Content	Proline content	Number of seeds / pod
45	45-10kR-RGC-1038	3.50	1.43	86.20	28.28	31.35	88.30	6.50
46	46-10kR-RGC-1038	3.05	1.46	83.25	29.91	29.35	92.00	6.50
47	47-10kR-RGC-1038	3.60	0.88	83.69	30.81	29.35	95.10	6.50
48	48-10kR-RGC-1038	3.60	1.18	71.58	41.71	30.35	94.10	6.50
49	49-10kR-RGC-1055	3.40	1.19	78.44	16.91	23.85	60.45	7.50
50	50-10kR-RGC-1055	3.30	1.40	49.32	19.96	25.55	57.35	7.50
51	51-10kR-RGC-1055	3.45	0.56	58.79	24.96	26.25	54.75	6.50
52	52-10kR-RGC-1055	3.35	1.21	69.86	21.55	21.15	59.35	6.50
53	53-10kR-RGC-1055	3.65	1.48	78.49	28.47	25.35	60.35	6.50
54	54-10kR-GST-15-204	3.45	0.85	43.14	7.98	27.55	77.45	6.50
55	55-10kR-GST-15-204	3.60	0.80	63.23	7.77	20.55	66.35	5.50
56	56-10kR-GST-15-204	3.00	0.81	47.20	13.96	22.65	68.75	6.50
57	57-10kR-GST-15-204	3.80	1.44	51.86	28.45	26.45	56.55	5.00
58	58-10kR-GST-15-204	4.20	0.67	63.92	15.58	20.05	72.65	5.50
59	59-10kR-GST-15-204	3.80	1.36	67.92	12.43	20.05	65.55	6.50
60	60-15kR-RGC-1066	4.35	1.49	40.87	24.34	21.95	39.15	8.50
61	61-15kR-RGC-1066	4.40	0.63	60.54	34.47	23.65	42.85	8.50
62	62-15kR-RGC-1066	3.45	1.26	70.91	13.91	24.35	40.95	8.50
63	63-15kR-RGC-1066	3.55	0.99	71.47	16.72	19.25	39.45	8.50
64	64-15kR-RGC-1066	3.45	1.20	63.27	23.27	23.45	41.05	8.50
65	65-15kR-RGC-1066	3.70	0.67	58.44	2.11	24.85	39.25	8.50
66	66-15kR-RGC-1038	3.40	1.40	88.33	41.66	27.35	98.00	6.50
67	67-15kR-RGC-1038	3.30	1.55	83.11	42.45	25.85	86.60	6.50
68	68-15kR-RGC-1038	3.45	0.92	79.64	49.40	26.45	97.60	6.00
69	69-15kR-RGC-1038	3.15	1.47	84.00	39.15	23.65	92.30	6.50
70	70-15kR-RGC-1038	3.45	1.44	73.38	60.87	24.95	90.30	5.50
71	71-15kR-RGC-1038	3.10	0.62	78.33	52.59	24.55	84.40	7.50
72	72-15kR-RGC-1038	4.25	1.29	84.89	46.12	20.75	82.60	5.50
73	73-15kR-GST-15-204	4.75	1.69	80.16	24.12	31.75	79.35	5.50
74	74-15kR-GST-15-204	4.05	1.55	63.99	14.55	28.95	67.65	7.50
75	75-15kR-GST-15-204	4.35	0.83	59.25	6.25	27.95	69.75	7.50
76	76-15kR-GST-15-204	4.20	1.32	59.56	19.71	26.95	73.75	5.50
77	77-15kR-GST-15-204	4.10	1.32	60.44	27.06	24.95	73.55	6.50
78	78-15kR-GST-15-204	4.35	0.82	66.10	16.39	24.95	70.75	6.50
79	89-15kR-GST-15-204	3.65	1.17	60.17	14.54	25.95	67.35	5.50
80	80-15kR-GST-15-204	3.20	1.07	59.63	11.50	22.95	72.35	6.50
81	81-20kR-RGC-1066	4.13	3.60	67.31	23.95	24.45	93.10	6.50
82	82-20kR-RGC-1066	4.05	3.67	65.68	19.03	20.65	94.60	6.50
83	83-20kR-RGC-1038	4.45	1.06	77.97	45.71	18.05	91.60	7.50
84	84-20kR-RGC-1038	4.15	1.11	83.54	45.88	15.65	92.90	6.50
85	85-20kR-RGC-1038	3.90	1.30	78.33	58.54	17.55	91.50	8.50
86	86-20kR-RGC-1038	4.10	1.48	69.42	47.80	18.45	91.55	8.00
87	87-20kR-RGC-1038	4.05	1.07	85.03	46.66	15.65	93.40	6.50
88	88-20kR-RGC-1038	3.45	0.88	80.45	58.49	14.65	66.15	6.50
89	89-20kR-RGC-1055	3.24	3.24	61.32	21.47	26.75	64.65	6.50
90	90-20kR-RGC-1055	3.15	2.51	50.73	18.18	26.35	67.35	8.50

S. No.	Mutant lines/Controls	Mean performance						
		Seed yield/ Plant (gm)	100 seed weight(gm)	RWC(1)	RWC(2)	Gum Content	Proline content	Number of seeds / pod
91	91-20kR-RGC-1055	3.50	3.27	62.07	26.18	22.55	63.25	8.50
92	92-20kR-RGC-1055	4.10	3.78	64.58	31.46	19.85	81.35	8.50
93	93-20kR-GST-15-204	3.05	1.82	48.78	6.28	21.45	78.15	5.50
94	94-20kR-GST-15-204	3.65	1.18	44.82	4.76	22.05	67.92	7.50
95	95-25kR-RGC-1066	3.65	2.35	69.61	17.50	22.55	47.05	7.50
96	96-25kR-RGC-1066	3.35	2.30	62.98	12.79	20.15	48.85	7.50
97	97-25kR-RGC-1066	3.40	1.28	51.78	30.70	22.05	46.15	6.50
98	98-25kR-RGC-1038	3.65	1.45	15.24	10.25	15.85	100.50	8.50
99	99-25kR-RGC-1038	3.30	1.17	60.12	28.10	21.45	104.90	4.50
100	100-25kR-RGC-1038	3.30	1.49	50.24	8.94	22.65	106.90	7.50
101	101-25kR-RGC-1055	7.04	2.70	40.45	20.50	17.45	77.25	8.50
102	102-25kR-RGC-1055	5.97	2.91	46.39	21.57	19.35	75.65	9.50
103	103-25kR-RGC-1055	5.75	2.58	31.32	25.66	20.25	72.25	6.50
104	104-25kR-RGC-1055	5.16	2.23	68.08	31.50	17.55	72.70	7.50
105	105-25kR-RGC-1055	5.00	3.09	72.52	22.21	16.55	70.30	8.50
106	106-25kR-RGC-1055	4.90	3.65	37.19	14.89	17.75	74.10	7.50
107	107-25kR-GST-15-204	5.09	3.70	58.78	9.94	21.35	90.65	5.50
108	108-25kR-GST-15-204	4.10	3.13	56.51	14.94	22.65	80.85	6.50
109	109-25kR-GST-15-204	4.00	2.79	58.11	12.78	22.25	79.95	6.50
110	110-25kR-GST-15-204	3.40	2.97	61.69	15.83	18.45	87.35	5.50
111	111-25kR-GST-15-204	3.80	1.16	43.86	20.83	15.75	81.45	6.50
112	112-25kR-GST-15-204	4.05	1.04	60.46	17.42	13.35	85.15	5.50
113	113-25kR-GST-15-204	3.80	1.55	52.35	24.34	15.25	89.35	5.50
114	114-30kR-RGC-1066	3.60	2.28	75.00	22.24	22.95	50.85	6.50
115	115-30kR-RGC-1066	3.45	2.17	61.06	6.77	20.15	57.95	8.50
116	116-30kR-RGC-1038	3.35	1.66	81.64	67.34	24.65	130.80	9.50
117	117-30kR-RGC-1038	3.50	1.21	81.00	78.35	24.65	136.80	7.50
118	118-30kR-RGC-1038	3.40	0.89	60.48	19.47	25.65	128.90	7.50
119	119-30kR-RGC-1038	3.30	1.36	61.84	9.97	26.35	133.70	6.50
120	120-30kR-RGC-1038	3.10	1.50	77.51	13.00	25.65	129.30	5.50
121	121-30kR-RGC-1038	3.70	0.77	81.17	15.76	24.85	135.80	7.50
122	122-30kR-RGC-1038	3.35	1.16	70.90	19.15	25.65	132.80	8.50
123	123-30kR-RGC-1038	3.45	0.66	79.33	14.15	25.65	130.30	6.50
124	124-30kR-GST-15-204	3.35	1.61	61.96	17.34	16.15	95.85	7.50
125	125-30kR-GST-15-204	3.95	1.22	62.66	14.05	13.35	91.75	6.50
126	126-30kR-GST-15-204	3.30	0.98	51.21	22.05	12.35	88.45	6.50
127	127-30kR-GST-15-204	4.70	1.35	65.06	27.33	13.55	92.35	6.50
128	128-35kR-RGC-1038	3.60	1.49	67.52	25.53	19.15	135.90	5.50
129	129-35kR-RGC-1038	3.40	1.40	77.80	17.47	20.75	137.80	7.50
130	130-35kR-RGC-1038	3.60	0.88	78.30	17.58	24.55	138.70	6.50
131	131-35kR-RGC-1038	3.50	0.82	68.37	14.72	22.35	134.70	6.50
132	132-35kR-RGC-1038	3.70	1.25	77.45	24.99	22.33	131.20	7.50
133	133-35kR-RGC-1038	3.65	1.03	59.84	9.73	34.05	132.40	7.50
134	134-35kR-GST-15-204	4.40	1.92	55.92	16.37	19.15	99.15	7.50
135	135-35kR-GST-15-204	4.05	2.24	62.34	17.44	20.35	104.05	7.50
136	136-35kR-GST-15-204	4.40	1.77	54.60	21.53	22.35	99.45	7.00

