EFFECT OF GAMMA IRRADIATION AND SEED TREATMENT CHEMICALS ON SEED LONGEVITY OF SOYBEAN (*Glycine max)* AND GREEN GRAM (*Vigna radiata* L.)

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF GAMMA IRRADIATION AND SEED TREATMENT CHEMICALS ON SEED LONGEVITY OF SOYBEAN (*Glycine max*) AND GREEN GRAM (*Vigna radiata* L.)**” submitted by **Mr. PREMKUMAR.HUGAR** in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SEED SCIENCE AND TECHNOLOGY** to the University of Agricultural Sciences, Raichur is a record of research work done by him during the period of his study in this University under my guidance and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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AFFECTIONATELY DEDICATED

TO

To my beloved parents
Sri. Hanumanthappa & Smt. Veenashree

Grandfather, Geera Siddanna

Late Dean, Dr. L.B. Hugar

Lovely brother, Praveen kumar Hugar

Bestfriends -Sunil kumar, Mamatha.Madli,
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LIST OF ABBREVIATIONS

Abbreviation		**Expansion**
%	:	Per cent
±	:	Plus or minus
CD	:	Critical Difference
cm	:	Centimeter/s
CRD	:	Complete Randomized Design
et al.	:	And others
Fig.	:	Figure
g	:	Gram/s
i.e.,	:	That is
ISTA	:	International Seed Testing Association
kg	:	Kilogram
l	:	Litre/s
mg	:	Milligram/s
ml	:	Millilitre/s
mm	:	Millimeter/s
NS	:	Non-significant
^oC	:	Degree Celsius
S.Em.	:	Standard Error of the mean
viz.	:	Namely

α	: Alpha
μg	: Microgram
MAS	: Months after storage
OD	: Optical density
&	: And
Gy	: Grey
Kr	: Kilo rad
LD	: Lethal Dosage
HYVs	: High yielding varieties
ha	: Hectare
mha	: Million hectare
mt	: Million tonne
γ	: gamma rays
KeV	: Kilo electron volts
EMS	: Ethylmethane-sulphonate
MMS	: Methylmethane-sulphonate
nm	: Nano meter
t	: Tonne
q	: Quintal
cft	: Cubic foot
lb	: Pound

Introduction

I. INTRODUCTION

Pulses are an integral part of an average Indian meal as they form the main source of protein due to large proportion of Indian population is vegetarian. In India, pulses are being cultivated over an area of 24.9 mha with an annual production of 16.3 mt and productivity of 656 kg per ha (Anon., 2016). However, the per capita availability of pulses in India is 40 gram per person per day as against 140 gram per person per day as advocated by Indian Council of Medical Research (Anon., 2013). Thus, there is a challenge for agricultural scientists, extension workers, planners and farming community to enhance and sustain pulse productivity to meet national pulse requirement. Non-availability of good quality seed of high yielding varieties (HYV) of pulses, lack of knowledge about HYV, poor technical knowledge, untimely availability of inputs (seeds, agro-chemical and fertilizers *etc*.) and climatic effect are some of socioeconomic, environmental and institutional constraints for pulse production in India. Thus, there is a necessity to focus on bridging the yield gaps by area expansion and adoption of appropriate new production as well as safe storage technologies.

Soybean [*Glycine max* (L.) Merill] is one of the most important protein rich oil seed crops used throughout the world as it possess largest component of edible oil (22%) and protein (42-45%). It is an important ingredient of more than 50 per cent of the world’s high protein meal. It was introduced to India during 1880 and globally grown over an area of 91.40 mha with a production of 204.00 mt and the productivity of 2233 kg per ha. In India, soybean is grown on an area of 11.60 mha with a production of 14.22 mt and productivity of 1263 kg per ha which is much below world’s average productivity. In Karnataka, it is being cultivated in 0.29 mha with a production of 0.27 mt and 952 kg per ha productivity (Anon., 2016). In Karnataka, the major soybean growing districts are Dharwad, Belgaum, Bidar, Bagalkot and Haveri.

Green gram (*Vigna radiate* L.) another important pulse crop of south and south-east Asia is the third most widely cultivated pulse after bengal gram and pigeonpea. In India, it is grown in an area of 3.82 mha with a production of 1.59 mt and average productivity of 416 Kg per ha which accounts for 65 per cent of world acreage and 54 per cent world's production. In Karnataka it is widely grown in *kharif* covering an area of 0.34 mha with a production of 0.43 mt and 126 kg per ha productivity (Anon., 2016). More than 90 per cent of the area is concentrated in Northern districts of Karanataka *viz,* Belgaum, Bidar, Dharwad Haveri and Gulbarga.

Pulses are usually attacked in stores by different insect pests. Some of these are carried from the fields into stores (Appert, 1987). A good percentage of infestation occurs due to unhygienic stores. Although insect pests have been a menace to stored pulses, farmers have to store the seeds for planting next season (Muir, 1994). Pulses and legumes are stored by the farmers and governmental agencies for its utilization in the off season. Post harvest damages by insects have been recognized as an increasing important constraint for pulse production (Khaire *et al.,* 1992). Infestation of stock comes either from outside or inside where the seeds are stored. The larva feeds on the endosperm and germ of the grain and finally creates irregular holes with transparent thin outer covering (Appert, 1987). The extent of infestation by various insect pests is variable under different storage structure, conditions and practices. In each stored seeds, pest consumes 5-7 per cent resulting up to 30-50 per cent seed damage (Agrios, 1988 and Caswell, 1981).

Considering the extent of losses and damage of pulse produce, several research strategies are being adopted for management of these stored pests, of which, use of methyl bromide is common. This has led to objectionable residues in treated commodity as the chemical is hazardous to handle besides leading to development of insecticide resistant strains by the storage pests (Bhatia, 1990) and impact on the environment as a significant ozone depleting substance (Ross, 1999). Other methods to protect the seeds from insects and diseases are use of safe insecticides and fungicides as seed treatment chemicals and exposure of seed to fumigants during storage. Another method which is newly adopted to overcome the pests menaces is exposing the seeds to gamma radiation.

Radiation technology such as gamma irradiation is an effective disinfestation treatment for stored food products. Ionizing radiation has been suggested as a useful alternative to methyl bromide, as there is no development of insect resistance, absence of residue in treated food and no significant loss of nutrients in the treated commodities (Lapidot *et al.*, 1991). In view of global trends towards a cleaner agriculture, irradiation strategy is becoming a popular phytosanitary treatment worldwide due to its positive attributes like facilitating trade, effective means for minimizing post harvest losses, fast and easy application, non-use of chemicals and wide application compared to other phytosanitary treatments (Richard and Patrick, 2014). A key reason as to why irradiation has been adopted as a phytosanitary treatment of fresh commodities is that it is generally less damaging to fresh commodities than alternative temperature and fumigation treatments (Hallman, 2011), especially in case of some fruits (*e.g* Rambutan) which tolerate no other commercial phytosanitary treatments.

Irradiation is an ionic, non-heat process that continues to receive attention as a preservation and functional modification agent. It is considered as one of the physical modification methods of natural polysaccharides. In comparison with other physical modification methods, irradiation treatment is rapid, convenient and more extensive because of their easy availability and power of penetration (Delia *et al.*, 2013). However, the morphological, structural and functional changes in crop plants depend on the strength, duration and exposure to gamma rays. Hence, gamma radiation is a technology with immense application in agriculture for seed industry and medicine. In agriculture, it is being utilised in solving various agricultural problems such as reduction of post-harvest losses through suppressing sprouting and contamination, eradication or control of insect pests, reduction of food-borne diseases, extension of shelf life and breeding of high performance well adapted and disease resistant agricultural crop varieties. Gamma rays are known to influence plant growth and development by inducing cytological, genetical, biochemical, physiological and morphogenetic changes in cells and tissues (Gunkel and

Sparrow, 1961). Further, Gamma irradiation of seeds helps to keep seeds away from any pest and storage fungi. It also have some positive physiological effect on seeds particularly at low dosage thus improving its quality and helps to eliminate the time consuming process of treating the seeds manually or mechanically by chemicals (Mashev *et al*., 1995). But, its potential exploitation in agriculture especially with reference to Seed Science and Technology is limited mainly because of lack of information about the optimal dose of irradiation and repeated exposures as they differs from crop to crop. Further, the research findings on the effect of irradiation on seed quality as well as biochemical and physiological changes during seed germination and storability which helps in seed industry to adopt this method as an effective means to control insect pests during storage. One of the irradiation studies of (Khatri *et al.*, 2005) noticed induction of seed coat hardness of some crop seed usually which is considered to lose very rapidly during the storage resulting in seed deterioration Therefore, irradiation study may also through a light on possibility to understand the reason for developing seed coat hardness due to irradiation.

In general, a common practice of treating the seeds with thiram and carboxin before storage are known to be effective against a wide range of seed storage pathogens (Chanhan *et al*., 1984; Subramanya *et al.*, 1988 and FAO, 1999) and thiram could delay the seed deterioration (Shekaramurthy *et al.* 1994). Quantifying the longevity of seeds after these treatments would further elucidate the effects of these chemicals on physiological quality of dressed seeds thereby it is possible to standardise procedures of seed treatment for improving seed longevity with better seed health during storage.

Another common practice adopted to control the seed infestation during storage in all the ware house is fumigation. For this purpose phosphine is successfully used as a fumigant as it is found effective against most of common storage insects. Lindgren *et al.* (1958) reported that phosphine readily penetrate flour and without any apparent effect on seed germination or baking quality and produced satisfactory mortalities of storage insect. Fumigation with hydrogen phosphide can effectively control the storage pests of cereals and small legumes without affecting the germination capacity of the seeds (Strong and

Lindgren, 1961). Further, through fumigation it is possible to maintain satisfactory seed germination with higher seed quality parameters even up to six months of storage (Kambli *et al.*, 2013).

With these background in view, an experiment on “Effect of gamma irradiation and seed treatment chemicals on storability of soybean [*Glycine max* (L.) Merill] and green gram [*Vigna radiata]*” was carried out with the following objectives,

1. To study the Influence of gamma irradiation and seed treatment chemicals on seed longevity of soybean and green gram.
2. To know the influence of mid storage gamma irradiation and fumigation on seed quality of soybean and green gram.

Review of Literature

II. REVIEW OF LITERATURE

In recent years, exposure to gamma rays is a useful technology in solving various agricultural problems like reduction of post-harvest losses by suppressing sprouting and contamination, eradication or control of insect pests, reduction of food-borne diseases, extension of shelf life, breeding of high performance well adapted and disease resistant agricultural crop varieties (Andress *et al*., 1994 and Emovon, 1996). Ionizing radiations are also used to sterilize some agricultural products in order to increase their conservation (storage) time or to reduce pathogen propagation when trading these products within the same country or from one country to another (Melki and Salami, 2008).

Presently gamma radiation has been employed as an excellent tool for sterilization and preservation of food (Maity *et al*., 2008; Hyun-Pa *et al*., 2006 and Bari *et al*., 2003). Gamma rays belong to ionizing radiation and are the most energetic form of electromagnetic radiation. Therefore, they are more penetrating than other types of radiations such as alpha and beta rays (Kovacs and Keresztes, 2002). Considering the practical difficulties in current approaches of bulk seed storage and their associated issues concerning cost involved and environmental pollution, application of gamma irradiation provides a tangible technology for developing safe seed storage protocols on a long term basis. Adoptions of cost effective and environmentally safe seed storage protocols are essential for sustaining production and distribution of quality seed. Hence, the reviews pertaining to gamma irradiation, plant protection chemicals and fumigation on seed storability have been discussed in this chapter. For convenience the chapter is divided into

2.1 Influence of gamma irradiation on seed quality

2.2 Influence of insecticide (malathion) and fungicide (thiram) on seed quality

2.3 Influence of fumigation on seed quality

2.1 Influence of gamma irradiation on seed quality

Linko and Milner (1960) reported a rapid decrease in seed germination of wheat varieties with an increase in gamma irradiation (0.05, 0.1, 0.5, 1.0 and 3.0 mega reps).