S. No.	Mutant lines/Controls	Mean performance							
		Seed yield/ Plant (gm)	100 seed weight(gm)	RWC(1)	RWC(2)	Gum Content	Proline content	Number of seeds / pod	
137	137-35kR-GST-15-204	4.45	2.09	61.16	27.37	24.12	102.35	7.00	
138	138-35kR-GST-15-204	3.20	1.13	52.16	18.08	23.35	96.55	7.50	
139	139-40kR-RGC-1038	3.55	1.73	81.45	22.95	31.80	135.20	5.50	
140	140-40kR-RGC-1038	3.55	1.29	70.14	20.71	30.25	150.70	4.50	
141	141-40kR-RGC-1038	3.45	0.77	78.70	15.52	29.25	157.40	6.50	
142	142-40kR-RGC-1038	3.25	1.47	78.43	16.07	27.25	151.10	7.50	
143	143-40kR-RGC-1038	3.60	0.67	76.09	12.53	27.25	149.90	6.50	
144	144-40kR-RGC-1038	4.05	1.29	77.11	15.71	28.25	152.80	8.00	
145	145-45kR-RGC-1066	5.20	3.30	54.81	20.87	19.15	169.15	6.50	
146	146-45kR-RGC-1066	4.18	3.10	79.24	24.97	16.35	171.65	6.50	
147	147-45kR-RGC-1066	3.47	3.85	77.46	2.96	21.95	164.55	6.50	
148	148-45kR-RGC-1066	4.23	3.25	72.55	35.61	23.15	170.75	7.50	
149	149-45kR-RGC-1066	3.45	3.38	66.40	39.36	25.15	169.25	6.50	
150	150-45kR-RGC-1038	4.15	1.75	70.74	8.48	25.25	185.00	4.50	
151	151-45kR-GST-15-204	4.15	2.51	72.83	10.76	24.05	151.65	6.50	
152	152-45kR-GST-15-204	3.70	2.06	51.96	5.94	23.35	152.45	6.00	
153	153-45kR-GST-15-204	3.80	1.97	75.05	15.04	22.55	151.05	7.50	
154	154-45kR-GST-15-204	4.20	2.08	52.07	6.96	23.35	149.45	8.50	
155	155-45kR--GST-15-204	3.50	2.22	63.43	23.11	23.35	156.55	6.50	
156	156-45kR--GST-15-204	3.55	2.55	80.82	12.96	16.35	154.15	4.50	
157	157-45kR--GST-15-204	3.20	1.24	70.02	7.59	18.45	156.10	7.50	
158	158-45kR-GST-15-204	3.45	2.22	70.61	10.96	22.05	149.60	6.00	
159	159-50kR-RGC-1066	4.15	3.20	51.24	45.34	25.15	193.85	7.50	
160	160-50kR-RGC-1066	3.50	3.50	58.04	45.50	26.15	189.15	6.50	
161	161-50kR-RGC-1038	4.85	2.45	67.23	18.03	23.75	199.50	6.50	
162	162-50kR-RGC-1038	4.56	3.30	78.17	17.20	24.35	196.30	8.50	
163	163-50kR-RGC-1055	3.30	2.49	54.40	10.07	23.35	172.20	9.50	
164	164-50kR-GST-15-204	4.25	3.50	58.77	11.31	19.85	196.70	8.50	
165	165-50kR-GST-15-204	4.16	3.25	71.77	16.56	19.85	191.70	7.50	
166	166-50kR-GST-15-204	3.15	2.55	52.10	3.85	29.05	193.10	7.50	
167	167-50kR-GST-15-204	3.25	2.07	65.04	3.64	26.25	189.00	7.50	
	<b>Total mean</b>	<b>3.72</b>	<b>1.69</b>	<b>64.92</b>	<b>22.35</b>	<b>23.44</b>	<b>90.55</b>	<b>6.99</b>	
	<b>Range</b>	<b>Max</b>	<b>7.04</b>	<b>3.85</b>	<b>95.53</b>	<b>78.35</b>	<b>36.15</b>	<b>9.50</b>	<b>9.50</b>
		<b>Min</b>	<b>2.95</b>	<b>0.56</b>	<b>15.24</b>	<b>2.11</b>	<b>12.35</b>	<b>4.50</b>	<b>4.50</b>
		<b>SE(m)</b>	<b>0.14</b>	<b>0.11</b>	<b>5.59</b>	<b>1.09</b>	<b>0.70</b>	<b>0.61</b>	<b>0.27</b>
		<b>CD 5%</b>	<b>0.38</b>	<b>0.32</b>	<b>15.50</b>	<b>3.02</b>	<b>1.95</b>	<b>1.69</b>	<b>0.74</b>
		<b>CV%</b>	<b>1.43</b>	<b>1.77</b>	<b>13.88</b>	<b>4.61</b>	<b>2.91</b>	<b>1.28</b>	<b>2.02</b>

RWC-1= Relative water content (irrigated condition)

RWC-2= Relative water content (non-irrigated condition)

#### **4.3.3.3 Mean performance of gamma rays doses for 19 characters in M<sub>2</sub> Generation**

On the basis of mean performance, germination % decreased with increased doses (10kR to 50kR) over control. All the doses (5 kR to 50 kR) were found delayed in flowering as compared to control. Doses from 5 kR to 50 kR reduced canopy temperature at vegetative and reproductive stages except 45 kR dose. Doses 45 and 20 kR enhanced early maturity than control. Tallest height were found in all doses as compared to control. However among all doses 45 kR dose was produced tallest plants as compared to control and 40kR was promoted dwarfism. Pod length was proved highly significant superior with 5 kR dose and the lowest with 30 kR as compared to control. Maximum number of pods/plant was found with 50kR and minimum with 30kR. Maximum number of pods/cluster was found with 15kR and minimum with 30kR. Maximum number of cluster/plant was found with 50kR and minimum with 20kR. A dose of 45kR enhanced leaf area index and 40 kR dose proved significantly lowest performer for this parameter. 5 and 10kR dose produced significantly lowest seed yield/plant and 25, 50, 45, 35, 15, 20, 40 and 30 showed highest seed yield/plant as compare to control. In comparison to control 100 seed weight were recorded maximum in all doses with higher with 50kR dose. Dose 45kR was proved significantly superior and 25kR significantly inferior for relative water content (irrigated condition). Relative water content at non-irrigated condition was found highest at 20kR and lowest at 45 kR doses respectively. High gum content was found with 40kR over the control. Proline content was found the lowest at 5 kR and the highest at 50kR doses respectively. Maximum number of seeds/pod was found at 20 and 50 kR doses.

Table 4.25 (a): Mean performance of Kr doses for 19 characters

Doses (Kr)	Germination %	Days to 50 % Flowering	Canopy temp (1)	Canopy temp (2)	No of primary branches / plant	Days to 80 % Maturity
	Mean	Mean	Mean	Mean	Mean	Mean
0	89.63	54.38	30.25	38.54	1.38	83.25
5	67.70	55.61	27.98	36.60	1.41	84.21
10	69.93	56.35	27.63	36.79	1.37	85.20
15	56.93	55.07	27.78	36.20	1.40	86.07
20	47.54	57.07	28.20	37.93	1.43	83.11
25	36.39	55.47	27.42	37.03	1.34	84.66
30	53.82	56.29	28.74	38.11	1.46	85.79
35	50.77	56.68	28.81	37.75	1.59	85.09
40	45.25	58.42	29.02	38.97	1.42	81.92
45	19.29	56.64	27.01	34.91	1.50	83.00
50	18.28	59.83	28.80	37.03	1.22	85.44

Table-4.25 (b): Mean performance of Kr doses for 19 characters

Doses (Kr)	Plant height (cm)	Pod length (cm)	Number of pods /plant	Number of pods /cluster	Number of cluster /plant	Leaf area index
	Mean	Mean	Mean	Mean	Mean	Mean
0	55.88	4.16	74.25	2.88	15.63	13.80
5	66.89	4.77	81.55	3.50	16.50	16.19
10	63.81	4.71	78.85	3.35	14.74	13.49
15	65.40	4.34	73.17	3.74	13.36	15.46
20	62.25	4.35	81.96	3.07	16.71	15.19
25	68.13	4.75	90.21	3.68	20.11	14.41
30	61.11	4.19	70.00	2.82	17.14	16.79
35	71.18	4.39	86.00	3.32	16.82	13.55
40	57.25	4.29	88.17	3.67	18.33	12.77
45	74.79	4.67	83.11	3.25	14.57	17.95
50	67.56	4.22	111.06	3.06	20.28	15.29

Table- 4.25 (c): Mean performance of Kr doses for 19 characters

Doses (Kr)	Seed yield/ Plant (gm)	100 seed weight (gm)	RWC (1)	RWC (2)	Gum Content	Proline content	No of seeds/ pod
	Mean	Mean	Mean	Mean	Mean	Mean	Mean
0	3.48	1.07	55.62	15.74	25.75	93.04	7.25
5	3.44	1.36	64.14	19.88	24.86	42.78	7.11
10	3.45	1.40	65.77	24.38	25.68	65.06	6.74
15	3.79	1.17	68.88	27.68	25.02	69.00	6.95
20	3.78	2.14	67.14	32.46	20.29	81.25	7.25
25	4.35	2.29	52.51	18.98	19.09	78.49	6.92
30	3.54	1.34	69.34	24.78	21.54	109.69	7.21
35	3.81	1.45	65.04	19.16	22.95	119.30	7.05

40	3.58	1.20	76.99	17.25	29.01	149.52	6.42
45	3.87	2.53	68.43	16.11	21.75	160.81	6.50
50	3.91	2.92	61.86	19.05	24.19	191.28	7.72

#### 4.3.3.4 Genetic variability for quantitative, morpho-physiological, biochemical and quality traits

One of the most important considerations in any crop improvement is the detailed study of genetic variability. Variability measured by the estimates of genotypic and phenotypic variation, heritability and genetic advance.

##### 4.3.3.4.1 Coefficient of variation

The variance measures the variation within a particular trait but it does not provide any real measure for comparison of variance between different traits. The term “coefficient of variation (CV)” truly provides a relative measure of variance among different traits. In general, estimate of phenotypic coefficient of variation (PCV) were found to be higher than their corresponding genotypic coefficient of variation (GCV), due to environmental component, which was being added to GCV. The estimates of GCV and PCV for all nineteen characters have been presented in Table-

##### 4.3.3.4.1.1 Phenotypic coefficient of variation

A wide range of phenotypic coefficient of variation (PCV) was observed for all characters varied from days to 80% maturity (7.20) to germination% (101.90). higher magnitude of PCV was recorded for germination % (101.90) followed by RWC(Non-Irrigated Condition) (88.64), number(s) of cluster/plant (84.31), days to 80% maturity (74.04), leaf area index (64.91), plant height (cm) (52.38), 100 seed weight (gm) (51.43), number(s) of primary branches/plant, (48.21), number of pods/cluster (47.73), gum content (38.62), number(s) of seeds/pod (37.30), RWC(Irrigated Condition) (27.95), proline content (31.43), number(s) of pods/plant (27.67), seed yield/Plant (gm) (27.14), however canopy temperature (at reproductive stage) (17.95), canopy temperature (at vegetative stage (14.32), days to 50 %flowering (11.29) exhibited moderate values of PCV, low value was observed for only pod length (cm) (7.20).

##### 4.3.3.4.1.2 Genotypic coefficient of variation

A wide range of genotypic coefficient of variation (GCV) was observed for all the characters varied from days to 80% maturity (3.96) to relative water content (non-irrigated condition) (58.17). Higher magnitude of GCV was recorded for RWC(Non-Irrigated Condition) (58.17) followed by, proline content (51.06), 100 seed weight(gm) (47.28), germination % (42.14), number(s) of cluster/plant (34.43), number(s) of pods/plant (29.26),

leaf area index (26.77), number(s) of pods/cluster (22.27), plant height (cm) (21.53), However gum content (17.43), RWC(Irrigated Condition) (16.23), pod length (cm) (14.93), seed yield/plant (gm) (14.75), number(s) of seeds/pod (13.84), number(s) of primary branches/plant (13.51), exhibited moderate values of GCV, low value was observed for days to 80% maturity (3.96), days to 50 % flowering (6.39), canopy temperature at vegetative stage (6.92) and canopy temperature at reproductive stage(7.40).

#### **4.3.3.4.1.3 Heritability**

The estimates of heritability have been presented in table 26. A wide range of heritability was observed for all the characters varied from number of primary branch/plant (14.95) to proline content (97.27). Higher magnitude of heritability was recorded for proline content (97.27) followed by RWC (non-irrigated condition) (97.27), germination % (96.85), days to 50% flowering (94.70), 100 seed weight(gm) (92.35), plant height (cm) (91.94), number of pods/plant (91.73), leaf area index (89.72), gum content (89.40), days to 80% maturity (87.58), number of cluster/plant (83.43), pod length (cm) (83.37), seed yield/plant (gm) (79.80), number of seeds/pod (76.66), canopy temperature (reproductive stage) (73.73), number of pods/cluster (57.00), however, RWC (irrigated condition) (47.02), canopy temp (vegetative stage) (35.93), exhibited moderate values of heritability, low value was observed for number of primary branches/plant (14.95).

#### **4.3.3.4.1.4 Genetic advance**

The estimates of genetic advance have been presented in Table 26. A wide range of genetic advance was observed for all the characters varied from proline content (4403.72) to number(s) of primary branches/plant (0.07). Higher magnitude of genetic advance was recorded for proline content (4403.72) followed by, number(s) of pods/plant (1191.67), germination % (995.73), plant height (cm) (414.00), RWC (non-irrigated condition) (348.19), RWC(irrigated condition) (228.74), number of cluster/plant (65.78), however, gum content (34.40), leaf area index (34.04), days to 50 % flowering (26.60), days to 80% maturity (23.08), exhibited moderate values of heritability, low value was observed for number(s) of primary branches/plant (0.07), seed yield/plant (gm) (0.62), pod length (cm) (0.94), number(s) of pods/cluster (1.16), 100 seed weight (gm) (1.31), canopy temperature (at vegetative stage) (7.76), canopy temperature (at reproductive stage) (15.39).