Studies on the effects of radiation in plants are broad and complex. Work is being carried out in many areas on a large number of plant species. Radiation has been found to affect the size and weight of plants. In many radiobiological reactions, the effect of a given dose depends on the intensity of radiation or the manner in which the total dose in fractioned (*i.e.*, the time intensity factor). Gamma rays are known to influence plant growth and development by inducing cytological, genetical, biochemical, physiological and morphogenetic changes in cells and tissues (Gunckel and Sparrow, 1961).

Woodstock and Justice (1967) reported radiation-induced changes in respiration of corn, wheat, sorghum and radish seeds during initial stages of germination in relation to subsequent seedling growth. Goud *et al.* (1967) compared six varieties of rice after irradiation of seeds with different doses (20, 30 and 40 Kr) of gamma rays and observed delayed germination with an increase in gamma irradiation dosage in all the varieties except Taichung Native-1. Hell and Silveria (1974) stated that treating seeds of *Phaseolus vulgaris* with high dosage of gamma radiation reduced the seed germination. Khamankar and Singh, (1988) concluded that the initial inhibition of mitosis and cell elongation affects the seedling emergence and growth of *Leucaena leucocephala* due to gamma radiation. The stimulating effects of gamma rays on seed germination of castor may be attributed to activation of RNA synthesis (Kuzin *et al*., 1975) or protein synthesis (Kuzin et al., 1976) during the early stage of germination. Keredy and Abd Alla (1976) concluded that out of nine varieties of rice, IR 22 was the most sensitive to gamma rays with less germination and TKM-6 was more resistant which gave higher germination when irradiated with different doses. Khader Mohiden (1988) noticed decrease in seed germination with an increase in dosage of gamma rays. The degree of susceptibility to gamma rays depends on the variety, radiation dose and number of treatments in soybean when exposed to a single or double dose (2, 4 and 8 Kr) of gamma rays (Mashkina and Nikdaeva, 1979).

Vadher *et al*. (1988) studied the response of Surat 1, GJ 108 and BPM 53 varieties of sorghum exposed to gamma rays at 10, 20, 30 and 40 Kr and found that the variety GJ 108 showed a more marked reduction in germination (31.3%) and seedling growth than the others.

Kataria and Singh (1989) reported that gamma rays were more effective in producing chlorophyll mutations than the chemical mutagens in onion varieties (Pusa Red, Pusa Ratnar and white Warangal) at 10 and 12.5 Kr doses producing more number of mutations. The order of varietal susceptibility to the mutagens was white Warangal >Pusa>Ratnar>Pusa Red.

Bhatnagar *et al*. (1989) treated the seeds of Bragg variety of soybean with EMS (Ethylmethane-sulphonate), MMS (Methylmethane-sulphonate) and gamma rays with or without additional exposure to UV light for 2 hours at 260 nm and observed that the mutant T-214 exceeded the parent in germinability by 15 per cent and was five days earlier in maturity.

As per Krishnaswamy and Seshu (1989) the stimulatory effects of gamma radiation on germination of rice could be attributed to its influence on oxygen uptake, dehydrogenase activity by providing energy to the germinating embryo and overall capacity of enhancing metabolic machinery. While, the inhibitory effect at high doses could be as a result of greater loss of leachates due to enhanced membrane permeability.

Ionizing irradiation kills the insects by producing ions or free radicals (charged molecules that are very reactive). There have been several researches on the sterilization of grains by ionizing radiation. A dose of 500 Gy caused 100 per cent mortality of *Callosobuchus chinensis* (L) in lentil, bengal gram, green gram and mashkalai (Bhuiya *et al*., 1991). Further, studies showed that 200 Gy killed about 99.9 per cent of adult *Sitophilus zea mays* and *Sitophilus oryzae* within 21days in maize and rice (Bhuiya *et al*., 1991). However, most of these studies were focused on seed preservation and storage with less emphasis on the viability of seed after irradiation process.

Lokesha *et al*. (1992) stated that the inhibitory effect on germination at higher dose by γ-rays could be due to several reasons like histological and cytological changes, disruption and disorganization of seed layer and generation of free radicals resulting in metabolic disorders in the germinating seeds (*Bambusa arundinacea*) that is directly proportional to the intensity of exposure to γ-rays.

The radio sensitivity of *Bambusa arundinaceae* was assessed by exposing the seeds to gamma rays from 10 to 150 Kr at an interval of 10 Kr. The results revealed that the gamma rays enhanced the seed germination at 10 Kr compared to control. However, there was a drastic reduction and delayed germination at 20 and 30 Kr. The LD50 for seed germination was 19.3 Kr, 26.30 Kr for shoot length and 22.04 Kr for root length indicating high sensitivity of *B. arundinaceae* (Lokesha *et al*., 1992).

Gamma irradiation induce oxidative stress with overproduction of reactive oxygen species (ROS) such as superoxide radicals, hydroxyl radicals and hydrogen peroxides which react rapidly with almost all structural and functional organic molecules including proteins, lipids and nucleic acids causing disturbances of cellular metabolism. (Salter and Hewitt, 1992)

Antioxidants and peroxidase are involved in the compensatory mechanisms for inhibition of free radicals formed upon UV irradiation of wheat seeds (Rogozhin *et al.,* 2000). Correlation between growth and antioxidant enzyme activity of seedlings after gamma and neutron irradiation of pea seeds has been earlier reported. Depending on the gamma radiation dose (between 15 and 300 Gy) the height of pea seedlings was found shorter while, the peroxidase activities was higher than the un irradiated control (Bagi *et al.,* 1988). Similarly, an increased level of glutathione peroxidase activity (Marchenko *et al.,* 1996) was reported in corn (*Zea mays* L.) after exposure to low doses of gamma irradiation.

Aspergillus flavus and *Aspergillus parasiticus* are the primary fungal species that produce aflatoxins in food and feed commodities (Gowrama and Bullerman, 1995). Various methods of preservation, such as fumigation and heat treatment have been applied to arrest the mould growth in food material, but none of these methods offers a complete control. Nargis (1995) reported higher speed of germination in tomato seeds subjected to low dose (10 kr) of radiation over control.

Among the various dosages, maximum reduction in germination (%) was observed in 100 Kr irradiated seeds and 50 per cent germination (LD50 value for gamma rays) at 50 Kr in sesame variety TMV-3, (Ganesan, 1996 and Govindarasu, 2000). Seedling height (shoot length), root length, number of lateral branches per primary root decreased gradually with an increase in irradiation dosages (Prabhakar, 1985 and Shivaraj *et al.*, 1962) and 50 per cent reduction in seedling height (injury) in 50 Kr irradiated seedling in sesame.

Satpule *et al.* (1996) reported a significant increase in crude protein, fibre, fat and ash contents in gamma rays induced mutants of horse gram. Selvaraju (2001) observed that, the low dose of gamma irradiation (1 kr) improved the seed germination in all the three rice varieties compared to untreated control and the effect was more pronounced in two year old seeds than fresh and one year old seeds. Even shoot length, dry matter production and vigour index showed the stimulatory effect at lower dose gamma irradiation.

Increasing dose of gamma irradiation caused reduction in germination in cowpea (Uma and Salimath, 2001) and chickpea (Toker and Cargirgan, 2004). This reduction is largely attributed to the delayed or inhibition of mitotic process. Similarly, Toker and Cargirgan (2004) reported that chickpea seedlings irradiated with 200 Gy had significantly increased the shoot length, but at 400 Gy an obvious depression in shoot length was observed.

There is an increasing interest in the use of ionizing radiation for killing the fungal flora and reducing the production of mycotoxins in stored seeds. It was reported that the fungal strain, condition of storage, humidity, inoculum size and irradiation dose affect the mould growth and toxin production (Aziz *et al.,* 2005). Aziz and Mahrous (2004) and Aziz *et al.* (2005) reported that the total viable population of the mycotoxic moulds and mycotoxin production decreased significantly with an increasing γ-irradiation doses and no growth occurred at 4.0 to 6.0 kGy. Hanis and Mnukova (1985) reported increase in peroxide in cereals values with an increase in radiation dose.

Muhammad Amjad and Muhammad Akbar (2002) conducted an experiment to study the effect of gamma radiation on onion seed viability, germination potential, seedling growth and morphology. They exposed the seeds to various gamma irradiation doses (10, 20, 40, 80 and 100 kr) and noticed no significant effect on seed viability, except at highest dose (100 kr) which reduced the viability. However, the electrical conductivity of seed leachates exposed to gamma irradiation was higher than that of the un irradiated seeds (control). Seed germination improved at lower doses (10 and 20 k rad) and was unaffected at higher doses. The number of abnormal seedlings increased with increasing irradiation dose. However, the type of abnormalities could not be linked with a particular irradiation dose. Seedling growth was reduced severely with an increase in irradiation dose up to 40 kr. The root was more sensitive to gamma radiation than the shoot.

Cheema and Atta (2003) evaluated the seeds of three basmati rice cultivars *viz*., Basmati 370, Basmati Pak and Super Basmati for varietal differences in radio sensitivity to gamma radiation irradiated at 150, 200, 250, and 300 Gy. The germination decreased after gamma irradiation, but the decrease was neither proportional to the increase in dosage nor a definite pattern was found in all the three rice varieties. The reduction in emergence of seedlings under field conditions occurred with each corresponding increase in dosage of gamma ray. With respect to seedling emergence, 150 and 200 Gy doses did not have drastic effect but the emergence decreased significantly at higher doses. Further, decrease in peak value of germination with an increase in gamma dose was earlier reported by Din *et al*. (2003).

Tokar and Cagirgan (2004) reported induction of shoot length of kabuli chickpea was at 100 Gy irradiation compared to control. Thapa (2004) reported that *Pinus kesiya* seeds exposed to 30 Kr germinated but in *Pinus wallichiana* 30 Kr was lethal for seed germination and it was restricted up to 20 Kr only. With an increasing dosage, the root, hypocotyl and epicotyl elongation decreased in both the species. In *P. kesiya* more than 50 per cent inhibition was induced by 10 Kr but in *P. wallichiana* this exposure induced 100 per cent inhibition of growth in all the cases. In both the species the intensity of inhibition increased with increasing exposures though, the low dosage of exposure in some cases was stimulatory.

Exposure of legumes to gamma radiation (1 KGy) has been recommended for quarantine purpose (Variyar *et al*., 2004). Whereas, exposure to higher doses (up to 5 KGy) results in less cooking time and improvement in texture without production of off flavour (Wilkinson and Gould, 1996). There are reports which indicate that low doses of gamma irradiation could induce antioxidant activities in plant material (Variyar *et al*., 2004). Electric or magnetic treatment are assumed to enhance vigour for fresh and stored seeds by influencing the biochemical processes that involve free radical quenching or stimulating the activity of related proteins. Further, the sensitivity of fungi to ionizing radiation (Aziz *et al.*, 2005) as well as the efficacy of gamma irradiation for decontamination of food commodities has been reported (Aziz and Moussa, 2002) in soybean.

Addai and Safo Kantanka (2006) studied the effect of ^{60}Co gamma irradiation (0, 50, 100, 200, 250 and 300 Gy) on storability of two genotypes of soybean (Gmx 98-6-5-4^{D} and TGX 87^{D} 1303) and reported that 250 Gy reduced both the percentage emergence and seedling height by 50 per cent compared to control and can be used for inducing mutations.

Mahrous (2007) conducted an experiment on chemical properties of *Aspergillus flavus* infected soybean seeds exposed to gamma radiation during storage at 0, 1, 2, 3 and 5KGy. The results revealed that there was no effect of gamma irradiation at different dose on moisture, protein, total lipids and amino acids content of seed even up to 60 days of storage at ambient temperature. It is concluded that gamma irradiation of *A.flavus* infected soybean seeds at 5KGy is sufficient to inhibit fungus growth aflatoxin production over a storage period of 60 days without change in major chemical composition of seeds.

The mean germination time of chickpea increased with an increasing gamma irradiation dose (100-1000 Gy) in both desi and kabuli types. However, the delay was more pronounced in kabuli type than desi type. Similarly the root length deceased with an increase in gamma irradiation dosage compared to non irradiated control in both desi and kabuli types. Maximum decease in root length was observed at 1000 Gy in desi type while, at 600 Gy in kabuli type. The root to shoot ratio increased at 800 Gy in desi while, at 900 Gy in kabuli type. Collective data for protein contents, peroxidise and protein activities suggested that irradiation should be limited to 500 Gy for desi type while, 600 Gy for kabuli type (Hameed *et al*., 2008). They also opined that the biochemical parameters (protein, protease, peroxidise and lipid peroxidation) may be helpful in early assessment of effectiveness and superiority of irradiation dose. Seeds irradiated at low doses (20 Gy) of gamma rays resulted in a significant elongation of root in chick pea (Melki and Salami, 2008).

Maity *et al*. (2009) advocated an effective gamma irradiation (^{60}Co) method for removal and long-time prevention of contaminating fungi in rice without loss of seed viability. The fungal growth and their population on gamma treated seeds decreased significantly with an increase in irradiation dose and storage time. Immediately after irradiation, the depletion of fungal population on rice seed was noticed at 2 KGy, whereas, total inhibition was noticed at 3 KGy after 1.5 months of storage.

Two wheat genotypes (Roshan and T-65-58-8) irradiated with gamma irradiation showed a significant decrease in mean germination time (8.9, 6.4 and 5.2), root length (9.8, 9.5 and 3.7), shoot length (3.5, 3.8 and 2.5) with an increase (0, 100, 200 Gy) in radiation doses (Borzouei *et al*., 2010).

Ritambhara and Kumar (2010) studied the effect of gamma irradiation on somatic cells of *Lathyrus sativus* seeds irradiated with 200, 400, 600 and 800 Gy and noticed a significant reduction in moisture, germination with the corresponding increase in chloroplast anomalies in gamma irradiated stored seeds. Further, they also opined that immediate sowing of irradiated seeds is of prime importance as it may adversely affect the survivability of the seeds as well as seedling when sowing is delayed.

Majeed *et al*. (2010) found that the mean germination time of *Lepidum sativam* was significantly affected and delayed at high doses of gamma rays. The other growth parameters like shoot and root length, number of branches and leaves per plant showed a declining trend with an increase in doses of gamma irradiation.

Abdei-Moneim *et al.* (2011) studied the effect of gamma radiation (0.0, 0.5, 1.0, 2.0, 3.0, 5.0 and 7.5 KGy) on total protein solubility, albumin, globulin and SDS-ME fractions using SDS-polyacrylamide gel electrophoresis in three oil seed crop (soybean, peanut and sesame). The results showed that the solubility of total protein decreased and reached minimum at 7.5 KGy compared to control. The interesting phenomenon is that the albumin and globulin fractions decreased in their solubility while that of SDS-ME fraction increased. This may be due to the effect of gamma radiation on the protein, which may dissociate this fraction to small subunits and rearrange to form a complex protein. These changes in protein profile were depended even on radiation dose and on the nature of crop.

Mousa (2011) investigated an interaction of low dose of gamma irradiation and water stress on growth, biochemical, anatomical and antioxidative parameters in soybean. He reported that, low dose increased the biomass accumulation and finally seed yield by counter balancing the destructive effects of water stress. Hence, pre-treatment with low dose (20 Gy) of gamma rays to dry seeds before planting can be used to enhance the drought tolerance and minimize the yield loss caused by water stress.

Hamid and Abolfazl (2012) recorded higher number of pods (326.3 / m^2) and seed yield (570.8 g / m^2) when pinto bean seeds were exposed to 3Gy compared to 21 Gy (108.3/ m^2 and 204.5 g / m^2, respectively).

Harding *et al.* (2012) reported that gamma irradiation of rice seeds above 300 Gy caused severe physiological damage on seedling height, per cent field survival and tiller production without any effect on seed germination. The optimum dose determined for improving the efficiency in rice varieties based on per cent field survival ranged from 345 Gy for ROK18 to 423 Gy for ROK22 which could be useful in rice varietal improvement programmes.

Amir and Khavar (2012) reported a significant increase in germination index in three amaranthus lines with an increase in gamma doses. While, the germination percentage decreased significantly with an increase in gamma doses. Irrespective of gamma-rays, the highest and lowest germination belonged to K-433 and D-136 lines, respectively. In addition, in all lines, gamma-rays decreased the shoot and root length of amaranthus seedlings. The variation in germination index was mainly attributed to genetic differences of amaranthus lines. Based on the collective data of this study it seems that both inherent differences in amaranth varieties and gamma doses influenced more on amaranth seed germination and their parameters.

Achchhelal Yadav and Bhupinder Singh (2013) conducted an experiment to determine the effect of gamma irradiation (control, 0.0025, 0.005, 0.01, 0.05, 0.1, 0.2, 0.3, 0.4 0.5, 0.75, 1.0 and 2.0 KGy) on seedling length, enzymatic activity and seedling vigour of two maize genotypes (HM-4 and HQPM-1). The results revealed that the seedling height increased at lower dose and reduced beyond the 0.2 KGy in both the genotypes. Similarly, the seedling vigour index reduced beyond 0.2 KGy. The water activity did not show any significant change. However, the germination per cent showed a significant change in HM-4 genotype and it was unaffected for HQPM-1genotype with the gamma irradiation dosages. Enzymatic activity also showed the same trend with corresponding change in plant height and seedling vigour indices.

Delia *et al*. (2013) noticed decrease in the germination potential and physiological parameters of maize seedlings with an increase in irradiation dose. Further, the biochemical differences based on photosynthetic pigment content revealed an inversely proportional relationship to the dosage of exposure (0.1 to 1 KGy).

Anbarasan *et al*. (2013) studied the effect of gamma rays (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 Kr) on seed germination and seedling growth of sesame genotype TMV3. The sensitivity of gamma irradiation was observed with respect to germination rate (%), seedling height (shoot length), root length, number of lateral branches per primary root and seedling vigour (vigour index). The results showed negative effects wherein, with an increase in radiation dosages 50 per cent reduction in germination and seedling size (injury) was observed in 50 Kr gamma irradiated seeds.

Aparna *et al*. (2013) conducted an experiment to study the influence of gamma rays on seed germination and seedling growth of groundnut (*Arachis hypogaea* L.). The results revealed that the germination percentage decreased after irradiation and the effect become stronger with an increase in gamma irradiation dose. Parameters such as germination percentage, speed of germination, mean daily germination, peak value and germination value decreased significantly with an increased irradiation doses. Similarly, the root length, shoot length, vigour index and root to shoot length ratio also expressed higher reduction at higher doses compared to non irradiated seeds.

Richard and Patrick (2014) noticed decrease in viability of maize and cowpea seeds than 40 Gy dose as a result of higher feeding by the insects which may have damaged the seed germ, resulting in poor seed germination and less viability. However, doses above 80 Gy recorded higher seed germination percentage and less viability because of the decrease in feeding by insects and also reported 100 per cent mortality of *Sitophilus zea mays* in maize and *Callosobruchus maculatus* in cowpea when exposed to gamma radiation at 300 Gy and 500 Gy, respectively. However, gamma radiation treatments did not have any effect on seed viability.

Narayan *et al*. (2014) noticed decrease in seed germination of moth bean seeds with an increase in gamma irradiation dosage from 200 to 800 Gy and the regeneration potential of callus derived from primary leaves of treated seeds increased at lower doses of gamma irradiations (200 and 400 Gy).

The seed germination and seedling growth of pigeon pea was inhibited at higher doses/concentrations of mutagens (Ariramana *et al*., 2014). The survival rate was highly reduced with increasing dose/concentration of mutagens. Almost all the mutagenic treatments caused decrease in seedling height, (root and shoot length), seedling injury and seedling vigour index under laboratory conditions.

Monica and Seetharaman (2014) noticed a significant effect of gamma rays and EMS (Ethyl methane sulphonate) on seed germination and seedling growth in *Lablab purpureus* (L.) sweet variety. typicus cv. CO (Gb) 14. The seed germination and seedling growth decreased with an increase in dose / concentration of mutagens. Based on the seed germination percentage, LD_{50} value was 25 Kr gamma rays and 30 mM of EMS.

Ludvik (2014) studied the effect of gamma radiation on seed germination of barley at different doses (0.1 KGy, 0.2 KGy and 0.4 KGy) and reported that the seeds treated with 0.4K Gy had significantly low germination rate. But the seeds treated with 0.1 KGy had same germination capacity as that of control even after fifth year of storage at 4˚C.

The seed germination and seedling growth of pea was inhibited with an increasing dose of mutagens (Dhulgande *et al*., 2015). The survival rate was highly reduced at higher dose/concentration of mutagens. Almost all the mutagenic treatments caused decrease in seedling height, seedling injury and seedling vigour index under laboratory condition. Comparatively the physical mutagen, gamma rays showed more inhibitory effect for all the parameters observed.

Radha and Uma (2015) reported that increase in gamma doses from 0.40 to 0.60 KGy had no effect on the seed germination percentage of irradiated and non irradiated seeds of all varieties of finger millet (*Eleusine coracana* L.) but a significant difference in germination percentage was observed at 0.20, 0.80 and 1.00 kGy. Seedling parameters such as root length, shoot length, vigour index and root/shoot length ratio expressed higher reduction at higher doses compared to non irradiated seeds.

Vasudevan *et al*. (2015) reported that water soaking of bengal gram seeds for 3-4 hours (T_2) and drying to optimum moisture content with 30 minute exposure to UV-irradiation recorded highest seed quality parameters followed by T_4 (T_2+60 minute exposure to UV-irradiation) whereas, T_6 (T_2+120 minute exposure to UV-irradiation) showed lowest values for all these characters compared to control. Irrespective of the genotypes and irradiation treatments, all the quality parameter decreased with advancement in storage period. Hence, storage of chick pea genotypes after exposure to irradiation for shorter period (30 minute) was better.

2.2 Influence of insecticide (malathion) and fungicide (thiram) on seed quality

Out of seventeen chemicals tested, thiram (2 g/ kg) proved as an excellent chemical in preventing seed loss due to rotting in soybean during storage (Anahosur and Bidari 1973). The germination was 85-87 per cent even after six months of storage in thiram treated seeds.

Casela *et al*. (1979) reported that soybean seeds treated with thiram (2 g / kg of seed) improved the seed germination from 50 to 63 per cent. Radhakrishnan *et al.* (1983) reported over 90 per cent pulse bruchid mortality with dust formulations of five per cent malathion and registered higher germination (70.3%) compared to control (68.1%) even after ten months of storage in pigeon pea seeds.

Nedrow and Horman (1980) reported that the soybean seeds treated with thiram (2 g/ kg of seed) and carboxin + thiram (each @ 2 g/ kg) showed a reduction in the infection of *Phomopsis sojae* and *Fusarium spp*. and also improved the seed germination. However, benomyl + thiram (each @ 2.5 g/ kg of seed) was most effective in improving the germination under laboratory conditions.

Singh and Agarwal (1986) reported that, dry seed treatment with thiram prevented *Cercospora kikuchii* and improved the seed germination of soybean seeds. Soybean seeds treated with thiram (2 g/ kg of seed) registered higher germination and field emergence than the untreated seeds (Voroveni *et al.,* 1986).

Ravikumar *et al.* (1987) stated that treatment of soybean seeds with malathion (10 g/ kg of seed) or in combination with thiram (2 g/ kg of seed) prevented insect infestation, increased the germination, root and shoot length, seedling dry weight, vigour index and reduced EC of seed leachate compared to control during eight month of storage.