**Table-4.26: Coefficient of variation, heritability & genetic advance for 19 contributing characters in cluster bean mutant lines**

S. No.	Characters	PCV	GCV	ECV	Heritability%	Genetic advance
6	Days to 80% Maturity	7.20	3.96	1.49	87.58	23.08
2	Days to 50 %Flowering	11.29	6.39	1.51	94.70	26.60
3	Canopy temp (1)	17.95	6.92	9.25	35.93	7.76
4	Canopy temp (2)	14.32	7.40	4.41	73.73	15.39
5	Number of primary branches /plant	51.43	13.51	32.21	14.95	0.07
19	Number of seeds/pod	27.14	13.84	7.64	76.66	1.92
13	Seed yield/Plant (gm)	27.67	14.75	7.42	79.80	0.62
8	Pod length (cm)	27.95	14.93	6.67	83.37	0.94
15	RWC(Irrigated Condition)	37.30	16.23	17.23	47.02	228.74
17	Gum Content	31.43	17.43	6.00	89.40	34.40
7	Plant height (cm)	38.62	21.53	6.37	91.94	414.00
10	Number of pods/cluster	47.73	22.27	19.34	57.00	1.16
12	Leaf area index	48.21	26.77	9.06	89.72	34.04
9	Number of pods/plant	52.38	29.26	8.79	91.73	1191.67
11	Number of cluster/plant	64.91	34.43	15.35	83.43	65.78
1	Germination %	74.04	42.14	7.60	96.85	995.73
14	100 seed weight(gm)	84.31	47.28	13.61	92.35	1.31
18	Proline content	88.64	51.06	1.35	99.93	4403.72
16	RWC(Non-Irrigated Condition)	101.90	58.17	9.75	97.27	348.19

#### 4.3.3.5 Character association studies

##### 4.3.4.1 Correlation coefficients

The estimation of phenotypic, genotypic and environmental correlation coefficient between different pairs of characters in the induced mutant lines of M<sub>2</sub> generations presented in Table 27 and Table 28.

Correlation analysis provides information about yield components and helps the plant breeders in selection of superior genotypes.

##### 4.3.4.1.1 Genotypic correlation

##### 4.3.4.1.1 Germination %

Germination % showed positive and significant correlation with gum content (0.338), RWC (non-irrigated condition) (0.210) while showed positive and non-significant association with RWC (irrigated condition) (0.134), canopy temperature at reproductive (0.128) and vegetative stage (0.125), days to 80% maturity (0.067) and number of primary branch/plant (0.033). The correlation showed negative and significant association with seed yield/plant (-0.497), number of seeds/pod (-0.448), proline content (-0.426), number(s) of pods/plant (-0.231), days to 50% flowering (-0.192), 100 seed weight (-0.190), number(s) of cluster/plant (-0.167) while negative and non-significant association with leaf area index (-0.110), plant height (-0.079), number of pods/cluster (-0.055) and pod length (-0.054) were documented.

#### **4.3.4.1.2 Days to 50% flowering**

Days to 50% flowering showed positive and significant correlation with number(s) of seeds/pod (0.401) and proline content (0.213) while positive and non-significant association was observed with seed yield/plant (0.137), gum content (0.101), number(s) of pods/plant (0.042), 100 seed weight (0.042) and number(s) of pods/cluster (0.017). The correlation showed negative and significant association with number of primary branch/plant (-0.255) while negative and non-significant with RWC (irrigated condition) (-0.110), RWC (non-irrigated condition) (-0.092), pod length (-0.082), canopy temperature at reproductive stage (-0.082), days to 80% maturity (-0.063), leaf area index (-0.051), plant height (-0.020), temperature at vegetative stage (-0.009) and number of cluster/plant (-0.002).

#### **4.3.4.1.3 Canopy temperature (at vegetative stage)**

Canopy temperature at reproductive stage (1.132), number of seeds/pod (0.510), RWC at irrigated condition (0.375), pod length (0.224) traits were significant and positively correlated with canopy temperature at vegetative stage while RWC at non-irrigated condition (0.123), plant height (0.097), number of pods/plant (0.079), gum content (0.054), seed yield/plant (0.003) showed positive and non-significant correlation. The correlation showed negative and significant association with days to 80% maturity (-0.292), number(s) of primary branch/plant (-0.177), 100 seed weight (-0.197) while negative and non-significant with leaf area index (-0.072), number(s) of pods/plant (-0.042), number(s) of cluster/plant (-0.015) and proline content (-0.013).

#### **4.3.4.1.4 Canopy temperature at reproductive stage**

Canopy temperature (at reproductive stage) was not correlated either positively or negatively with any of the traits. It only showed positively non-significant association with RWC (irrigated condition) (0.37), pod length (0.25), number of seeds/pod (0.24), RWC (non-irrigated condition) (0.22), number(s) of cluster/plant (0.05), number(s) of pods/plant (0.02) and negatively non-significant association with days to 80% maturity (-0.26), 100 seed

weight (-0.18), leaf area index (-0.14), proline content (-0.08), gum content (-0.06), number(s) of pods/cluster and number(s) of primary branch/plant (-0.02), plant height and seed yield/plant (-0.01).

#### **4.3.4.1.5 Number of primary branch/plant**

Number(s) of primary branches/plant was not giving positive or negative significant correlation with any traits. It showed positively non-significant correlation with days to 80% maturity (0.25), 100 seed weight (0.17), RWC (non-irrigated condition) (0.14), leaf area index (0.12), RWC (irrigated condition) (0.11), number of pods/cluster (0.08), seed yield/plant (0.01) and negatively non-significant correlation with number(s) of seeds/pod (-0.58), number(s) of cluster/plant (-0.38), number(s) of pods/plant (-0.30), gum content (-0.16), plant height (-0.14) and pod length (-0.08).

#### **4.3.4.1.6 Days to 80% maturity**

Number(s) of primary branch/plant was not associated either positively or negatively with any of the traits. It showed positively non-significant correlation with 100 seed weight (0.19), leaf area index (0.09) and negatively non-significant correlation with number(s) of cluster /plant (-0.23), seed yield/plant (-0.17), 100 seed weight (-0.16), gum content and number(s) of seeds/pod (-0.15), proline content (-0.11), RWC (irrigated condition) and number(s) of pods/plant (-0.06), plant height and pod length (-0.04), number(s) of pods/cluster and RWC (non-irrigated condition) (-0.01).

#### **4.3.4.1.7 Plant height (cm)**

Plant height (cm) was not giving positively or negatively significant correlation with any traits. It showed positively non-significant correlation with pod length (0.29), leaf area index (0.27), seed yield/plant (0.23), number of pods/cluster (0.15), number of seeds/pod (0.13), number of pods/plant & 100 seed weight (0.01) and negatively non-significant correlation with gum content (-0.16), RWC (irrigated condition) (-0.09), RWC (non-irrigated condition) (-0.07), proline content (-0.05). Zero correlation was found with number of cluster/plant.

#### **4.3.4.1.8 Pod length (cm)**

Pod length (cm) was not positively or negatively significant correlation with any traits. It showed positively non-significant correlation with number of seeds/pod (0.20) & number of cluster/plant (0.11) and negatively non-significant correlation with proline content (-0.30), 100 seed weight & gum content (-0.19), RWC (non-irrigated condition) (-0.10), leaf area

index (-0.09), RWC (irrigated condition) (-0.08), number of cluster/plant (-0.06), number of cluster/plant (-0.04) & seed yield/plant (-0.02).

#### **4.3.4.1.9 Number of pods/plant**

Number of pods/plant was not giving positively or negatively significant correlation with any traits. It showed positively non-significant correlation with number of cluster/plant (0.58) & seed yield/plant (0.30), number of pods/cluster (0.29), proline content (0.17), and number of seeds/pod (0.03) and negatively non-significant correlation with RWC (non-irrigated condition) (-0.24), leaf area index (-0.13), gum content (-0.09), RWC (irrigated condition) (-0.07), 100 seed weight (-0.06).

#### **4.3.4.1.10 Number of pods/cluster**

Number of pods/cluster was not showed positively or negatively significant correlation with any traits. It showed positively non-significant correlation with number of cluster/plant (0.12) & seed yield/plant (0.11), number leaf area index (0.05), 100 seed weight (0.04) and negatively non-significant correlation with proline content (-0.20), RWC (non-irrigated condition) & RWC (irrigated condition) (-0.13), gum content (-0.07). Zero correlation was found with number of seeds/pod (0.00).

#### **4.3.4.1.11 Number of cluster/plant**

Number of cluster/plant was not positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with seed yield/plant (0.19) & proline content (0.15), number of seeds/pod (0.12) and negatively non-significant correlation with leaf area index (-0.11), 100 seed weight (-0.05), RWC (irrigated condition) (-0.04), gum content (-0.02), RWC (non-irrigated condition) (-0.01).

#### **4.3.4.1.12 Leaf area index**

Leaf area index was not giving positively or negatively significant correlation with any traits. It showed positively non-significant correlation with seed yield/plant (0.13) & proline content (0.15), number of seeds/pod (0.12), RWC (irrigated condition) (0.11), RWC (non-irrigated condition) (0.10) and negatively non-significant correlation with 100 seed weight (-0.10), gum content (-0.01).

#### **4.3.4.1.13 Seed yield/plant (gm)**

Seed yield/plant (gm) showed positively significant correlation with days to 50% flowering (0.137) and positively significant correlation with 100 seed weight (0.24), number of

seeds/pod (0.30) & proline content (0.24) and negatively non-significant correlation with gum content (-0.28), RWC (irrigated condition) (-0.16) & RWC (non-irrigated condition) (-0.06).

#### **4.3.4.1.14 100 seed weight (gm)**

100 seed weight showed positively non-significant correlation with number of seeds/pod (0.28), proline content (0.02) & RWC (non-irrigated condition) (0.04) and negatively non-significant correlation with gum content (-0.22), RWC (irrigated condition) (-0.07).

#### **4.3.4.1.15 Relative Water Content (irrigated condition)**

RWC at irrigated condition showed positively non-significant correlation with RWC at non-irrigated condition (0.37), gum content (0.19) & proline content (0.18) and negatively non-significant correlation with number of seeds/pod (-0.05).

#### **4.3.4.1.16 Relative Water Content (non-irrigated condition)**

RWC at non-irrigated condition) showed positively non-significant correlation with gum content (0.02) and negatively non-significant correlation with number of seeds/pod (-0.18) & proline content (-0.01).

#### **4.3.4.1.17 Gum content**

Gum content showed positively non-significant correlation with proline content (0.04) and negatively non-significant correlation with number of seeds/pod (-0.12)

#### **4.3.4.1.17 Proline content**

Proline content showed positively non-significant with number of seeds/pod (0.11).

#### **4.3.4.1.2 Phenotypic correlation**

##### **4.3.4.1.1 Germination %**

Germination % showed positive and non-significant association with gum content (0.108), RWC (non-irrigation condition) (0.068), RWC (non-irrigation condition) (0.042), canopy temperature (at vegetative stage) (0.030), days to 80% maturity (0.021), number of primary/plant (0.004). The correlation showed negative and non-significant association with seed yield/plant (-0.160), proline content (-0.140), number of pods/plant (-0.073), days to

50% flowering ( -0.061), 100 seed weight (-0.057), number of seeds/pod (-0.047), leaf area index (-0.036), plant height (-0.025), pod length (-0.019), number of pods/cluster (-0.013).

#### **4.3.4.1.2 Days to 50% flowering**

Days to 50% flowering showed positive & non-significant correlation with proline content (0.069), number of seeds/pod (0.044), seed yield/plant (0.044), gum content (0.024), 100 seed weight (0.018), number of pods/plant (0.015), canopy temperature (at reproductive stage) (0.004), number of pods/cluster (0.004) and number of cluster/plant (0.004). The correlation showed negative and non-significant association with number of primary branch/plant (-0.033), canopy temperature (at reproductive stage) (-0.032), RWC (non-irrigation condition) (-0.028), RWC (non-irrigation condition) (-0.026), pod length (-0.022), days to 80% maturity (-0.018), plant height (-0.006), leaf area index (-0.016).

#### **4.3.4.1.3 Canopy temperature at vegetative stage**

Canopy temperature at reproductive stage (0.251) was significant and positively correlated with canopy temperature at vegetative stage while RWC at irrigated condition (0.069), RWC at non-irrigated condition (0.044), pod length (0.034), plant height (0.022), number of cluster/plant (0.021), number of pods/plant (0.015), number of pods/cluster (0.003), number of seeds/pod (0.002) showed positive and non-significant. The correlation showed negative & non-significant association with days to 80% maturity (-0.044), number of primary branch/plant (-0.034), leaf area index (-0.016), 100 seed weight (-0.011), gum content (-0.010), proline content (-0.05) and seed yield/plant (-0.002).

#### **4.3.4.1.4 Canopy temperature at reproductive stage**

Canopy temperature (at reproductive stage) was not showed positively or negatively significant correlation with any traits. It only showed positively non-significant association with RWC (irrigated condition) (0.10), RWC (irrigated condition) (0.06), pod length (0.06), number of pods/plant (0.01), number of cluster/plant (0.01) and negatively non-significant association with days to 80% maturity (-0.07), 100 seed weight (-0.05), number of primary branch/plant (-0.03), leaf area index (-0.03), proline content (-0.02), gum content (-0.01) Zero correlation was found with plant height, number of pods/cluster, seed yield/plant, and number of seeds/pod.

#### **4.3.4.1.5 Number of primary branch/plant**

Number of primary branch/plant was not showed positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with days to 80% maturity (0.03), leaf area index (0.03), 100 seed weight (0.03), number of seeds/pod (0.02), RWC (non-irrigated condition) (0.02), RWC (non-irrigated condition) (0.02), seed yield/plant (0.01), proline content (0.01) negatively non-significant correlation with number of cluster/plant (-0.05), number of pods/plant (-0.04), gum content (-0.03), plant height (-0.01), pod length (-0.08). Zero correlation was found with number of pods/cluster.

#### **4.3.4.1.6 Days to 80% maturity**

Number of primary branch/plant was not giving positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with 100 seed weight (0.06), leaf area index (0.03), number of pods/cluster and negatively non-significant correlation with number of cluster /plant (-0.06), gum content (-0.05), seed yield/plant (-0.05), number of seeds/pod (-0.03), proline content (-0.03), RWC (irrigated condition) (-0.02), plant height (0.01), pod length (-0.01) and number of pods/plant (-0.01). **4.3.4.1.7 Plant height (cm)**

Plant height (cm) was not giving positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with pod length (0.09), leaf area index (0.08), seed yield/plant (0.08), number of pods/plant (0.04) number of seeds/pod (0.01) and negatively non-significant correlation with gum content (-0.05), RWC (irrigated condition) (-0.02), RWC (non-irrigated condition) (-0.02), proline content (-0.02). Zero correlation was found with number of pods/plant, number of cluster/plant, 100 seed weight.

#### **4.3.4.1.8 Pod length (cm)**

Pod length (cm) was not giving positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with number of pods/cluster (0.03) and negatively non-significant correlation with proline content (-0.09), 100 seed weight & gum content (-0.06), RWC (irrigated condition) (-0.04), leaf area index (-0.03), RWC (non-irrigated condition) (-0.03). Seed yield/plant was showing no correlation with pod length.

#### **4.3.4.1.9 Number of pods/plant**

Number of pods/plant was not giving positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with number of cluster/plant (0.17) and seed yield/plant (0.09), number of pods/cluster (0.08) and proline content (0.05) and negatively non-significant correlation with RWC (non-irrigated condition)

(-0.08), leaf area index (-0.04), gum content (-0.03), RWC (irrigated condition) (-0.02), 100 seed weight (-0.01) and number of seeds/pod (-0.01).

#### **4.3.4.1.10 Number of pods/cluster**

Number of pods/cluster was not showed positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with number of cluster/plant (0.04), seed yield/plant (0.03), 100 seed weight (0.02), leaf area index (0.01), and negatively non-significant correlation with proline content (-0.05), RWC (non-irrigated condition) (-0.03), gum content (-0.02). Zero correlation was found with number of seeds/pod & RWC (irrigated condition).

#### **4.3.4.1.11 Number of cluster/plant**

Number of cluster/plant was not showed positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with seed yield/plant & proline content (0.05), RWC (irrigated condition) (0.01) and negatively non-significant correlation with leaf area index (-0.04), gum content (-0.02), 100 seed weight (-0.01), number of seeds/pod (-0.01). Zero correlation was found with RWC (non-irrigated condition).

#### **4.3.4.1.12 Leaf area index**

Leaf area index was not showed positively or negatively significant correlation with any traits. It only showed positively non-significant correlation with seed yield/plant (0.04), RWC (irrigated condition) & RWC (non-irrigated condition) (0.03) & proline content (0.02) and negatively non-significant correlation with 100 seed weight (-0.03). Zero correlation was found with gum content & number of seeds/pod.

#### **4.3.4.1.13 Seed yield/plant (gm)**

**Seed yield/plant (gm)** showed positively significant correlation with 100 seed weight (0.07), number of seeds/pod (0.03) & proline content (0.08) and negatively non-significant correlation with gum content (-0.08), RWC (irrigated condition) (-0.05) & RWC (non-irrigated condition) (-0.02).

#### **4.3.4.1.14 100 seed weight (gm)**

100 seed weight showed positively non-significant correlation with number of seeds/pod (0.02), proline content (0.01) & RWC (non-irrigated condition) (0.02) and

negatively non-significant correlation with gum content (-0.08), RWC (irrigated condition) (-0.02).

#### **4.3.4.1.15 Relative Water Content (irrigated condition)**

RWC (irrigated condition) showed positively non-significant correlation with RWC (non-irrigated condition) (0.10), proline content (0.05), gum content (0.04) & and negatively non-significant correlation with number of seeds/pod (-0.01).

#### **4.3.4.1.16 RWC (non-irrigated condition)**

RWC (non-irrigated condition) showed zero correlation with gum content & proline content and negatively non-significant correlation with number of seeds/pod (-0.2)

#### **4.3.4.1.17 Gum content**

RWC (non-irrigated condition) showed positively non-significant correlation with proline content (0.01) and negatively non-significant correlation with number of seeds/pod (-0.1)

#### **4.3.4.1.17 Proline content**

Proline content showed positively non-significant with number of seeds/pod (0.1).





## **CHAPTER - V**

### **DISCUSSION**

According to report by the Population Division of United Nations, the World population will increase to a total of 8.5 billion inhabitants by the year 2025 (Anon., 1991) of which seven billion people will be living in less developed regions in the World. Therefore, the task of farmers to increase production in the developing countries of the tropics and subtropics to provide food security coupled with nutritional security to this burgeoning population. To meet the demand there is need to improve, identify, and popularize new crops yielding multiple products having food, industrial, forage and nutritional value. For this purpose there is need to create genetic variability. Genetic variation can be created by using various breeding methods eg. hybridization, domestication and plant introduction etc. In the clusterbean to create genetic variability through the recombination of genes by hybridization is very difficult and cumbersome owing to small, delicate flower structures resulting in low percentage of crossed seed setting in the manually hybridized buds. Due to these reasons, not much desirable genetic variability has been generated through conventional breeding approaches.

Mutation breeding is important tool for enriching genetic variation in a cluster bean and hence looking at this limitation, efforts was initiated during the research work to create variability in clusterbean by using the tool of induced mutations. Mutation has been proven flexible, workable, and ready to use in many crop. It is a non-hazardous and low-cost technology that has the ability to address current challenges in agriculture. The aim of new mutant varieties - higher yield potential, more productive biomass for energy use, better nutrient composition for human health, better adaptation to climate and variability will be the driving force to meet the challenges of the 21<sup>st</sup> century. Genetic variability is the most essential requirement for clusterbean crop improvement programme. Genetic variability available today in plant collections is the result of spontaneous mutation, recombination and exposure to natural selection over centuries; different crop plants

have moulded themselves to the needs of nature through course of evolution. As time passed and men's per suite for the better genotypes progressed, the concept of mutations was evolved as a means to generate more variability by recombination. A large number of adopted varieties have been developed through mutation breeding in pulse crops. Because of increasing demand of nutritious food it is necessary to develop a new mutant with the desirable characteristics due to burgeoning population. For this purpose the present study entitled "Genetic manipulation through induced mutation for yield & gum content in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.)" was carried out and salient findings have been discussed under the following sub-head in the light of literature available.

### **5.1 Screening of sixteen genotypes**

On the basis of per se performance four genotypes from sixteen genotypes viz., RGC-1066, RGC-1055, RGC-1038, GST-15-204 were observed for early flowering, early maturity, maximum number of pods/plant, maximum number of pods/cluster, maximum number of seeds/pod and also found highly significant for plant height and pod length but these genotypes were found non-significant for 100 seed weight. Present finding are in confirmation with (Morris, 2007, 2008, 2010), Krishnan *et al.*, (2011) and Muhammad *et al.*, (2017).

### **5.2 Studies in M1 Generation**

Physical mutagen (gamma rays) can affect the treated plant in diverse ways. These manifestations are evidenced in various complicated and integrated growth processes such as seed germination, survival of plant, pollen sterility and chromosomal abnormalities in M1 generation. Hence, these are also called as the M<sub>1</sub> biological effects. The mode of action of the mutagen on the plant may broadly be classified into three categories:

The physiological damage is caused due to the toxicity of the mutagens and / or the disruption in cell physiology, leading to imbalance in growth. However, this damage, is restricted to the M1 generation. The point mutations or factor mutations affect the genetic material, DNA, and consequently heritable and transmitted to

further generations. The cells with chromosomal aberrations, while competing with the normal cells during the process of cell division, tend to get eliminated and hence one of the factors contributing to the lowered germination percentage and lethality. It has been very much established that the sensitivity of a plant to the applied mutagen depends upon a number of factors. These are genotype of the plant, nuclear volume, ploidy level, period of treatment, duration of pre-soaking and post-washing, the concentration/dose of the mutagen, pH of the solution, temperature, the light conditions and the seed size.

In the present investigation, various parameters were taken into consideration to assess the M<sub>1</sub> biological effects:

### **1. Germination percentage**

In the present investigation, the germination percentage decreased with increasing dose/concentration of gamma rays. Dose 5kR showed the maximum germination % (87.35%) and 50kR showed minimum germination% (35.35%) compared to other doses of gamma rays in all four genotypes. The results of germination percentage of clusterbean in M<sub>1</sub> generation clearly indicate that the mutagenic treatments show the inhibitory effect on seed germination percentage. Similar inhibitory effect on seed germination have also been reported in Groundnut (Venkatachalam and Jaybalan, 1997); in *Vigna* (Subramanian, 1980); in Urdbean (Makeen Kouser *et al.*, 2007; Sharma *et al.*, 2005); in Cowpea (Toker and Cagiranan, 2004; Apparao, 2005); in Chickpea (Barshile *et al.*, 2006); in Mungbean (Khan and Wani, 2006) and in Horse gram (Bolbhat and Dhumal, 2009).

### **2. Pollen sterility.**

The presents study revealed that the pollen sterility was recorded lower to high with the increasing doses of physical mutagen in all cluster bean genotypes in M<sub>1</sub> generation. The maximum pollen sterility was recorded at 50kR dose in all four genotype viz., GST-15-204 (59.09%), RGC-1055 (43.53%), RGC1066 (40.26%), RGC-1038(41.76%) and minimum pollen sterility was recorded at 5 KR in all four genotypes viz., GST-15-204(6.63%), RGC-1055 (7.225%), RGC-1066 (5.89%), RGC-1038 (5.26%). Hence, higher dose of gamma rays might be very useful in

clusterbean for producing male sterility during hybridization program of cluster bean. The increased sterility with increasing doses of mutagens also reported by several investigators Patil et al.,(2015), Bhosle and Kothekar (2010), S. Velu et al., (2007), Reddy et al., (1991) in cluster bean.

### **3. Survival of plants at maturity**

The survival of plants at maturity revealed reduced values after the mutagenic treatments than their respective control. Survival of plants at maturity was decreased with increases dose gamma rays. On the basis of mean performance of all genotype maximum survival of plants at maturity were recorded at 5kR (71.35) and minimum at 50kR (9.35). The extent of survival of plants is considered as one of the most reliable indices in evaluating the effect of any mutagen. Similarly Barshile (2006) in Chickpea, Sharma *et al.*, (2005) in Urdbean, Satpute and Kothekar (1996) in Safflower, Mundhe (2008), Tambe (2009) in Soybean, Gaikwad and Kothekar (2004) in Lentil, KamileUlukapetal., (2018) in cluster bean reported that the survival percentage decreases with increases mutagenic treatments.