Saroj and Yadav (1989) reported full protection of green gram seeds with 40 ppm of malathion (10%) against pulse beetle without affecting the seed germination.

Hunje *et al*. (1990) conducted an experiment in cowpea by seed treatment with insecticides (10 g malathion or BHC [HCH] @ 10 g/ kg seed), fungicides (2 g thiram or Dithane M-45 [mancozeb] @ 2 g/ kg of seed) or both insecticides + fungicides in different combinations and stored in cloth bags under ambient conditions and tested at one month intervals for germination and vigour index. They did not notice any decrease in germination of seeds treated with insecticides and/or fungicides during six months of storage. The germination of untreated seeds markedly decreased after three months of storage. The decrease could be attributed to seed infestation with *Callosobruchus chinensis* and fungal infection.

Misra and Dharamvir (1990) reported that discolouration of paddy seeds was caused by *Fusarium equiseti, F. solani, F.moniliforme, Pyricularia oryzae, Epicoccum purpurascens, Sarcocladium oryzae, Alternaria alteranta, A. padwickii* and *Sclerotium oryzae* which were deleterious to seed germination at high inoculum pressure. Seed treatment with 0.3 per cent thiram was found effective as protectant against seed discoluring fungi.

Ravindranath *et al*. (1990) reported that cow pea seeds treated with malathion (5%) dust and thiram (2 g/ kg of seeds) maintained higher germination compared to control up to six months of storage. Whereas, a sudden decrease in germination and seedling dry weight was seen in untreated seeds three months after storage due to infestation.

Lakshminarasimhaiah (1993) in pigeon pea observed no bruchid infestation in the seeds treated with malathion (5 g/ kg of seed) even up to six months of storage without impairing seed germination and vigour. Treating sorghum seeds with malathion at 3.0 g per kg of seed was able to control *Rhizopertha dominica* effectively and also maintained high seed germination and vigour throughout the storage period of 18 months (Savitri *et al*., 1994).

Groundnut seeds treated with thiram (3 g/ kg of seeds) recorded significantly higher germination (85.0%) over control (23.4%) even after 24 months of storage (Ranga Rao *et al*., 1996). Soybean seeds treated with thiram (2 g/ kg of seed) completely protected the seeds from storage fungi (*Aspergillus flavous*, *Aspergillus niger, Rhizopus* spp. and *Penecillium* spp.) compared to control (Vamadevappa, 1998).

Muthuraj *et al*. (2002) noticed that soybean seeds treated with thiram (2 g/ kg of seed) improved the seed germination (80.75%) and field emergence (70.52%) compared to untreated control (79.10 and 58.63%, respectively). Green gram seeds treated with malathion (10 g/ kg of seed) recorded higher germination (80.76%), germinate rate index (17.09), root length (9.75 cm), shoot length (7.00 cm) and vigour index (1332) as against control at end of 10 months of storage (Biradar, 2001).

Pramanik and Sardar (2006) carried out an experiment in the laboratory to assess the effectiveness of Nogos, Malathion, Sevin and Limper on lentil, gram, grasspea, green gram and black gram seeds with eggs of pulse beetle, *Callosobruchus chinensis* L. The insecticides were sprayed on the seeds along with eggs and found that all the tested insecticides inhibited hatching of eggs resulting in significantly lowest rate of adult emergence. Nogos and malathion recorded the lower number of emerged adults. Overall

26 to 100 per cent reduction of seed damage and 40-100 per cent weight loss were achieved without affecting the seed germination in insecticides treated seeds in five different types of pulses showing highest reduction in seed damage and weight losses due to Nogos and Malathion.

Vijay kumar *et al*. (2007) reported that cotton seeds coated with thiram (1.50 g/ kg of seed) and imidachloprid (7.50 g/ kg of seed) recorded significantly higher germination (77.00%) followed by seed coating with polymer (5.00 g / kg of seed) and thiram (1.50 g / kg of seed) compared to control (52.00%).

Chilli seeds coated with polymer (7.0 g/ kg of seed) and thiram (2.0 g / kg of seed) recorded significantly higher germination (69.44%) and field emergence (66.14%) compared to control (71.08%) and (38.15%) respectively, at the end of 12 months of storage (Manjunatha *et al*., 2008).

Pathania and Thakur (2012) studied the effect of insecticides, *viz.*, cypermethrin, deltamethrin, dichlorvos, fenvalerate and malathion for their efficacy against *Callosobruchus chinensis* on stored black gram. They reported that malathion (0.5%), deltamethrin (0.1%) and cypermethrin (0.0025%) were found most effective resulting in 100 per cent adult mortality seven days after exposure. Malathion (0.5%) also proved to be best in minimizing the oviposition (1.33 eggs/ 100 grains), seed damage (1.07%) and weight loss (0.28%).

Seed treatment of pigeon pea Cv. BRG-1 with thiram (3 g/ kg of seed) + spinosad (0.04 ml/ kg of seed) stored in super bag recorded significantly higher germination (83.50%), seedling length (30.43 cm), seedling dry weight (28.90 mg), seedling vigour index-I (2555) and II (2427) with low seed moisture (8.45%) at the end of sixth months of storage compared to control (Shivagouda *et al*., 2014).

*Tesema et al. (2015) reported that among all the treatments imposed (*cow dung ash, leaf powder of neem, leaf powder of basil and malathion*) for control of Callosobruchus chinensis* in chick pea which cause a significant yield loss both quantitatively and qualitatively, malathion (3 g/ kg of seed) dust was observed to be the most effective of all treatments.

2.3 Influence of fumigation on seed quality

Walton *et al*. (1958) reported complete mortality of *Tribolium confusum* when wheat seeds were fumigated with methyle bromide (5 ml/ q) at 70 ^{o}F with 24 hours exposure period. Strong and Lindgren (1961) reported that fumigation of corn seeds with methyl bromide and hydrocyanic acid with 9-15 per cent moisture content for 2-72 hours exposure period showed retarded emergence of seedlings.

Cogburn and Tilton (1963) reported that aluminium phosphide tablets (between 73 and 121/ 1000 cubic feet) was sufficient to kill cent per cent immature rice weevils in rough rice at 11 to 14^{o}C temperature. Germination of rice seed was not affected by fumigation with any dosage or combination of dosage of phosphine.

Gopp and Zaake (1963) reported no effect on germination of barley seeds when fumigated for 24 hours with 1: 9 mixtures of ethylene oxide and carbon dioxide at 50 kg per 100 tonne of seeds. Cereal seeds fumigated with ethylene dibromide (EDB) maintained satisfactory germination even up to six years (Blackith and Lubatti, 1965).

Joubert and Du Toit (1965) fumigated the seeds of maize, wheat, sorghum, groundnut and cowpea for 24 hours with ethylene oxide and carbon dioxide in 1:10 proportion at dosage of 2 lb per 226 cft. They noticed that a dosage of two lb killed all the storage insects while one lb of the same gas killed only the adults. The seed germination was slightly affected while field emergence was significantly reduced in treated seeds except in sorghum.

Rout and Mohanty (1967) reported that, fumigation of paddy seeds with aluminium phosphide with 4.98 (1/2 tablet), 2.49 (1/4 tablet), 1.24 (1/8 tablet) and 0.62 (1/16 tablet) mg per litre at 32 to 84 ^{0}C temperature did not affect the seed germination.

Polchaninova (1969) reported that fumigation with chloropicrin and methyl bromide at 20 g per m^{3} for 24 hours killed all insect pests in wheat and barley without affecting the germination rate and energy. The germination rate and energy decreased when wheat and barley seeds were fumigated at 30 and 40 g per m^3 with two fumigants for 72 hours of exposure period.

Minett *et al.* (1976) reported that fumigation of wheat seeds caused a significant reduction in germination and vigour. Orth *et al.* (1977) fumigated seeds of wheat with methyl bromide (4.2 mg / litre) for 48 hours and noticed no significant reduction in seed germination (94.2%) compared to control (95.2%).

Shadi *et al.* (1978) fumigated wheat seeds with 16 to 64 g methyl bromide or 9 to 36 g phastoxin per cubic metre and noticed reduction in germination due to phosphorylation activity leading to blocking of glycolysis with repeated fumigations.

Yadav *et al.* (1980) reported that wheat cultivars exhibited different levels of tolerance to methyle bromide. The seed germination reduced in cultivar HD 1593 due to fumigation. Further, they observed higher abnormal seedlings in certain cultivars indicating the adverse effect of fumigation.

Ashok *et al.* (1981) reported that aluminium phosphide (6 g/ cubic metre) for seven days exposure was effective against wheat stored grain insects. Kirsur (1985) fumigated maize seeds with ethylene dibromide (EDB) and reported a significant beneficial effect on germination and field emergence immediately as well as one month after fumigation. Agarwal *et al.* (1987) noticed no adverse effect on maize seeds germination when seeds were exposed for 30 days to EDB at seven ml per quintal.

Ramazan and Chahal (1989) repeatedly fumigated wheat seeds with 10, 12 and 15 per cent moisture content for one to five times with aluminium phopsphide (ALP) at 1.2 g per tonne. They noticed reduction in germination when fumigation was repeated five times. At higher moisture content of seeds decrease in germination was even more when more than three fumigations were given.

Krishnaswamy and Seshu (1990) reported that the normal recommended dose of 3 g per m^3 of phosphine, fumigation did not affect the seed germination or vigour of rice, but at 6 g per m^3, vigour decreased and the effect became more at 90 days of storage.

Fumigation of green gram with phosphine at a dosage of 0.125, 0.250, 0.500 mg per litre recorded 85.0, 95.1 and 96.8 per cent bruchid mortality with 80.00, 81.00 and 79.00 per cent germination, respectively (Gupta and Kashyap, 1995). Further, they reported that fumigation of green gram seeds with phosphine for one day exposure recorded higher germination (84.0%), shoot length (15.8 cm), root length (9.9 cm) and seedling vigour index (216) and it was lowest (78%, 10.8 cm, 7.0 cm and 1610, respectively) in 45 days exposure period and also they reported that fumigation of green gram seeds with phosphine (0.125 mg / litre) once recorded higher germination (80%), shoot length (13.2 cm), root length (8.2 cm) and seedling vigour index (173) compared to three time fumigation (79%, 12.5 cm, 7.7 cm and 16.1, respectively).

Panigrahi and Sahoo (1996) stated that among the treatments of pulsaf (5.0 g / q), aluminium phosphide (0.6 g / q) and ethylene dibromide (3.0 ml/q), aluminium phosphide was found to be highly effective by maintaining germination above minimum seed certification standards (>80%) in rice with high vigour besides controlling the insect infestation.

The level of seed germination (95.7%) was quite high at the time of first fumigation with phosphine (3 g/ m^3) and repeated fumigation with phosphine up to four times carried out at monthly intervals for a period of seven days had no adverse effect on the germination (94.0%) and seedling vigour index (1455.9) of wheat seed (Singh *et al*., 1999).

Gupta *et al*. (2000) observed that wheat (cv. Raj 3077) seeds with 9.7 per cent moisture content fumigated with 3, 6 and 9 g phosphine per m^3 five times at one month intervals and stored at ambient conditions for 4 months. They reported that fumigation significantly protected the seeds from *Rhyzopertha dominica* infestation. Repeated fumigation, even at higher dose, had no adverse effect on seed germination and vigour.

While, *R. dominica* infestation in non-fumigated seeds increased from 0 to 7.33 per cent after 4 months of storage. Phosphine fumigation had no significant effect on seed microflora during storage.

Singh *et al*. (2002) reported that seeds of green gram and chick pea fumigated at 12 per cent moisture with phosphine at ambient temperature lost their germination completely within 24 months. While, in unfumigated green gram seeds it was 80 per cent and in chickpea, it was 97 per cent even after 24 months of storage. Further, they reported that at nine per cent seed moisture the unfumigated seeds did not show a significant decline in germination percentage up to 42 months of storage at ambient temperature. Whereas, phosphine fumigated seeds showed a decline in germination after 21 months and were dead by 39 months.