### **4. Mortality**

Higher mortality was recorded at 50 KR in genotypes viz., GST-15-204 (77%), RGC 1055 (72%), RGC1066 (74%), RGC-1038 (71%) and lower lethality at 5 KR dose in genotypes viz., GST-15-204 (15%), RGC-1055 (18%), RGC1066 (7%), RGC-1038 (11%) in all the four genotypes. Similar result was found by Mahla et al., (2010).

## **5.3 STUDIES IN M<sub>2</sub> GENERATION**

### **5.3.1 Evaluation of selected mutant lines and gamma rays effects in selected mutant lines in M<sub>2</sub> generation**

#### **5.3.1.1 Spectrum and frequency of induced chlorophyll mutations**

The practical application of mutagenesis resets largely on increasing the effectiveness and efficiency of mutation production. The frequency of the mutants recovered depends on the methods both of induction and of selection. To obtain desired mutations at maximum rates, the choice of best mutagen applied at an optimal dose level is evidently a prime consideration. The first evident manifestation of the mutagenic treatment of the seeds is the occurrence of chlorophyll mutants in the  $M_2$  generation. In the present investigation, the chlorophyll mutants were scored in the field from 10-12 days old seedlings and have been classified according to Gustafson (1940). Four types of chlorophyll mutations were found in Guar namely *albino*, *xantha*, *chlorina*, and *viridis*.

The  $M_2$  families were scored for detectable mutations at different stages of growth. Mutation frequency is frequency of chlorophyll mutations calculated on  $M_2$  plant basis. It was noticed that the percentage of xantha chlorophyll mutant was maximum in majority of the mutagenic treatments followed by chlorina, viridis and albina in that order. In the present investigation, it was recorded that the mutation frequency increased with increasing doses of gamma rays only in two genotypes of clusterbean viz GST-15-204 & RGC-1066 but mutation frequency decreased with increasing doses of gamma rays in two other genotypes viz. RGC-1055 & RGC-1038. Chlorophyll mutants were found in almost all the mutagenic doses of gamma rays except some doses viz. 25kR, 35kR & 45kR in genotype GST-15-204, 20kR in genotype RGC-1066, 35kR in genotype RGC-1038, 10kR in genotype RGC-1055. Chlorophyll mutation was not recorded at 35kR treatment of gamma rays in all studied genotypes. The highest chlorophyll mutation frequency 1.5 was recorded in 50kR while, the lowest 0.5 recorded in 30kR treatments. The chlorophyll mutation frequency was increased from 5kR (0.75) to 20kR (1.5) but it decreased in 30kR but frequency of 50kR (0.75) was same as 5kR (0.75) in genotype GST-15-204, in RGC-1055 chlorophyll mutation frequency is increased from 10kR (0.75) to 50kR (1.5). The chlorophyll mutation frequency was decreased from 5kR to 45kR in two genotype RGC-1055 & RGC-1038. In the segregating  $M_2$  generation, spectrum of chlorophyll mutations indicated the presence of four types of chlorophyll mutants viz, albina, xantha, viridis, chlorina. Viridis and chlorina were observed in 5, 10, 15, 20,

25, 30, 40 & 50 kR treatments but Albino was observed in only 10kR & Xantha was observed in only in 15 and 50kR. Chlorina was found in mostly doses. The highest frequency of chlorina mutant was recorded 1.75% in 5 kR and lowest 20 kR treatments. Despite adverse effects on seed production, the chlorophyll mutants have been considered to be useful in understanding different physiological function, pathological invasions and different biochemical reactions (Miller, 1968). According to Robbelen (1968), the chlorophyll mutants can prove useful during the study of the effect of specific gene products in differentiations.

Bhosle S.S. and Kothekar V.S. (2010) also recorded that the mutation frequency is increased with increasing doses of gamma rays, EMS and SA in M<sub>2</sub> progenies of cluster bean varieties GE-36 and HR. Among the gamma rays treatment, the highest mutation frequency was recorded 2.6% in 15KR and lowest 1.66% in 5 KR treatment in the variety GE-36 while it was higher 3.33% in 15KR and 1.61% in 5 KR treatment of gamma rays in the variety HR. Patil et. al., (2015) was also observed chlorine mutant in 30 40 and 50kR doses.

### **5.3.1.2 Spectrum and frequency of induced viable mutations:**

In M<sub>2</sub> generation cluster bean genotypes shows differential viable mutations like plant type mutations. A broad range of viable mutants has been observed in M<sub>2</sub> generation of cluster bean, but some important mutants are discussed here. The different viable mutants obtained were of the following type:

#### **1. Dwarf mutants**

Dwarf mutants were observed in genotype viz., RGC-1066 at 5kR & 10kR, RGC-1055 at 35 kR, RGC-1038 at 15kR. Al-Rubeai (1982) also reported the dwarf, green, giant, high yielding and seed coat color mutants in French bean, while studied with gamma radiation treatments.

#### **2. Tall mutants**

Tall mutants were recorded in genotype viz., RGC-1066 at 5kR, 20kR, 45kR & 50kR, RGC-1055 at 20kR, 35kR & 45kR, GST-15-204 at 20kR, 45kR & 50kR.

Several researchers also obtained the tall mutants e.g. Khan and Wani (2004) in mungbean, and Wani and Anis (2001) in chickpea, Solanki and Sharma (2003) in lentil, Kumar *et al.*, (2007) in blackgram, Manjaya and Nandanwar (2007) in soybean. Tall mutants were also reported by, Kothekar and Kothekar (1992) and Khadke (2005) in moth bean, Gaikwad (2002) in lentil, Badere and Choudhary (2007) in Linseed and Barshile *et al.*, (2009) in chickpea. According to Jana (1962) the tallness of tall mutants is fundamentally due to increase in number and length of internodes.

### **3. Spreading type mutants**

Spreading type mutants were found in genotype viz., RGC-1066 at 5kR, RGC-1055 at 15kR, 20kR, 25kR & 45 kR, RGC-1038 at 20kR, GST-15-204 at 50kR. Similarly, four different types of morphological mutants were observed with the maximum mutation frequency of spreading types in case of higher doses of gamma rays by Mahla (2010).

### **4. Early and late type mutant**

Genotypes viz., RGC-1066 at 5kR, 15kR 25kR & 45kR, RGC-1055 at 5kR, 10kR, 20kR, 25kR, RGC-1038 at 25kR were recorded for early maturity and late maturity in genotype viz., RGC-1066 at 10kR & 20kR. Dhole *et al.*,(2003) in Soybean isolated tall, dwarf, leaf, high yielding sterile and late mutants.

### **5. Apical mutant**

One apical bearing type mutant was found in genotype viz., RGC-1066 at 45kR.

#### **5.3.1.3 Mutagenic effectiveness and efficiency**

The mutagenic effectiveness is a measure of factor mutations induced by a unit dose of mutagen. In  $M_2$  generation of clusterbean after Gamma rays treatment, the numerical value of effectiveness gradually decreased with increases in the dose of the mutagen in all the genotypes. The range for Gamma rays treatment was 5 kR to 50kR. The highest value of mutagenic effectiveness (0.15) was recorded in 5KR treatment and lowest (0.01) in 50 kR treatment in genotype GST-15-204, In

genotype RGC-1066 highest mutagenic effectiveness value was 0.07 (10kR) & lowest was 0.03 (50kR), in RGC-1055 highest mutagenic effectiveness value was 0.3 (5kR) & lowest was 0.03(25kR), in RGC-1038 highest mutagenic effectiveness value was 0.35(5kR) & lowest was 0.005(45kR). 0.35 was the highest value of efficiency which was found in genotype RGC-1038 at 5kR dose. Thus the lower doses of gamma rays were most effective. These results were supported by the results obtained in cluster bean by Velu S. et al., (2007). They reported higher mutagenic effect variety Pusa-Navbahar at lower doses of gamma rays and EMS. However EMS and its doses were found to be more effective mutagen than the gamma rays. Bhosle S.S. and Kothekar V.S. (2010) also reported reduction in the value of mutagenic effectiveness with the increased doses or concentration of mutagens gamma rays, EMS and SA respectively in the cluster bean varieties GE-36 and HR. SA proved to be more effective than gamma rays and EMS in both the varieties. The mutagenic effectiveness was also reported by K.G. Dube et al.,(2011) in cluster bean variety Sharada by using variable doses of Gamma rays, EMS and their combination. The mutagenic effectiveness was calculated on the basis of chromosomal aberrations rather than chlorophyll mutation frequency in  $M_2$  plants. These results also confirmed results of present investigation.

The mutagenic efficiency is the ratio of chlorophyll mutations induced in the  $M_2$  generation to the various biological damages induced in  $M_1$  generation such as lethality and pollen sterility. In the present study, the mutagenic efficiency decreased with the increasing doses of gamma rays with respect to lethality (L). Highest value of mutagenic efficiency was recorded 0.05 (GST-15-204), 0.08 (RGC-1055), 0.15 (RGC-1038) & 0.06 (RGC-1066) at 5KR, 10kR and lowest 0.009 (GST-15-204), 0.02 (RGC-1066), 0.01(RGC-1055) & 0.003 (RGC-1038) at 50, 25 & 45kR doses of mutagen. The observations in respect to efficiency with reference to pollen sterility demonstrated a doses dependent enhancement in majority of the mutagenic treatments in  $M_2$  generation of clusterbean genotype. The value of efficiency decreased as there were increases in doses of Gamma rays treatments. It was ranged from 0.01 to 0.29. Highest value of mutagenic efficiency was recorded 0.14 (GST-15-204), 0.20 (RGC-1055), 0.15 (RGC-1038) & 0.29 (RGC-1066) at 5KR,

10kR and lowest 0.01 (GST-15-204), 0.04 (RGC-1066), 0.06 (RGC-1055) & RGC-1038(0.05) at 50, 25 & 45Kr doses of mutagen.

On the basis of mean values, the highest mutagenic efficiency was recorded 0.0610 in relation to pollen sterility and lowest 0.0249 in relation to lethality. Similar results were also reported by S. Velu et al., (2007) in cluster bean variety Pusa-Navbahar and K. G. Dube et al., (2011) in cluster bean variety Sharada. They proved that lower doses of gamma rays were more efficient than the higher doses. These results were also supported by Manrique et al., (1998) in french bean, M. Khan and Tyagi (2010) in Soybean, S. K. Sharma et al.,(2005) in Urd bean, S. K. Sharma and B. Sharma (1979) in Lentil. They concluded that mutagenic efficiency was higher at lower doses of mutagens. These results are in agreement with the results of present investigation.

### **5.3 ANOVA for compact family block design**

The analysis of variance for quantitative traits is a prerequisite for plant breeding programmers, which can lead to a systemic method of design and to the appropriate planning of plant breeding strategies. Analysis of variance revealed that the difference among 163 mutant lines were highly significant for all the characters except number of primary branch/plant and number of seeds/pod and 100 seed weight in M<sub>2</sub> generation. Similar result was carried out by Sultan *et al.*, (2012) by evaluating 101 guar accessions collected from diverse areas of Pakistan by using 14 quantitative and three qualitative characters They were found High variation in germplasm for all traits except for, branches per plant, seeds per pod, 100 seed weight.. This shows strong variability between the mutant lines for all the characters, large spectrum of genetic variability among the mutant lines along with suitable selection criteria offer better scope for selection of appropriate mutant lines. But the difference among 163 mutant lines due to treatments almost found to be significant for all characters under all doses except 5 kR for 100 seed weight, 20, 25,35 kR for canopy temperature (at vegetative stage), 40 kR for days to 50% flowering, number of seeds/pod, relative water content, 45kR (within progeny) for germination %, days

to maturity, number of pods/plant 50 kR for number of primary branch/plant, relative water content, seed yield/plant, were observed non-significant in M<sub>2</sub> generation

The above discussion clearly demonstrated that lower doses of gamma rays give more useful variability than higher doses. However, work on mutation breeding of guar is limited and only a few mutants carrying one or two useful attributes have been obtained so far. Therefore, there is a need to initiate extensive research work using large number of lower doses of gamma rays to induce really desirable variability in vitro as well as in vivo in order to exploit the same in breeding for developing early maturing, resistant to major diseases, high seed and gum yielding improved cultivars in guar which is a highly drought tolerant and industrially important crop for semi arid and arid regions.

### **5.3.2 Mean performance of mutant lines for 19 characters in M<sub>2</sub> Generation**

The per se performance was recommended by Genter and Alexander (1962). It is one of the useful methods for evaluating the parents. Germplasm with high mean performance for grain yield per plant would result in good performing offspring. The potentiality of a strain or germplasm to be used as a parent in hybridization, or in cross to be used as a commercial hybrid, may be judged by comparing the per se performance of the parents. On the basis of per se performance five mutant lines viz., 46-10-RGC-1038 (91.00) followed by 42-10-RGC-1038 (88.50), 100-25-RGC1038 (86.50), 40-10-RGC-1038 (86.00) and 46-10-RGC-1038 (85.60) recorded for highest germination % in M<sub>2</sub> generation

The mutant lines viz., 11-5-RGC-1066 (47.50) followed by 64-15-RGC-1066 (48.00), 9-5-RGC-1066 (48.50) and 70-15-RGC-1038 (50.00) observed for early flowering than the two best control RGC-1066 (53.50) & RGC-1055 (53.50). Vyas *et al.*, (2003) reported that soil moisture extraction pattern in early flowering genotypes utilized 15.9% less water during vegetative growth compared to late flowering genotypes in moth bean. The early genotypes consumed available soil moisture slowly during the pre-flowering period and utilized the conserved water more efficiently during the reproductive growth for higher seed yield.

At vegetative stage thirty five mutant lines viz., 31-5-GST-15-204 (22.80), 58-10-GST-15-204 (22.80), 78-15-GST-15-204(22.80), 27-5-GST-15-204 (22.90), 147-45-RGC-1066, (23.25), 59-10-GST-15-204 (23.40), 75-15-GST-15-204 (23.50), 79-15-GST-15-204(23.60), 74-15-GST-15-204 (23.80), 77-15-GST-15-204 (23.80), 30-5-GST-15-204 (23.90), 55-10-GST-15-204 (23.90), 57- 10-GST-15-204 (23.90), 80-15-GST-15-204 (23.90), 28-5-GST-15-204 (24.10), 56-10-GST-15-204 (24.10), 54-10-GST-15-204 (24.20), 29-5-GST-15-204 (24.30), 73-15-GST-15-204 (24.40), 76-15-GST-15-204 (24.40), 32-5-GST-15-204 (24.50) 97-25-RGC-1066 (24.95), 93-20-GST-15-204 (25.00), 110-25-GST-15-204 (25.10), 109-25-GST-15-204 (25.30), 96-25-RGC-1066 (25.45), 145-45-RGC-1066 (25.45), 146-45-RGC-1066 (25.45), 148-45-RGC-1066 (25.45), 95-25-RGC-1066 (25.75), 14-5-RGC-1038 (26.10), 159-50-RGC-1066 (26.10), 137-35-GST-15-204 (26.20), 114-30-RGC-1066 (26.25), 90-20-RGC-1055 (26.30) showed significantly lowest canopy temperature from range and best control (26.90). At reproductive stage twenty one mutant lines viz., 31-5-GST-15-204 (30.60), 58-10-GST-15-204 (30.60), 78-15-GST-15-204 (30.60), 27-5-GST-15-204 (30.70), 147-45-RGC-1066 (30.90), 59-10-GST-15-204 (31.20), 75-15-GST-15-204 (31.30), 79-15-GST-15-204 (31.40), 74-15-GST-15-204 (31.60), 77-15-GST-15-204 (31.60), 30-5-GST-15-204 (31.70), 55-10-GST-15-204 (31.70), 57-10-GST-15-204 (31.70), 80-15-GST-15-204 (31.70), 28-5-GST-15-204 (31.90), 56-10-GST-15-204 (31.90), 54-10-GST-15-204 (32.00), 29-5-GST-15-204 (32.10), 73-15-GST-15-204 (32.20), 76-15-GST-15-204 (32.20), 32-5-GST-15-204 (32.30), 93-20-GST-15-204 (32.80) showed lowest canopy temperature from range and controls mean (38.53). These selected mutant lines which show minimum temperature at vegetative and reproductive stage may be used as a heat tolerant lines.

The mutant lines viz., 13- 5-RGC-1066 (2.00) followed by 14- 5-RGC-1066 (2.00), 20- 5-RGC-1066 (2.00), 2513- 5-RGC-1066 (2.00), 39- 10-RGC-1038 (2.00) recorded for maximum number of primary branch/plant than three best control RGC-1066 (1.50), RGC-1038 (1.50) & GST-15-204 (1.50)

The mutant lines viz., 132-35-RGC-1038 (75.50) followed by 133-35-RGC-1038 (77.00), 10-RGC-1055 (77.00) and 50-10-RGC-1055 (77.50) observed for early

maturity over the best control RGC-1055 (81.50). Early maturity is an excellent drought escape mechanism in the drought-prone growing areas.

The mutant lines viz., 11-5-RGC-1066 (108.50), followed by 106-25-RGC-1055 (103.50), 13-5-RGC-1066 (103.50), 80-15-GST-15-204 (101.50), 159-50-RGC-10669(100.50) showed significantly tallest and the mutant lines viz., 49-10-RGC-1055 (31.50) and 25-5-RGC-1055 (34.50) showed significantly dwarf over control mean (55.87)

The mutant lines viz., 11- 5-RGC-1066 (5.90) followed by 37-10-RGC-1066 (5.10), 33-10-RGC-1066 (6.05), and 96-25-RGC-1066 (6.00) showed maximum pod length than best control RGC-1066 (5.05)

The mutant lines viz., 158-45-GSt-15-204 (183.00) followed by 165- 50-GST-15-204 (180.00), 164-50-GST-15-204 (174.51) showed maximum number of pods/plant over best control GST-15-204 (86.50).

The mutant lines viz., 58-10-GST15-204 (6.50) and 107-25-GST-204 (7.50) showed maximum number of pods/cluster over best control RGC-1038 (3.50).

The mutant lines viz., 164-50-GST-15-204 (40.00) showed significantly superior over best control GST-15-204 (18.00)for number cluster/plant.

The mutant lines viz., 146-45-RGC-1066 (34.10) showed highly significant than best control RGC-1066 (16.15) for trait leaf area index

The mutant line viz., 101-25-RGC-1055 (7.04) showed significantly highest yield than best control GST-15-204 (3.55).

The mutant line viz.,70-15-RGC-1038 (3.60) followed by 29-5-GST-15-204 (3.65), 43-10-RGC-1038 (3.67), 73-15-GST-15-204 (3.70), 60-15-RGC-1066 (3.78), 148-45-RGC-1066 (3.85)showed significantly highest yield than best control GST-15-204 (1.62).

Relative water content (RWC) is a measure of plant water status, reflecting the metabolic activity in tissue and used as a most meaningful index for identifying

legumes with contrasting differences in dehydration tolerance (Sinclair and Ludlow, 1986). Under irrigated condition Relative water content nineteen mutant lines viz., 73-15-GST-15-204 (80.16), 88-20-RGC-1038 (80.45), 156-45-GST-15-204 (80.82), 117-30-RGC-1038 (81.00), 121-30-RGC-1038 (81.17), 139-40-RGC-1038 (81.45), 116-30-RGC-1038 (81.64), 8-5-RGC-1066 (81.68), 67-15-RGC-1038 (83.11), 46-10-RGC-1038 (83.25), 84-20-RGC-1038 (83.54), 47-10-RGC-1038 (83.69), 69-15-RGC-1038 (84.00), 72-15-RGC-1038 (84.89), 87-20-RGC-1038 (85.03) 45-10-RGC-1038 (86.20), 44-10-RGC-1038 (86.91), 66-15-RGC-1038 (88.33), 11-5-RGC-1066 (95.53) showed highly significant and only mutant lines viz., 98-25-RGC-1038 (15.24) and 103-25-RGC-1055 (31.32) was less significant.

Under Non- irrigated condition Relative water content seven mutant lines viz., 117-30-RGC-1038 (78.35), 116-30-RGC-1038 (67.34), 70-15-RGC-1038 (60.87), 85-20-RGC-1038 (58.54), 88-20-RGC-1038 (58.49), 71-15-RGC-1038 (52.59), 6815-RGC-1038 (49.40) showed highly significant and six mutant lines 65-15-RGC-1066 (2.11), 147-45-RGC1066 (2.96), 167-50-GST-15-204 (3.64), 166-50-GST-15-204 (3.85), 36-10-RGC-1066 (4.70), 94-20-GST-15-204 (4.76) showed lowest significant.

In the present investigation RWC decreased under non-irrigated condition than under irrigated condition in all mutant lines. With the decrease in soil moisture content, the RWC of leaf decreased in clusterbean (Kuhad and Sheoran, 1986; Garg *et al.*, 2001) Similar results have also been reported by Garg *et al.*, (2001), Durga *et al.*, (2003) and Upreti and Murti (2004).

The mutant lines viz 42-10-RGC-1038 (36.15) and 133-35-RGC-1038 (34.05) showed significantly high gum content than best control RGC-1066 (26.85).

The mutant line viz 161-50-GST-15-204 (199.50) showed highly significant and 5-5-RGC-1066 (12.65), 8-5-RGC-1066 (12.95), 7-5-RGC-1066 (14.85) showed lowest significant for proline content. The mutant line viz., 102-25-RGC-1055 (9.50), 116-30-RGC-1038 (9.50), 163-50-RGC-1055 (9.50) showed significantly maximum

number of seeds/pod than best three control RGC-1066 (7.50), RGC-1038 (7.50), RGC-1055 (7.50).

All the doses (5 kR to 50 kR) were late in flowering compare to control. Doses from 5 kR to 50 kR were significantly lowest for canopy temperature at vegetative and reproductive stage except 45 kR dose. Dose 45, 45 & 20 kR recorded for early maturity than control. Maximum height were found in all dose compare to control but 45 kR dose observed significantly tallest compare to control and all doses. 40kR recorded as significantly shortest. Pod length showed highly significant for dose 5 kR and significantly lowest for 30 kR compare to control. Maximum number of pods/plant was found in 50kR and minimum in 30kR. Maximum number of pods/cluster was found in 15kR and minimum in 30kR. Maximum number of cluster/plant was found in 50kR and minimum in 20kR. 45kR dose recoded as highly significant and 40 kR significantly lowest for leaf area index than control. 5 and 10kR dose showed significantly lowest seed yield/plant and 25, 50, 45, 35, 15, 20, 40, 30 showed highest seed yield/plant compare to control. Compare to control 100 seed weight recorded as maximum in all dose but at 50kR 100 seed weight was recorded as maximum than other dose. 45kR showed significantly highest and 25 significantly lowest than control for relative water content (irrigated condition). Relative water content (non-irrigated condition) was found highest at 20kR and lowest at 45 kR. High gum content was found only at 40kR over the control. Proline content was found lowest at 5 kR and highest at 50kR. Maximum number of seeds/pod was found at 20 and 50 kR.

### **5.3.3 Genetic variability for quantitative, morpho-physiological, biochemical and quality traits**

Success in plant breeding depends upon the amount of genetic variability available for different traits, free pleiotropy and tight linkage in the population. It is a well-established fact that wider is the variability, greater may be the scope for improvement of a trait under selection. In the present study Higher magnitude of PCV was recorded for germination % (101.90) followed by RWC(Non-Irrigated Condition) (88.64), Number of cluster/plant (84.31), Days to 80% Maturity (74.04),

Leaf area index (64.91), Plant height (cm) (52.38), 100 seed weight(gm), (51.43), Number of primary branches/plant, (48.21), Number of pods/cluster (47.73), Gum Content (38.62), Number of seeds/pod (37.30), RWC(Irrigated Condition) (27.95), Proline content (31.43), Number of pods/plant (27.67), Seed yield/Plant (gm) (27.14), However Canopy temp (2) (17.95), Canopy temp (1) (14.32), Days to 50 %Flowering (11.29) exhibited moderate values of PCV, low value was observed for only Pod length (cm) (7.20). Similar result was found by many researcher in clusterbean e.g. Rai *et al.* (2012); Sultan *et al.* (2012) Girish *et al.* (2013).