Rathod *et al.* (2002) reported that wheat seeds fumigation with EDB (entylene di-bromide) at higher level (6 ml/ q) was found to reduce all the seed quality parameters drastically compared to 2 ml and 4 ml per quintal seed.

Wheat seeds fumigated with aluminum phosphide tablets (1.5 g/ m^3) for 17 days completely controlled *Rhyzopertha dominica* and other storage pests (Ridley *et al.*, 2011).

Francisco *et al.* (2012) evaluated germination and vigour of two cultivars (Embrapa 48 and CD 202) of soybean by exposing the seeds to different dosages of phoshine gas (0.0,1.0; 2.0 and 3.0 $g.m^{-3}$) and concluded that there was no significant effect on the observed parameters compared to control.

The experiment carried out to study the influence of fumigants and number of fumigation on seed quality parameters of groundnut during storage revealed that, groundnut seeds fumigated with ethylene di-bromide at 30 and 90 days after harvest retained satisfactory (70%) germination and higher values for all seed quality parameters up to six months of storage. Whereas as the seeds fumigated with aluminium phosphide four times recorded the lowest groundnut beetle population at the end of ten months of storage (Kamble *et al*., 2013).

Attia *et al.* (2015) showed that the best results of storage efficacy [number of insects (1.25, 1.16 and 2.00), insect infestation (0.91, 1.33 and 2.33%) and seed weight loss (12.51, 14.67 and 20.35%)] of paddy were obtained by treating with phosphine at the rate of 6 balls per tonne, followed 4 balls per tonne and 2 balls per tonne of seed.

Salama *et al.* (2016) exposed wheat seeds to 0, 3, 5, 7 tablets per m^3 of aluminium phosphide and observed lowest insect infestation (4.21, 4.19, 4.14 and 3.91%) and weight loss (12.82, 12.57, 12.62 and 12.21%) by fumigating with 7 tablets of 3 gram per m^3. While, maximum germination (85.7, 87.2, 89.0 and 88.2%) and seedling length (20.73, 20.84, 21.31 and 21.15 cm) was obtained by fumigation with phosphine at the rate of 5 tablet of 3 g per m^3.

Material and Methods

III. MATERIAL AND METHODS

The laboratory experiments related to "Effect of gamma irradiation and seed treatment chemicals on seed longevity of soybean [*Glycine max* (L.) Merill] and green gram (*Vigna radiata*)" were conducted in the Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Raichur during 2015-16 to assess the storage potential of soybean and green gram through gamma irradiation and seed treatment chemicals and also to study the effect of mid storage gamma irradiation and fumigation on seeds of these pulses. The details of the materials used and methods followed during the course of investigation are described in this chapter.

3.1 General description

3.1.1 Experimental site

The research studies were carried out in the laboratory of Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Raichur.

3.1.2 Location

Geographically, the station is situated in the North-Eastern dry zone (Zone- 2) of Karnataka state at 16° 15' North latitude and 77° 20' East longitude with an altitude of 389 meters above mean sea level.

3.1.3 Weather data during storage period

The meteorological data for the year 2015 to 2016 recorded at the meteorological observatory of Main Agricultural Research Station, Raichur are presented in Annexure-I.

3.1.4 Seed source

The freshly harvested seeds of soybean (DSB-21) and green gram (BGS-9) were procured from Agriculture Research Station, Bidar, UAS, Raichur, Karnataka for conducting the experiment.

3.2 Experiment 1: Influence of gamma irradiation and seed treatment chemicals on seed longevity of soybean and green gram

3.2.1 Treatment details

The experiment consisted of 18 treatments laid out in CRD (completely randomised design) with two factors in four replications with crops as main factor and nine gamma irradiation and seed treatment chemicals as sub treatment as mentioned below.

Factor 1: Crop (C)

C_1: Soybean

C_2: Green gram

Factor 2: Treatments (T)

T_1: Control
T_2: Gamma irradiation @ 200 Gy
T_3: Gamma irradiation @ 400 Gy
T_4: Gamma irradiation @ 600 Gy
T_5: Gamma irradiation @ 800 Gy
T_6: Gamma irradiation @ 1000 Gy
T_7: Malathion @ 2 g per kg of seed
T_8: Thiram @ 2 g per kg of seed
T_9: Malathion @ 2 g per kg of seed + Thiram @ 2 g per kg of seed

3.2.2 Design and layout

The experiment was laid out in completely randomized block design with four replications.

3.2.3 Imposition of treatments

3.2.3.1 Procedure for imposition of gamma irradiation

3.2.3.1.1 Gamma irradiation instruments and its source

For the present study, the gamma chamber-5000 was used for irradiating the seeds which is available at Agricultural Research Station, Aland road Kalaburgi, UAS, Raichur.

3.2.3.1.2 Features of Gamma chamber - 5000

- **Safe and self shield:** The shielding provided is adequate to limit the radiation field on the external surface of the unit, well within the permissible levels. No additional shielding is required for its installation and use.

- **Automatic control of irradiation time:** Built in timer provides accurate control of irradiation time from six seconds onwards. The unit can also be operated manually. Solid state programmable controls have been provided. In the event of power failure battery backup displays the programme.

- **Manual control of irradiation temperature:** It is possible to irradiate samples at low or high temperature by circulating liquid nitrogen or hot air. This can be introduced through the service sleeves provided in the vertical drawer. The irradiation temperature is sensed by a thermocouple and displayed on the panel.

- **Remote operation:** An additional table top control panel is provided for remote operation in addition to the normal one provided on the unit.

- **Dose uniformity:** Stationary source pencils, symmetrically placed in a cylindrical cage ensure good and uniformity of radiation field in the sample chamber. In addition a mechanism is also provided for rotating or stirring samples during irradiation.

- **Easy loading and unloading of samples:** Sample chamber extends to a convenient height for easy loading and unloading of samples.

- **Safety assurance:** The design of gamma chamber conforms to American National Standards, ANSI-N433.1-1977 for safe design and use of self contained dry source storage gamma irradiations. It also meets the requirements of type B (U) package for safety in transport of radioactive materials as per AERB code No.SC/TR-1, 1986 of Atomic Energy Regulatory Board of India.

3.2.3.1.3 Specifications of gamma chamber – 5000

Sl. No.	Specification	Details
1	Maximum Co-60 source capacity	518 TBq (14000Ci)
2	Dose rate of maximum capacity	9 KGy/hr
3	Dose rate uniformity	At the centre of sample chamber
4	Irradiation volume	5000cc approximately
5	Size of sample chamber	17.2 cm (diameter) x 20.5 cm (height)
6	Shielding material	Lead and stainless steel
7	Weight of the unit	5600 kg approximately

8	Size of unit	125 cm (length) x 106.5 cm (width) x150 cm (height)
9	Timer range	6 seconds on wards

3.2.3.1.4 Description and working principle of irradiation unit- Gamma chamber 5000

Gamma chamber – 5000 is compact self shielded cobalt-60 gamma irradiation chamber providing an irradiation volume of approximately 5000 cc. The seed material for irradiation can be placed in a sample chamber located in vertical drawer inside the lead flask and as per the treatment doses. This drawer can be moved up and down with the help of a system motorised drive which enables precise positioning of the sample chamber at the centre of radiation field. Radiation field is provided by a set of stationary cobalt-60 sources placed in a cylindrical cage. The sources are doubly encapsulated in corrosion resistant stainless steel pencils and are tested in accordance with international standards. Two access holes of eight mm diameter are provided in the vertical drawer for introduction of services sleeves for gases, thermocouple, *etc*. A mechanism for rotating or stirring samples during irradiation is also provided. The lead shield provided around the source is adequate to keep the external radiation field well within the permissible limits. Time taken by imposition of irradiation to sample varies as per the dosage set. After imposition of irradiation vertical drawer comes up from which samples can be taken out.

3.2.3.1.5 Procedure for imposition of gamma irradiation

For imposition of gamma irradiation treatments, 3 kg seed was used for each treatment. Since, the sample chamber capacity was only up to 1.5 kg, the seed was divided into two parts and exposed twice. Once after filling the seeds in the container the lid was closed. Then the required gamma irradiation was set as per the treatments. Later the sample chamber moves inside cobalt-60 radiation isotope which emits gamma irradiation (Plate 1). The duration taken for gamma irradiation was automatically adjusted as per the dose set. That is lower dosage requires less time compared to higher dosage

Plate 1. Procedure of gamma irradiation

1. **Seeds taken in the hopper for irradiation**
2. **Inserting of hopper in the vertical drawer of the gamma chamber and the lid is closed**
3. **Later the sample chamber (vertical drawer) moves inside cobalt-60 radiation isotope for gamma irradiation**
4. **Control panel for setting gamma irradiavtion dosage**

3.2.3.2 Procedure for seed treatment

For imposition of treatments 7, 8 and 9 for factor 2, the seeds were placed in a plastic tray and the required quantity of thiram, malathion and their combinations were dusted after sprinkling a little quantity water to the seeds and mixed thoroughly in order to have uniform seed coating.

3.2.4 Seed storage

The seeds after imposition of treatments were stored in cloth bag for nine months at room temperature.

3.2.5 Observations recorded

The below mentioned physiological (monthly) and biochemical (bimonthly) parameters were recorded.

3.2.5.1 Physiological parameters

3.2.5.1.1 Germination (%)

The germination test was conducted in four replicates of 100 seeds each byfollowing between paper method and the rolled towels were incubated in the walk in seed

germination chamber maintained at 25 ± 2 °C temperature and 90 ± 5 per cent RH. The number of normal seedlings in each replication were counted on 8th day for both soybean and green gram and the mean germination was calculated and expressed in percentage (ISTA, 2013).

3.2.5.1.2 Abnormal seedling (%)

After completion of incubation period for the germination test, on the day of final count the numbers of abnormal seedlings in each replication were counted and the mean abnormal seedlings were expressed in percentage (ISTA, 2013).

3.2.5.1.3 Dead seed (%)

After completion of incubation period for the germination test, on the day of final count the numbers of dead seeds in each replication were counted and the mean dead seeds were expressed in percentage (ISTA, 2013).

3.2.5.1.4 Mean germination time (MGT)

For working out mean germination time, the procedure used for germination test was followed. However, the number of seeds that germinated were recorded on daily basis up to the day of final count for the respective crops. The mean germination time was calculated by following the formula as suggested by Azimi *et al*. (2013).

$$\text{Mean germinaton time} = \frac{(n1 \times d1) + (n2 \times d2) + ...}{\text{Total number of seeds germinated}}$$

Where,

n: number of seeds germinated on each day

d: number of days

3.2.5.1.5 Germination rate index (GRI)

For working out germination rate index, the procedure used for germination test was followed. However, the number of seeds that germinated were recorded on daily basis up to the day of final count for the respective crops. The germination rate index was worked out as suggested by Mudaris (1998).

$$\text{Germination rate index} = \frac{G_1}{1} + \frac{G_2}{2} + ... + \frac{G_n}{n}$$

Where,

G_1: germination percentage × 100 on 1st day

G_n: germination percentage × 100 on the nth day

3.2.5.1.6 Peak value of germination (PV)

For working out peak value of germination, the procedure that was used for germination test was followed. However, the number of seeds that germinated were recorded on daily basis up to the day of final count for the respective crops. The peak value is the cumulative germination percentage for each unit on its peak day divided by the number of days to reach that percentage (Gairola *et al*., 2011).

$$\text{Peak value of germination} = \frac{\text{maximum number of seeds germinated}}{\text{Number of days}}$$

3.2.5.1.7 Shoot length (cm)

From the germination test, ten normal seedlings were randomly selected from each replication treatment wise on 8th day and the shoot length was measured from the tip of shoot to the hypocotyl region and the mean length was calculated and expressed in centimetres.

3.2.5.1.8 Root length (cm)

From the germination test, the same ten normal seedlings which were randomly selected for measuring the shoot length were also used for measuring the root length. The root length was measured from tip of root to the hypocotyl region and the mean length was calculated and expressed in centimetres.