Higher magnitude of GCV was recorded for RWC(Non-Irrigated Condition) (58.17) followed by, Proline content (51.06), 100 seed weight(gm) (47.28), Germination % (42.14), Number of cluster/plant (34.43), Number of pods/plant (29.26), Leaf area index (26.77), Number of pods/cluster (22.27), Plant height (cm) (21.53), However Gum Content (17.43), RWC(Irrigated Condition) (16.23), Pod length (cm) (14.93), Seed yield/Plant (gm) (14.75), Number of seeds/pod (13.84), Number of primary branches/plant (13.51), exhibited moderate values of GCV, low value was observed for days to 80% Maturity (3.96), Days to 50 %Flowering (6.39), Canopy temp (1) (6.92), Canopy temp (2) (7.40). Similar result was found by Chaudhary *et al.*, (2003); Amrita *et al.* (2003); Hanchinamani (2004); Singh *et al.* (2005) Singh *et al.* (2010).

Higher magnitude of heritability was recorded for proline content (97.27) followed by, RWC (non-irrigated condition) (97.27) germination % (96.85), days to 50 %flowering (94.70), 100 seed weight(gm) (92.35), plant height (cm) (91.94), number of pods/plant (91.73), leaf area index (89.72), gum content (89.40), days to 80% maturity (87.58), number of cluster/plant (83.43), pod length (cm) (83.37), seed yield/plant (gm), (79.80), number of seeds/pod (76.66), canopy temp (2) (73.73), number of pods/cluster (57.00), however, RWC (irrigated condition) (47.02), canopy temp (1) (35.93), exhibited moderate values of heritability, low value was observed for number of primary branches/plant (14.95).

Higher magnitude of genetic advance was recorded for proline content (4403.72) followed by, number of pods/plant (1191.67), germination % (995.73),

plant height (cm) (414.00), RWC (non-irrigated condition) (348.19), RWC(irrigated condition) (228.74), number of cluster/plant (65.78), however, gum content (34.40), leaf area index (34.04), days to 50 %flowering (26.60), days to 80% maturity (23.08), exhibited moderate values of heritability, low value was observed for number of primary branches/plant (0.07), seed yield/plant (gm) (0.62), pod length (cm) (0.94), number of pods/cluster (1.16), 100 seed weight(gm) (1.31), canopy temp (1) (7.76), canopy temp (2) (15.39). Similar results for GCV, PCV, heritability and genetic advance were recorded by Vikas Kumar (2015); Rai *et al.*, (2012); Muthuselvi and Shanthi(2013) in cluster bean genotypes.

### **5.3.4.Character association studies**

#### **5.3.4.1 Correlation coefficients**

Positive correlation is a relationship between two variables in which both variables move in tandem. A positive correlation exists when one variable decreases as the other variable decreases, or one variable increases while the other increases. In the present investigation seed yield/plant was positively correlated with Days to 50% flowering, Canopy temperature (at vegetative stage), number of primary branch/plant, plant height, number of pods/plant, number of pods/cluster, number of cluster/plant, leaf area index, 100 seed weight, proline content and number of seeds/pod. Thus, by increasing characters (viz., Days to 50% flowering, Canopy temperature (at vegetative stage), number of primary branch/plant, plant height, number of pods/plant, number of pods/cluster, number of cluster/plant, leaf area index, 100 seed weight, proline content and number of seeds/pod), seed yield may increase. Positive correlation between proline and seed yield per plant indicates that high proline content is beneficial for maximum seed yield. Arumugarangarajan *et al.*, (2000), Patel and Chaudhary (2001), Singh *et al.*, (2001), Singh *et al.*, (2002), Singh *et al.*, (2004), Singh *et al.*, (2005), Shekhawat *et al.* (2005) and Saini *et.al.*, (2010), om vir (2013) also reported positive and significant associations of number of seeds per pod, number of pods per plant, number of pods per cluster, number of clusters per plant, days to 50% flowering and days to maturity with seed yield per plant. Negative correlation is a relationship

between two variables in which one variable increases as the other decreases, and vice versa. Seed yield/plant was negatively correlated with Germination %, canopy temperature (reproductive stage), days to 80% maturity, pod length, RWC (irrigated condition), RWC (non-irrigated condition), gum content.

Positive correlation between seed yield/plant and canopy temperature (at vegetative) and negative correlation between canopy temperature (At reproductive stage) & seed yield/plant indicates that high temperature at vegetative stage is effect seed yield but high temperature at reproductive stage effects seed yield/plant. Thus, on the basis of above result mutants lines which show low temperature at reproductive stage selected for heat tolerance against heat stress.

Gum content is the important quality character. To identify/screening high gum content we should know which traits are responsible for it. In the present investigation gum content was positively correlated with germination %, Days to 50 % flowering, Canopy temperature (At vegetative stage), RWC (irrigated condition), RWC (Non-irrigated condition), proline content. Except these characters all characters are negatively correlated with gum content similar result was found by Sivia *et al.*, (2016).

## Chapter-VI

### SUMMARY, CONCLUSION AND SUGGETIONS FOR FURTHER WORK

The present investigation entitled “Genetic manipulation through induced mutation for yield & gum content in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.)” was conducted at Experimental field of genetics and plant breeding, College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior (M.P). The experiment was carried out in three seasons from summer-2016 to *kharif* 2017. Sixteen genotypes were screened on the basis of mean performance for the Gwalior region (semi-arid zones).The experimental material used in the present study comprised of sixteen genotypes which were collected from two location, ARS, Durgapura, Jaipur and RVSKVV, Gwalior. The experiment was laid down in a RBD with two replications. For screening each genotype was sown in four rows with spacing 40 cm and row length of 1 m. Four genotypes were chosen for irradiation treatment based on mean performance of various yield attributing traits & canopy temperature. Four selected genotype from the first experiment was used for treatment by different 10 doses (5kR, 10kR 15kR, 20kR, 25kR, 30kR, 35kR, 40kR, 45kR, 50kR) of physical mutagen (gamma rays).The irradiated seeds along with controls were sown to raise  $M_1$  generation.  $M_1$  generation was raised without replication during *Kharif*-2016.The randomly mutant plants were selected from each treatment of all genotype on the basis of dominance mutation. The  $M_1$  generation was harvested on single plant basis. From each treatment, about 10-16 plants were taken to raise the  $M_2$  generation. The third experiment was conducted to evaluate the selected mutant lines for mutagenic effectiveness, mutagenic efficiency, gum content, proline-level to heat stress, yield and yield related traits. The  $M_2$  generation grown during *kharif*-2017 consisted of 163 progenies.The findings of present investigation are summarized as under:

- On the basis of per se performance out of sixteen genotypes four genotypes viz., RGC-1066, RGC-1055, RGC-1038, GST-15-204 were observed for early

flowering, early maturity, maximum number of pods/plant, maximum number of pods/cluster, maximum number of seeds/pod. Genotypes were highly significant for plant height and pod length but were found non-significant for 100 seed weight.

- Four genotypes were chosen for irradiation treatment based on mean performance of various yield attributing traits & canopy temperature. Gamma irradiation was exposed to 4 selected genotype viz., RGC 1066, RGC 1055, RGC 1038 and GST 15-204 to create variability.
- In  $M_1$  generation 5kR dose showed the maximum germination % (87.35%) and 50kR showed minimum germination % (35.35%) as compared to other doses of gamma rays. While the maximum pollen sterility was recorded with 50kR dose viz., GST-15-204 (59.09%), RGC-1055 (43.53%), RGC1066 (40.36%), RGC-1038(41.76%) and minimum pollen sterility was recorded with 5 KR viz., GST-15-204(6.63%), RGC-1055 (7.335%), RGC-1066 (5.89%), RGC-1038 (5.36%). Same as pollen sterility higher mortality was recorded at 50 KR viz., GST-15-304 (77%), RGC-1055 (73%), RGC1066 (74%), RGC-1038 (71%) and lower lethality at 5 KR dose viz., GST-15-304 (15%), RGC-1055 (13%), RGC1066 (13%), RGC-1038 (7%) in all the four genotypes.
- From  $M_1$  generation 163 mutant lines were selected on the basis of desired traits from all doses. Variability, Heritability, genetic advance, and correlation analysis were done in these 163 mutant lines.
- In the segregating  $M_2$  generation, spectrum of chlorophyll mutations indicated the presence of four types of chlorophyll mutants viz., albina, xantha, viridis, chlorina. Viridis and chlorina were observed with 5, 10, 15, 20, 25, 30, 40 & 50 kR treatments but Albino was observed with only 10kR & Xantha was observed in only 15 and 50kR. Chlorina was found in mostly doses. The highest frequency of chlorina mutant was recorded 1.75% in 5 kR and lowest 20 kR treatments.
- In  $M_2$  generation other macro mutations were identified for all the doses of gamma rays. The mutation affecting gross morphological changes in plant

height, leaf shape, pod bearing, apical bearing type were scored as visible mutations.

- The plant type mutants like dwarf in genotype viz., RGC-1066 at 5kR & 10kR, RGC-1055 at 35 kR, RGC-1038 at 15kR, tall in genotype viz., RGC-1066 at 5kR, 20kR, 45kR & 50kR, RGC-1055 at 20kR, 35kR & 45kR, GST-15-204 at 20kR, 45kR & 50kR, spreading type in genotype viz., RGC-1066 at 5kR, RGC-1055 at 15kR, 20kR, 25kR & 45 kR, RGC-1038 at 20kR, GST-15-204 at 50kR, early maturity in genotype viz., RGC-1066 at 5kR, 15kR 25kR & 45kR, RGC-1055 at 5kR, 10kR, 20kR, 25kR, RGC-1038 at 25kR, late maturity in genotype viz., RGC-1066 at 10kR & 20kR, apical bearing type in genotype viz., RGC-1066 at 45kR have been noticed under study.
- The highest value of mutagenic effectiveness (0.15) was recorded in 5KR treatment and lowest (0.01) in 50 kR treatment in genotype GST-15-204, In genotype RGC-1066 highest mutagenic effectiveness value was 0.07 (10kR) & lowest was 0.03 (50kR), in RGC-1055 highest mutagenic effectiveness value was 0.3 (5kR) & lowest was 0.03(25kR), in RGC-1038 highest mutagenic effectiveness value was 0.35(5kR) & lowest was 0.005(45kR). 0.35 was the highest value of efficiency which was found in genotype RGC-1038 at 5kR dose. Thus the lower doses of gamma rays were most effective.
- In the present study, the mutagenic efficiency decreased with the increasing doses of gamma rays with respect to lethality (L). Highest value of mutagenic efficiency was recorded 0.05 (GST-15-204), 0.08 (RGC-1055), 0.15 (RGC-1038) & 0.06 (RGC-1066) at 5KR, 10kR and lowest 0.009 (GST-15-204), 0.02 (RGC-1066), 0.01(RGC-1055) & 0.003 (RGC-1038) at 50, 25 & 45kR doses of mutagen. The observations in respect to efficiency with reference to pollen sterility demonstrated a doses dependent enhancement in majority of the mutagenic treatments in M<sub>2</sub> generation of clusterbean genotype. The value of efficiency decreased as there were increases in doses of Gamma rays treatments. It was ranged from 0.01 to 0.29. Highest value of mutagenic efficiency was recorded 0.14 (GST-15-204), 0.20 (RGC-1055), 0.15 (RGC-1038) & 0.29 (RGC-1066) at 5KR, 10kR and lowest 0.01 (GST-15-204), 0.04

(RGC-1066), 0.06 (RGC-1055) & RGC-1038(0.05) at 50, 25 & 45Kr doses of mutagen.

- On the basis of mean values, the highest mutagenic efficiency was recorded 0.0610 in relation to pollen sterility and lowest 0.0249 in relation to lethality.
- On the basis of mean performance mutant lines viz., 11-5-RGC-1066 (47.50) followed by 64-15-RGC-1066 (48.00), 9-5-RGC-1066 (48.50) and 70-15-RGC-1038 (50.00) observed for early flowering. And mutant line 132-35-RGC-1038 (75.50) was recorded for early maturity.
- The lowest canopy temperature was recorded in mutant lines viz., 31-5-GST-15-204 (22.80), 58-10-GST-15-204 (22.80), 78-15-GST-15-204(22.80), 27-5-GST-15-204 (22.90), 147-45-RGC-1066, (23.25) .
- High gum content & proline content were found in mutant lines 42-10-RGC-1038 (36.15) and 133-35-RGC-1038 (34.05), 161-50-GST-15-204 (199.50)
- All the doses (5 kR to 50 kR) showed significantly late in flowering compare to control. Doses from 5 kR to 50 kR were significantly lowest for canopy temperature at vegetative stage and reproductive stage except 45 kR dose. Dose 45, 45 & 20 kR recorded for early maturity than control. Compare to control more height was found in all dose but 45 kR dose was significantly more tall compare to control and all other doses. 40kR recorded as significantly shortest. Pod length showed highly significant for dose 5 kR and significantly lowest for 30 kR compare to control. Maximum number of pods/plant was found in 50kR and minimum in 30kR. Maximum number of pods/cluster was found in 15kR and minimum in 30kR. Maximum number of cluster/plant was found in 50kR and minimum in 20kR. 45kR dose recoded as highly significant and 40 kR significantly lowest for leaf area index than control. 5 and 10kR dose showed significantly lowest seed yield/plant and 25, 50, 45, 35, 15, 20, 40, 30 showed highest seed yield/plant compare to control. Compare to control 100 seed weight recorded as maximum in all dose but at 50kR 100 seed weight was recorded as maximum than other dose. 45kR showed significantly highest and 25 significantly lowest than control for relative water content (irrigated condition). Relative water content

(non-irrigated condition) was found highest at 20kR and lowest at 45 kR. High gum content was found only at 40kR over the control. Proline content was found lowest at 5 kR and highest at 50kR. Maximum number of seeds/pod was found at 20 and 50 kR.

- A wide range of phenotypic coefficient of variation (PCV) was observed for all characters varied from days to 80% maturity (7.20) to germination% (101.90). Higher magnitude of PCV was recorded for germination % (101.90) followed by RWC(Non-Irrigated Condition) (88.64), Number of cluster/plant (84.31), Days to 80% Maturity (74.04), Leaf area index (64.91), Plant height (cm) (52.38), 100 seed weight(gm), (51.43), Number of primary branches/plant, (48.21), Number of pods/cluster (47.73), Gum Content (38.62), Number of seeds/pod (37.30), RWC(Irrigated Condition) (27.95), Proline content (31.43), Number of pods/plant (27.67), Seed yield/Plant (gm) (27.14).
- Higher magnitude of GCV was recorded for RWC(Non-Irrigated Condition) (58.17) followed by, Proline content (51.06), 100 seed weight(gm) (47.28), Germination % (42.14), Number of cluster/plant (34.43), Number of pods/plant (29.26), Leaf area index (26.77), Number of pods/cluster (22.27), Plant height (cm) (21.53).
- Higher magnitude of heritability was recorded for proline content (97.27) followed by, RWC (non-irrigated condition) (97.27) germination % (96.85), days to 50 %flowering (94.70), 100 seed weight(gm) (92.35), plant height (cm) (91.94), number of pods/plant (91.73), leaf area index (89.72), gum content (89.40), days to 80% maturity (87.58), number of cluster/plant (83.43), pod length (cm) (83.37), seed yield/plant (gm), (79.80), number of seeds/pod (76.66), canopy temp (2) (73.73), number of pods/cluster (57.00).
- Higher magnitude of genetic advance was recorded for proline content (4403.72) followed by, number of pods/plant (1191.67), germination % (995.73), plant height (cm) (414.00), RWC (non-irrigated condition) (348.19), RWC(irrigated condition) (228.74), number of cluster/plant (65.78)

- Maximum number of pods/plant, plant height, pod length, number of pods/plant, number of pods/cluster, number of cluster/plant, seed yield/plant were found in mutant line viz 13- 5-RGC-1066 (2.00), 11-5-RGC-1066 (108.50), 11- 5-RGC-1066 (5.90), 158-45-GSt-15-204 (183.00) , 58-10-GST15-204 (6.50) , 164-50-GST-15-204 (40.00), 101-25-RGC-1055 (7.04) , 42-10-RGC-1038 (36.15)
- Days to 50% flowering was giving positive and significant correlation with number of seeds/pod (0.401) and proline content (0.213) and was negative & significant association with number of primary branch/plant (-0.255).
- Canopy temperature at reproductive stage (1.132), number of seeds/pod (0.510), RWC at irrigated condition (0.375), pod length (0.224) traits were significant and was positively correlated with canopy temperature at vegetative stage.
- Seed yield/plant (gm) was giving positively significant correlation with days to 50% flowering (0.137) and positively significant correlation with 100 seed weight (0.24), number of seeds/pod (0.30) & proline content (0.24) and negatively non-significant correlation with gum content -0.28), RWC irrigated condition (-0.16) and RWC non-irrigated condition (-0.06).
- Gum content was showing positively non-significant correlation with proline content (0.04) and negatively non-significant correlation with number of seeds/pod (-0.12)
- Proline content was positively non-significant with number of seeds/pod (0.11).

## **CONCLUSION**

The present investigation was undertaken to study the response of clusterbean genotypes to the physical mutagen gamma rays. We found several novel conclusions from the study as the germination percentage and Survival of plants at maturity decreased with increasing dose/concentration of gamma rays. Pollen sterility and mortality was recorded lower to high with the increasing doses of physical mutagen in all cluster bean genotypes in M<sub>1</sub> generation. Hence, higher

dose of gamma rays might be very useful in clusterbean for producing male sterility during hybridization program of cluster bean. It was noticed that the percentage of xantha chlorophyll mutant was maximum in majority of the mutagenic treatments followed by chlorina, viridis and albina in that order. it was recorded that the mutation frequency increased with increasing doses of gamma rays only in two genotypes of clusterbean viz., GST-15-204 & RGC-1066 but mutation frequency decreased with increasing doses of gamma rays in two other genotypes viz. RGC-1055 & RGC-1038. The plant type mutants like dwarf in genotype viz., RGC-1066 at 5kR & 10kR, RGC-1055 at 35 kR, RGC-1038 at 15kR, tall in genotype viz., RGC-1066 at 5kR, 20kR, 45kR & 50kR, RGC-1055 at 20kR, 35kR & 45kR, GST-15-204 at 20kR, 45kR & 50kR, spreading type in genotype viz., RGC-1066 at 5kR, RGC-1055 at 15kR, 20kR, 25kR & 45 kR, RGC-1038 at 20kR, GST-15-204 at 50kR, early maturity in genotype viz., RGC-1066 at 5kR, 15kR 25kR & 45kR, RGC-1055 at 5kR, 10kR, 20kR, 25kR, RGC-1038 at 25kR, late maturity in genotype viz., RGC-1066 at 10kR & 20kR, apical bearing type in genotype viz., RGC-1066 at 45kR have been noticed under study. Mutagenic effectiveness and mutagenic efficiency were highest at lower dose of gamma rays in the all clusterbean genotypes. The chlorophyll frequency increased with the increasing dose of gamma rays and it was maximum at higher doses and minimum at lower doses of gamma rays. The increased mutagenic dose causes the decrease in the mutagenic effectiveness at higher doses. The mutagenic efficiency was higher at lower doses due to the increased sterility and lethality with increasing doses of gamma rays. Thus gamma rays are effective and efficient mutagen in cluster bean which may create genetic variability useful in crop improvement. the difference among 163 mutant lines were highly significant for all the characters except number of primary branch/plant and number of seeds/pod and 100 seed weight in M<sub>2</sub> generation. The mutant lines viz., 11-5-RGC-1066 (47.50) followed by 64-15-RGC-1066 (48.00), 9-5-RGC-1066 (48.50) and 70-15-RGC-1038 (50.00) observed for early flowering than the two best control RGC-1066 (53.50) & RGC-1055 (53.50). At vegetative stage and reproductive thirty five mutant lines viz., 31-5-GST-15-204 (22.80), 58-10-GST-15-204 (22.80), 78-15-GST-15-204(22.80), 27-5-GST-15-204 (22.90), 147-45-RGC-1066, (23.25), 59-10-

GST-15-204 (23.40), 75-15-GST-15-204 (23.50), 79-15-GST-15-204(23.60), 74-15-GST-15-204 (23.80), 77-15-GST-15-204 (23.80), 30-5-GST-15-204 (23.90), 55-10-GST-15-204 (23.90), 57- 10-GST-15-204 (23.90), 80-15-GST-15-204 (23.90), 28-5-GST-15-204 (24.10), 56-10-GST-15-204 (24.10), 54-10-GST-15-204 (24.20), 29-5-GST-15-204 (24.30), 73-15-GST-15-204 (24.40), 76-15-GST-15-204 (24.40), 32-5-GST-15-204 (24.50) 97-25-RGC-1066 (24.95), 93-20-GST-15-204 (25.00), 110-25-GST-15-204 (25.10), 109-25-GST-15-204 (25.30), 96-25-RGC-1066 (25.45), 145-45-RGC-1066 (25.45), 146-45-RGC-1066 (25.45), 148-45-RGC-1066 (25.45), 95-25-RGC-1066 (25.75), 14-5-RGC-1038 (26.10), 159-50-RGC-1066 (26.10), 137-35-GST-15-204 (26.20), 114-30-RGC-1066 (26.25), 90-20-RGC-1055 (26.30) showed significantly lowest canopy temperature from range and best control (26.90). This mutant lines may selected for heat tolerance against heat stress. At high proline level mutant line viz. 161-50-GST-15-204 (199.50) selected for heat stress. The mutant lines viz. 42-10-RGC-1038 (36.15) and 133-35-RGC-1038 (34.05) showed significantly high gum content than best control RGC-1066 (26.85). The mutant line viz., 101-25-RGC-1055 (7.04) showed significantly highest yield than best control GST-15-204 (3.55). Higher magnitude of PCV was recorded for germination % (101.90) followed by RWC(Non-Irrigated Condition) (88.64), Number of cluster/plant (84.31), Days to 80% Maturity (74.04), Leaf area index (64.91), Plant height (cm) (52.38), 100 seed weight(gm), (51.43), Number of primary branches/plant, (48.21), Number of pods/cluster (47.73), Gum Content (38.62), Number of seeds/pod (37.30), RWC(Irrigated Condition) (27.95), Proline content (31.43), Number of pods/plant (27.67), Seed yield/Plant (gm) (27.14), However Canopy temp (2) (17.95), Canopy temp (1) (14.32), Days to 50 %Flowering (11.29) exhibited moderate values of PCV, low value was observed for only Pod length (cm) (7.20). Higher magnitude of GCV was recorded for RWC(Non-Irrigated Condition) (58.17) followed by, Proline content (51.06), 100 seed weight(gm) (47.28), Germination % (42.14), Number of cluster/plant (34.43), Number of pods/plant (29.26), Leaf area index (26.77), Number of pods/cluster (22.27), Plant height (cm) (21.53), However Gum Content (17.43), RWC(Irrigated Condition) (16.23), Pod length (cm) (14.93), Seed yield/Plant (gm) (14.75), Number of seeds/pod (13.84),

Number of primary branches/plant (13.51), exhibited moderate values of GCV, low value was observed for days to 80% Maturity (3.96), Days to 50 %Flowering (6.39), Canopy temp (1) (6.92), Canopy temp (2) (7.40). Days to 50% flowering showed positive & significant correlation with number of seeds/pod (0.401) & proline content (0.213). The correlation showed negative & significant association with number of primary branch/plant (-0.255). Canopy temperature (at reproductive stage) (1.132), number of seeds/pod (0.510), RWC (irrigated condition) (0.375), pod length (0.224) traits were significant and positively correlated with canopy temperature (at vegetative stage). Seed yield/plant (gm) showed positively significant correlation with days to 50% flowering (0.137) and positively significant correlation with 100 seed weight (0.24), number of seeds/pod (0.30) & proline content (0.24) and negatively non-significant correlation with gum content (-0.28), RWC (irrigated condition) (-0.16) & RWC (non-irrigated condition) (-0.06). Gum content showed positively non-significant correlation with proline content (0.04) and negatively non-significant correlation with number of seeds/pod (-0.12) Proline content showed positively non-significant with number of seeds/pod (0.11). Therefore, mutant lines which show broad spectrum of variability in segregating generation may be used as a parents for breeding programmes.

#### **SUGGESTIONS FOR FURTHER WORK:**

Based on experimental results best mutant lines selected from M<sub>2</sub> generation might be advanced for further selection and development of new varieties for high yield, high gum content and for heat tolerance.

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