3.2.5.1.9 Seedling dry weight (g)

Ten normal seedlings which were used for measuring shoot and root length were placed in butter paper and dried in a hot-air oven maintained at 70 ^{o}C temperature for 24 hours. Then, the seedlings were removed from hot air oven and allowed to cool in a desiccator for 20 minutes before weighing in an electronic balance. The average weight was calculated and expressed in gram.

3.2.5.1.10 Seedling vigour index (SVI)

The seedling vigour index was worked out by multiplying the per cent germination and total seedling length (Abdul-Baki and Anderson, 1973).

Seedling Vigour Index = Germination (%) × Total seedling length (cm)

3.2.5.1.11 Seed infection (%)

The infection was detected on monthly interval using blotter test (ISTA, 2013). Twenty five seeds were placed equidistantly on two layered moistened blotter in a sterilized petri plate with 80 per cent alcohol. Each treatment was replicated four times and incubated at 20 ^{o}C for seven days with alternate cycle of 12 hour near UV range and 12 hour in dark. On eighth day, the plates were examined under stereo binocular microscope for the presence of seed fungi. The number of seeds infected with seed borne fungi were counted and expressed in percentage by using the below mention formula.

$$\text{Seed infection (\%)} = \frac{\text{Number of seeds infected by seed borne fungi}}{\text{Total number of seeds sown in the petri plate}} \times 100$$

3.2.5.1.12 Insect egg (%)

For working out the insect egg (%), seeds were taken in 50 ml beaker in four replicates from each treatment on monthly intervals. From this sample the seeds with either single or multiple insect eggs were considered as infested seeds and expressed in percentage (Tamiru *et al.,* 2016).

$$\text{Insect egg (\%)} = \frac{\text{Number of seeds with at least one egg on its surface}}{\text{Total number of seeds in 50 ml beaker}} \times 100$$

3.2.5.1.13 Seed damage (%)

For working out the seed damage (%), seeds were taken in 50 ml beaker in four replicate from each treatment on monthly intervals. From this sample the seeds with either single or multiple pin hole damages were considered as infested seeds and expressed in percentage (Tamiru *et al.,* 2016).

$$\text{Seed damage (\%)} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds in 50 ml beaker}} \times 100$$

3.2.5.1.14. Per cent weight loss of seeds (%)

For working out the per cent weight loss, 100 gram seed were weighed and stored separately in plastic bags and nine months later the seeds were again weighed in order to check the weight loss. The per cent seed weight loss was computed by using the formula as suggested by (Harris and Lindblad, 1978).

$$\text{Per cent weight loss} = \frac{\text{Original weight} - \text{Final weight}}{\text{Original weight}} \times 100$$

3.2.5.2 Biochemical parameters

3.2.5.2.1 Dehydrogenase enzyme activity (OD value)

Twenty five representative seeds from each treatment in two replications were preconditioned overnight by soaking in water at room temperature. The embryos were exercised from the seeds and were steeped in 0.25 per cent solution of 2, 3, 5-triphenyl tetrazolium chloride and kept in dark for two hours at 40 ^{o}C for staining. The stained seeds were thoroughly washed with water and then soaked in ten ml of 2 methoxy ethanol (methyl cellosolve) and kept overnight for extracting the red colour formazan. The intensity of red colour was measured using ELICO UV-VIS spectrophotometer (model

SC-159) using blue filter at 470 nm wave length and methyl cellosolve was used as a blank. The OD value obtained was reported as dehydrogenase activity (Kittock and Law, 1968).

3.2.5.2.2 Alpha amylase activity (mm)

In order to analyse the α-amylase activity the method that was suggested by Simpson and Naylor (1962) was followed. Two gram of agar shreds and one gram of potato starch were mixed together in water to form paste and the volume was made up to 100 ml with distilled water. The homogenous solution of agar-starch mixture after boiling was poured into sterilized petri-dishes and allowed to settle in the form of gel after cooling. The pre-soaked (for 8 hour) and half cut seeds (with their half endosperm and embryo portion intact) were placed in the petri-dishes in such a way that the endospermic part remained in contact with agar-starch gel. The petri-dishes were closed and kept in dark at 30 ^{o}C. After 48 hour, the petri-dishes were uniformly smeared with potassium iodide solution (0.44 g of iodine crystal + 20.008 g potassium iodide in 500 ml distilled water) and the excess solution was drained off after few minutes. The diameter of halo (clear) zone formed around the seed was measured in mm and reported as α – amylase activity.

3.2.5.2.3 Electrical conductivity (dSm^{-1})

For this, five grams of seeds in two replications were soaked in acetone for half a minute and thoroughly washed in distilled water three times. Then, the seeds were soaked in 25 ml distilled water and kept in an incubator maintained at 25 °C ± 1 °C for twelve hours. The seed leachate was collected and the volume was made up to 25 ml by adding distilled water. The electrical conductivity of seed leachate was measured by digital conductivity bridge (ELICO) with a cell constant 1.0 and the mean values was expressed in desi simons (dSm^{-1}) per meter (Milosevic *et al*., 2010).

3.3 Experiment 2: Influence of mid storage gamma irradiation and fumigation on seed quality of pulses (soybean and green gram)

3.3.1 Treatment details

The experiment consisted of fourteen treatments laid out in CRD (completely randomised design) with two factors in four replications with two crops as main factor and seven gamma irradiation and fumigation treatments as sub factor as mentioned below.

Factor 1: Crop (C)

C_1: Soybean
C_2: Green gram

Factor 2: Treatments (T)

T_1: Control
T_2: Gamma irradiation @ 200 Gy
T_3: Gamma irradiation @ 400 Gy
T_4: Gamma irradiation @ 600 Gy
T_5: Gamma irradiation @ 800 Gy
T_6: Gamma irradiation @ 1000 Gy
T_7: Fumigation with aluminium phosphide @ 3 tablets per tonne of seed

3.3.2 Design and layouts

The experiment was laid out in a completely randomized block design with four replications.

3.3.3 Imposition of treatments

3.3.3.1 Procedure for imposition of mid storage gamma irradiation and fumigation

The gamma irradiation treatments were imposed as per procedure that was described under 3.2.3.1. However, the treatments were reimposed four times once in three months interval.

3.3.3.2 Procedure for Fumigation of seed

The two crop seeds were fumigated using aluminium phosphide tablets as per the standard dosage (3 tablets of 3gram each per tonne seed) for seven days (Rajendran, 2016). Fumigation was repeated four times once at three months interval.

3.3.4 Seed storage

The seeds after imposition of treatments were used for taking the below mentioned observations. Later the seeds were stored in cloth bag at room temperature. Once in every three months the seeds were taken out from the bags and used for repeated imposition of the treatments.

3.3.5 Observations recorded

3.3.5.1 Physiological parameters

3.3.5.1.1 Germination

The germination percentage was recorded as per the procedure described in section 3.2.5.1.1

3.3.5.1.2 Abnormal seedlings

The abnormal seedling percentage was recorded as per the procedure described in section 3.2.5.1.2

3.3.5.1.3 Dead seeds

The dead seed percentage was recorded as per the procedure described in section 3.2.5.1.3

3.3.5.1.4 Mean germination time (MGT)

The mean germination time was worked out as per the procedure described in section 3.2.5.1.4

3.3.5.1.5 Germination rate index

The germination rate index was worked out as per the procedure described in section 3.2.5.1.5

3.3.5.1.6 Peak value of germination (PV)

The peak value of germination was calculated as per the procedure described in section 3.2.5.1.6

3.3.5.1.7 Shoot length

The shoot length was measured as per the procedure described in section 3.2.5.1.7

3.3.5.1.8 Root length

The root length was measured as per the procedure described in section 3.2.5.1.8

3.3.5.1.9 Seedling dry weight

The seedling dry weight was taken as per the procedure described in section 3.2.5.1.9

3.3.5.1.10 Seedling vigour index (SVI)

The seedling vigour index was calculated as per the procedure described in section 3.2.5.1.10

3.3.5.1.11 Seed infection

The seed infection was calculated as per the procedure described in section 3.2.5.1.11

3.3.5.2 Biochemical parameters

3.3.5.2.1 Dehydrogenase enzyme activity

The dehydrogenase enzyme activity was analysed as per the procedure described in section 3.2.5.2.1

3.3.5.2.2 Alpha amylase activity

The α-amylase enzyme activity was measured as per the procedure described under section 3.2.5.2.2

3.3.5.2.3 Electrical conductivity

The electrical conductivity was recorded as per the procedure described in section 3.2.5.2.3

3.4 Statistical analysis

The data collected from the experiments were analysed statistically by following the procedure suggested by Sundararaj *et al.* (1972). Whenever ‘F’ test was found significant, the critical difference (CD) values were calculated and the treatment mean were compared at one per cent.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the study pertaining to "Effect of gamma irradiation and seed treatment chemicals on seed longevity of soybean [*Glycine max* (L.) Merill] and green gram (*Vigna radiata L.*)" are presented in this chapter.

4.1 Experiment I: Influence of gamma irradiation and seed treatment chemicals on seed longevity of soybean and green gram

4.1.1 Seed germination (Table 1)

The seed germination percentage was significantly influenced by gamma irradiation dosage and seed treatment chemicals between the crops.

Between the crops, C_1 (soybean) recorded significantly higher seed germination (85.5%) compared to C_2 (green gram) which recorded (83.0%) immediately after imposition of treatments. Further, C_1 maintained significantly higher seed germination (84.1, 80.8 and 79.2%) compared to C_2 (81.3, 79.9 and 78.4%) from one, two and three months after storage respectively. However, C_2 (green gram) recorded significantly higher seed germination (76.6, 74.7, 73.5, 72.6, 71.1 and 70.2%) compared to C_1 *i,e.,* soybean (75.9, 73.8, 72.1, 69.9, 67.9 and 64.5%) from four to nine months of storage, respectively.

Among gamma irradiation dosages and seed treatment chemicals, significantly higher seed germination (90.5%) was recorded by T_9 (Melathion + Thiram) compared to all other treatments and control (88.8%) immediately after the imposition of treatments. However, T_9 was on par with T_8 (Thiram) and T_7 (Malathion) which recorded 89.4 and 89.0 per cent seed germination. Further, exposing the seeds to gamma irradiation (T_2- T_6) showed a significant decrease in seed germination with the subsequent increase in gamma irradiation dosage wherein, T_6 (1000 Gy) recorded the lowest seed germination (74.6%) compared to control (88.8%) and all other treatments. However, the seed germination gradually decreased with an advancement of storage period from one to nine months irrespective of the dosages and seed treatment chemicals. Among the treatments, T_9

recorded significantly higher seed germination (89.6, 88.0, 86.4, 83.6, 81.6, 79.6, 77.9, 76.0 and 73.8%) from one to nine months of storage, compared to control (87.8, 86.4, 85.0, 81.0, 78.8, 76.9, 75.6, 72.9 and 71.1%). However, T_9 was found to be on par with T_8

Table 1. Influence of gamma irradiation and seed treatment chemicals on seed germination (%) of soybean and green gram

Treatments	Months after storage														
	Initial			1			2			3			4		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	92.0 *(73.6)	85.5 (67.2)	**88.8 (70.6)**	91.3 (72.8)	84.3 (66.6)	**87.8 (69.7)**	89.3 (70.9)	83.5 (66.0)	**86.4 (68.5)**	87.3 (69.1)	82.8 (65.4)	**85.0 (67.3)**	82.0 (64.9)	80.0 (63.4)	**81.0 (64.1)**
T_2	85.0 (67.2)	86.0 (68.0)	**85.5 (67.6)**	83.8 (66.7)	85.3 (67.5)	**84.5 (66.8)**	79.5 (63.1)	84.3 (66.6)	**81.9 (64.8)**	77.8 (61.8)	83.5 (66.0)	**80.6 (63.9)**	75.3 (60.1)	80.5 (63.8)	**77.9 (62.0)**
T_3	81.8 (64.7)	84.3 (66.6)	**83.0 (65.7)**	79.3 (62.9)	82.0 (64.9)	**80.6 (63.9)**	76.8 (61.2)	80.5 (63.8)	**78.6 (62.5)**	75.3 (60.1)	77.8 (61.8)	**76.5 (61.0)**	73.5 (59.0)	76.8 (61.2)	**75.1 (60.1)**
T_4	79.8 (63.2)	82.0 (64.9)	**80.9 (64.1)**	78.5 (62.4)	76.0 (60.6)	**77.3 (61.5)**	74.0 (59.3)	74.8 (59.8)	**74.4 (59.6)**	72.3 (58.2)	72.3 (58.2)	**72.3 (58.2)**	70.5 (57.1)	70.8 (57.2)	**70.6 (57.2)**
T_5	75.0 (60.0)	77.8 (61.9)	**76.4 (60.9)**	73.5 (59.0)	75.0 (60.0)	**74.3 (59.5)**	68.5 (55.3)	73.0 (58.7)	**70.8 (57.3)**	67.5 (55.2)	71.5 (57.7)	**69.5 (56.2)**	64.8 (53.6)	69.5 (56.5)	**67.1 (55.0)**
T_6	74.0 (59.3)	75.3 60.1)	**74.6 (59.7)**	72.8 (58.5)	74.8 (59.8)	**73.8 (59.2)**	67.3 (55.1)	72.0 (58.0)	**69.6 (56.6)**	65.8 (54.2)	69.8 (56.6)	**67.8 (55.4)**	63.8 (53.0)	68.5 (55.8)	**66.1 (54.4)**
T_7	93.3 (75.0)	84.8 (67.0)	**89.0 (71.0)**	92.3 (73.8)	84.0 (66.9)	**88.1 (70.1)**	90.0 (71.6)	83.0 (65.6)	**86.5 (68.6)**	88.3 (70.0)	82.5 (65.3)	**85.4 (67.6)**	83.8 (66.2)	80.3 (63.6)	**82.0 (64.9)**
T_8	93.8 (75.5)	85.0 (67.2)	**89.4 (71.4)**	92.5 (74.1)	84.5 (66.8)	**88.5 (70.5)**	90.5 (72.0)	83.3 (65.8)	**86.9 (68.9)**	89.0 (70.6)	82.3 (65.1)	**85.6 (67.9)**	84.5 (66.8)	80.5 (63.8)	**82.5 (65.3)**
T_9	94.8 (76.8)	86.3 (68.2)	**90.5 (72.5)**	93.5 (75.8)	85.8 (67.8)	**89.6 (71.5)**	91.0 (72.6)	85.0 (67.2)	**88.0 (69.9)**	89.5 (63.4)	83.3 (65.8)	**86.4 (68.5)**	84.8 (67.0)	82.5 (65.3)	**83.6 (66.1)**
Mean	**85.5 (68.4)**	**83.0 (65.7)**		**84.1 (67.2)**	**81.3 (64.5)**		**80.8 (64.6)**	**79.9 (63.5)**		**79.2 (63.4)**	**78.4 (62.4)**		**75.9 (60.8)**	**76.6 (61.2)**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.3	0.9	0.2	0.7	0.3	0.8	0.3	0.8	0.2	0.6
T	0.6	1.6	0.5	1.4	0.6	1.6	0.6	1.6	0.4	1.2
C x T	0.8	2.2	0.7	2.0	0.8	2.3	0.8	2.3	0.6	1.7

* Figure in the bracket indicates angular transformed values

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** - 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 1. Influence of gamma irradiation and seed treatment chemicals on seed germination (%) of soybean and green gram, *concluded*

Treatments	**Months after storage**														
	5			**6**			**7**			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	79.3 (62.9)	78.3 (62.2)	**78.8 (62.5)**	76.8 (61.2)	77.0 (61.3)	**76.9 (61.2)**	74.8 (59.8)	76.5 (61.0)	**75.6 (60.4)**	71.3 (57.6)	74.5 (59.7)	**72.9 (58.6)**	68.5 (55.8)	73.8 (59.2)	**71.1 (57.5)**
T_2	73.5 (59.0)	78.8 (62.5)	**76.1 (60.8)**	72.5 (58.4)	77.5 (61.7)	**75.0 (60.0)**	69.8 (56.6)	77.0 (61.3)	**73.4 (59.0)**	69.3 (56.3)	75.5 (60.3)	**72.4 (58.3)**	65.5 (54.0)	75.0 (60.0)	**70.3 (57.0)**
T_3	71.5 (57.7)	75.0 (60.0)	**73.3 (58.8)**	70.3 (56.9)	73.5 (59.0)	**71.9 (58.0)**	67.5 (55.2)	71.8 (57.9)	**69.6 (56.6)**	66.5 (54.6)	67.3 (55.1)	**66.9 (54.8)**	62.8 (52.4)	67.0 (54.9)	**64.9 (53.6)**
T_4	68.8 (56.0)	68.5 (55.8)	**68.6 (55.9)**	67.5 (55.2)	67.0 (54.9)	**67.3 (55.1)**	65.5 (54.0)	66.0 (54.3)	**65.8 (54.2)**	63.0 (52.5)	65.5 (54.0)	**64.3 (53.3)**	61.3 (51.5)	64.5 (53.4)	**62.9 (52.4)**
T_5	63.0 (52.5)	68.0 (55.3)	**65.5 (55.9)**	62.8 (52.4)	66.5 (54.6)	**64.6 (53.5)**	61.8 (51.8)	65.8 (54.2)	**63.8 (53.0)**	61.0 (51.3)	65.3 (53.9)	**63.1 (52.6)**	57.8 (49.4)	64.0 (53.1)	**60.9 (51.3)**
T_6	62.8 (52.4)	66.8 (54.8)	**64.8 (54.8)**	62.5 (52.2)	65.5 (54.0)	**64.0 (53.1)**	60.8 (51.2)	65.0 (53.7)	**62.9 (52.4)**	58.5 (49.9)	64.8 (53.6)	**61.6 (51.7)**	56.5 (48.7)	63.3 (52.7)	**59.9 (50.7)**
T_7	81.0 (64.2)	78.0 (62.0)	**79.5 (63.1)**	78.0 (62.0)	77.3 (61.5)	**77.6 (61.8)**	75.8 (60.5)	76.3 (60.8)	**76.0 (60.7)**	73.5 (54.0)	74.5 (59.7)	**74.0 (59.3)**	68.8 (56.0)	73.5 (59.0)	**71.1 (57.5)**
T_8	81.8 (64.7)	78.5 (62.4)	**80.1 (63.5)**	78.8 (62.5)	77.8 (61.8)	**78.3 (62.2)**	76.0 (60.7)	76.5 (61.0)	**76.3 (60.8)**	73.8 (59.2)	74.8 (59.8)	**74.3 (59.5)**	69.5 (56.5)	73.3 (58.6)	**71.4 (57.7)**
T_9	82.5 (65.3)	80.8 (64.0)	**81.6 (64.6)**	79.5 (63.1)	79.8 (62.2)	**79.6 (63.2)**	77.3 (61.5)	78.5 (62.6)	**77.9 (61.9)**	74.3 (61.8)	77.8 (61.8)	**76.0 (60.7)**	70.3 (56.9)	77.3 (61.5)	**73.8 (59.2)**
Mean	**73.8 (59.4)**	**74.7 (59.9)**		**72.1 (58.2)**	**73.5 (59.1)**		**69.9 (56.8)**	**72.6 (58.5)**		**67.9 (55.5)**	**71.1 (57.5)**		**64.5 (53.5)**	**70.2 (57.0)**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.4	0.2	0.8	0.2	0.5	0.2	0.5	0.2	0.5
T	0.3	0.9	0.4	1.0	0.4	1.2	0.4	1.1	0.4	1.1
C x T	0.5	1.3	0.5	1.5	0.6	1.6	0.5	1.5	0.6	1.6

* Figure in the bracket indicates angular transformed values

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 - 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

(88.5, 86.9 and 85.6%) from one to three months of storage and T_7 (86.5 and 85.4%) and T_1 (86.4 and 85.0%) at two and three months of storage.

Among the interactions, C_1T_9 maintained significantly higher seed germination (94.8, 93.5, 91.0, 89.5, 84.8, and 82.5%) from zero to five months of storage but from sixth to ninth months C_2T_9 maintained higher seed germination (79.8, 78.5, 77.8, and 77.3%) respectively. However, C_1T_9 was on par with C_1T_8 (93.8, 92.5, 90.5, 89.0, 84.5 and 81.8%) at zero, one, two, three, four and five months of seed storage and C_1T_7 (93.3, 92.3, 90.0, 88.3, and 83.8%) at zero, one, two, three and four months of seed storage. Further, C_2T_9 was on par with C_1T_9 (79.5 and 77.3%) at six and seven month of storage.

4.1.2 Abnormal seedlings (Table 2)

The gamma irradiation dosages and seed treatment chemicals had a significant influence on abnormal seedlings (%) between the two crops.

Between the crops, significantly lower abnormal seedlings were recorded by C_2 (4.8%) compared to C_1 (5.4%) immediately after imposition of treatments. However, C_2 maintained significantly lower abnormal seedlings (6.0, 7.0, 7.4, 7.9, 8.7, 10.5, 11.3, 12.8 and 13.2%) compared to C_1 (6.7, 8.4, 8.7, 9.3, 9.8, 11.9, 13.2, 14.3, and 15.0%) respectively, from one to nine months after storage.

Among the different treatments, significantly lower abnormal seedling (1.3%) were recorded by T_9 compared to all other treatments and control (1.5%) immediately after imposition of treatments. Further, exposing the seeds to gamma irradiation (T_2-T_6) showed a significant increase in abnormal seedlings (%) wherein, T_6 recorded the highest abnormal seedlings (14.0%) compared to control (1.5%). Subsequent increase in storage period from initial to nine months, the abnormal seedling percentage gradually increased. However, irrespective of the treatments imposed, treatment T_9 recorded significantly lower abnormal seedlings (2.6, 3.6, 3.9, 4.6, 5.4, 8.0, 9.3, 10.5 and 11.1%) compared to control (2.9, 4.0, 4.6, 5.3, 6.1, 8.8, 9.9, 11.4 and 12.0%) at one , two, three, four, five, six, seven, eight and nine months of storage, respectively. Further, T_9 was found on par with

T_8 (1.9, 3.0, 3.9, 4.1, 5.0, 5.8, 8.5, 9.8, 11.6 and 12.0%) and T_1 (1.5, 2.9, 4.0, 4.6, 5.3, 6.1, 8.8, 9.9, 11.4 and 12.0%) from initial to nine months after storage, respectively.

Among the interactions, C_2T_9 recorded significantly lower abnormal seedling (1.3, 2.3, 3.3, 3.5, 4.0, 5.0, 7.0, 8.0, 9.0 and 9.3%) during entire period of seed storage.

Table 2. Influence of gamma irradiation and seed treatment chemicals on abnormal seedling (%) of soybean and green gram

Treatments	**Months after storage**														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2.0	1.0	**1.5**	3.5	2.3	**2.9**	4.8	3.3	**4.0**	5.3	4.0	**4.6**	5.8	4.8	**5.3**
T_2	4.5	2.0	**3.3**	6.0	3.0	**4.5**	8.0	4.0	**6.0**	8.5	4.5	**6.5**	8.8	5.0	**6.9**
T_3	5.5	4.3	**4.9**	7.5	5.5	**6.5**	9.3	6.3	**7.8**	9.8	6.5	**8.1**	10.0	6.8	**8.4**
T_4	7.3	8.5	**7.9**	7.8	9.0	**8.4**	10.3	10.0	**10.1**	10.5	10.8	**10.6**	10.8	11.0	**10.9**
T_5	9.5	10.8	**10.1**	10.5	12.3	**11.4**	12.3	13.3	**12.8**	12.8	13.5	**13.1**	13.0	13.8	**13.4**
T_6	14.8	13.3	**14.0**	15.3	14.8	**15.0**	18.0	16.0	**17.0**	18.3	16.3	**17.3**	18.5	16.5	**17.5**
T_7	1.8	1.0	**1.4**	3.3	2.3	**2.8**	4.5	3.8	**4.1**	4.8	4.0	**4.4**	5.8	4.8	**5.3**
T_8	2.5	1.3	**1.9**	3.5	2.5	**3.0**	4.3	3.5	**3.9**	4.5	3.8	**4.1**	5.5	4.5	**5.0**
T_9	1.3	1.3	**1.3**	3.0	2.3	**2.6**	4.0	3.3	**3.6**	4.3	3.5	**3.9**	5.3	4.0	**4.6**
Mean	**5.4**	**4.8**		**6.7**	**6.0**		**8.4**	**7.0**		**8.7**	**7.4**		**9.3**	**7.9**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.5	0.2	0.6	0.2	0.7	0.2	0.5	0.2	0.6
T	0.4	1.1	0.5	1.4	0.5	1.5	0.4	1.1	0.4	1.2
C x T	0.5	1.4	0.6	1.8	0.7	2.0	0.5	1.5	0.6	1.7

Crops: **C_1-** Soybean **C_2-** Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 2. Influence of gamma irradiation and seed treatment chemicals on abnormal seedling (%) of soybean and green gram *concluded*

Treatments	**Months after storage**														
	5			**6**			**7**			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	6.5	5.8	**6.1**	9.8	7.8	**8.8**	11.0	8.8	**9.9**	12.3	10.5	**11.4**	12.5	11.5	**12.0**
T_2	9.0	6.8	**7.9**	10.3	9.8	**10.0**	12.5	10.3	**11.4**	13.0	11.5	**12.3**	13.8	12.0	**12.9**
T_3	10.5	7.5	**9.0**	12.5	11.0	**11.8**	13.8	12.3	**13.0**	14.5	13.8	**14.1**	15.8	14.0	**14.9**
T_4	11.8	11.3	**11.5**	13.3	12.3	**12.8**	15.0	13.5	**14.3**	15.8	14.8	**15.3**	16.0	15.3	**15.6**
T_5	13.3	14.0	**13.6**	14.8	14.3	**14.5**	15.3	14.5	**14.9**	16.0	15	**15.5**	17.5	15.8	**16.6**
T_6	18.8	17.0	**17.9**	19.0	17.3	**18.1**	19.3	17.5	**18.4**	20.8	17.8	**19.3**	21.3	18.0	**19.6**
T_7	6.0	5.8	**5.9**	9.5	7.5	**8.5**	10.8	9.0	**9.9**	12.5	11.5	**12.0**	12.8	11.8	**12.3**
T_8	6.3	5.3	**5.8**	9.3	7.8	**8.5**	11.0	8.5	**9.8**	12.3	11.0	**11.6**	12.5	11.5	**12.0**
T_9	5.8	5.0	**5.4**	9.0	7.0	**8.0**	10.5	8.0	**9.3**	12.0	9.0	**10.5**	13.0	9.3	**11.1**
Mean	**9.8**	**8.7**		**11.9**	**10.5**		**13.2**	**11.3**		**14.3**	**12.8**		**15.0**	**13.2**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.5	0.2	0.5	0.2	0.5	0.2	0.6	0.2	0.6
T	0.4	1.1	0.4	1.2	0.4	1.1	0.4	1.2	0.5	1.5
C x T	0.6	1.8	0.6	1.9	0.6	1.9	0.6	1.8	0.7	2.1

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 -- 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

However, C_2T_9 was on par with C_2T_8 (1.3, 2.5, 3.5, 3.8, 4.5, 5.3, 7.8 and 8.5%) from initial to seven months after storage and C_2T_7 (2.3, 3.8, 4.0, 4.8, 5.8, 7.5 and 9.0%) from one to seven month of storage. Even, C_2T_9 was also on par with C_2T_2 (2.0, 3.0, 4.0, 4.5, 5.0 and 6.8%) at zero, one, two, three, four and five month of storage and C_2T_1 (2.3, 3.3, 4.0, 4.8, 5.8, 7.8, 8.8 and 10.5%) at one, two, three, four, five, six, seven and eight months of storage. However, C_2T_9 was on par with C_1T_9 (1.3, 3.0, 4.0, 4.3, 5.3 and 5.8%) from zero to five months of storage, C_1T_8 (3.5, 4.3, 4.5, 5.5 and 6.3%) from one to five months of storage.

4.1.3 Dead Seeds (Table 3)

The data on dead seed (%) indicated a significant difference between the crops due to gamma irradiation and seed treatment chemicals.

Between the crops under study, C_1 recorded significantly lower dead seed (5.5%) compared to C_2 (8.2%) immediately after imposition of treatments. However, C_1 maintained significantly lower dead seed (6.6, 7.6, 8.1, 8.8, 9.7, 10.2, 10.5, 11.1 and 13.1%) compared to C_2 (9.3, 10.4, 11.2, 11.5, 11.9, 12.2, 12.6, 13.4 and 14.0%) respectively during the entire period of storage.

Among the gamma irradiation and seed treatment chemicals, treatment T_9 showed significantly lower dead seeds (5.0%) compared to all other treatments and control (5.8%) immediately after imposition of treatment. However, T_9 was on par with T_8 (5.4%) and T_7 (5.6%). Further, exposing the seeds to gamma irradiation (T_2-T_6) showed a significant increase in dead seed (%) with an increase in the gamma irradiation dosage wherein, T_6 recorded the highest dead seed (9.3%) compared to control (5.8%). The dead seed percentage increased as the storage period advanced to nine months. The treatment, T_9 recorded significantly lower dead seed (5.9, 7.0, 7.6, 8.1, 8.5, 8.9, 9.1, 10.1 and 11.5%) compared to control (6.6, 7.4, 8.0, 8.3, 9.3, 9.5, 9.8, 10.3 and 12.3%) from one to nine months after storage, respectively. However, T_9 was on par with T_8 (6.1, 7.1, 7.8, 8.3, 8.6, 9.3, 9.5, 10.4 and 11.5%) and T_7 (6.3, 7.3, 8.4, 8.6, 9.0, 9.4, 9.6, 10.6 and 11.9%) at one, two, three, four, five, six, seven, eight and nine months of storage, respectively. Further, T_9 was also on par with T_1 (5.8, 6.6, 7.4, 8.0, 8.3, 9.3, 9.5, 9.8, 10.3 and 12.3%) from zero to nine months of storage and T_2 (7.5, 8.4, 8.9, 9.1, 9.8, 10.1, 10.5, 11.0 and 12.5%) from one to nine months of storage, respectively

Table 3. Influence of gamma irradiation and seed treatment chemicals on dead seed (%) of soybean and green gram

Treatments	Months after storage														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	4.3	7.3	**5.8**	4.5	8.8	**6.6**	5.0	9.8	**7.4**	5.3	10.8	**8.0**	6.0	10.5	**8.3**
T_2	5.8	8.0	**6.9**	6.0	9.0	**7.5**	6.5	10.3	**8.4**	6.8	11.0	**8.9**	7.0	11.3	**9.1**
T_3	7.0	8.5	**7.8**	7.5	9.5	**8.5**	9.8	10.5	**10.1**	10.0	11.5	**10.8**	10.3	11.8	**11.0**
T_4	7.3	8.5	**7.9**	9.8	10.0	**9.9**	10.5	11.3	**10.9**	11.0	12.0	**11.5**	11.5	12.5	**12.0**
T_5	7.5	9.0	**8.3**	10.0	10.3	**10.1**	11.0	11.8	**11.4**	11.5	12.3	**11.9**	12.5	12.8	**12.6**
T_6	8.3	10.3	**9.3**	10.3	10.5	**10.4**	11.8	12.0	**11.9**	12.0	12.5	**12.3**	13.3	13.0	**13.1**
T_7	3.5	7.8	**5.6**	4.5	8.0	**6.3**	4.8	9.8	**7.3**	6.3	10.5	**8.4**	6.5	10.8	**8.6**
T_8	3.3	7.5	**5.4**	3.5	8.8	**6.1**	5.0	9.3	**7.1**	5.5	10.0	**7.8**	6.3	10.3	**8.3**
T_9	3.0	7.0	**5.0**	3.3	8.5	**5.9**	4.5	9.5	**7.0**	5.0	10.3	**7.6**	5.8	10.5	**8.1**
Mean	**5.5**	**8.2**		**6.6**	**9.3**		**7.6**	**10.4**		**8.1**	**11.2**		**8.8**	**11.5**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.6	0.3	0.8	0.2	0.6	0.2	0.6	0.2	0.6
T	0.4	1.2	0.6	1.7	0.5	1.4	0.5	1.4	0.5	1.4
C x T	0.6	1.8	0.8	2.3	0.7	2.1	0.7	2.0	0.7	2.1

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy **T_7 -** Malathion (2 g / kg of seed) **T_9-** Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy **T_8 -** Thiram (2 g / kg of seed)

Table 3. Influence of gamma irradiation and seed treatment chemicals on dead seed (%) of soybean and green gram *concluded*

Treatments	**Months after storage**														
	5			**6**			**7**			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	7.5	11.0	**9.3**	7.8	11.3	**9.5**	8.0	11.5	**9.8**	8.5	12.0	**10.3**	12.0	12.5	**12.3**
T_2	8.0	11.5	**9.8**	8.5	11.8	**10.1**	9.0	12.0	**10.5**	9.5	12.5	**11.0**	12.3	12.8	**12.5**
T_3	11.3	12.0	**11.6**	11.8	12.3	**12.0**	12.0	12.5	**12.3**	12.3	14.3	**13.3**	13.5	14.8	**14.1**
T_4	12.5	12.8	**12.6**	13.8	13.5	**13.6**	14.0	13.8	**13.9**	14.5	14.8	**14.6**	15.3	15.5	**15.4**
T_5	13.8	13.5	**13.6**	14.0	13.8	**13.9**	14.3	14.5	**14.4**	14.8	15.0	**14.9**	16.0	16.3	**16.1**
T_6	14.0	13.8	**13.9**	14.3	14.3	**14.3**	14.8	15.0	**14.9**	15.0	15.5	**15.3**	16.5	16.8	**16.6**
T_7	7.0	11.0	**9.0**	7.3	11.5	**9.4**	7.5	11.8	**9.6**	8.8	12.5	**10.6**	11.0	12.8	**11.9**
T_8	6.8	10.5	**8.6**	7.5	11.0	**9.3**	7.8	11.3	**9.5**	8.5	12.3	**10.4**	10.8	12.3	**11.5**
T_9	6.3	10.8	**8.5**	7.0	10.8	**8.9**	7.3	11.0	**9.1**	8.3	12.0	**10.1**	10.5	12.5	**11.5**
Mean	**9.7**	**11.9**		**10.2**	**12.2**		**10.5**	**12.6**		**11.1**	**13.4**		**13.1**	**14.0**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.3	0.8		0.2	0.6		0.2	0.7		0.2	0.6		0.3	0.7	
T	0.6	1.7		0.5	1.5		0.5	1.4		0.5	1.3		0.5	1.6	
C x T	0.8	2.3		0.6	1.8		0.7	2.0		0.6	1.8		0.8	2.4	

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** - 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Among the interactions, C_1T_9 recorded significantly lower dead seed (3.0%) compared to all other treatment combinations immediately after imposition of treatments. However, C_1T_9 maintained lower dead seed (3.3, 4.5, 5.0, 5.8, 6.3, 7.0, 7.3, 8.3 and 10.5%) at one, two, three, four, five, six, seven, eight and nine months of storage, respectively. Further, C_1T_9 was on par with C_1T_8 (3.3, 3.5, 5.0, 5.5, 6.3, 6.8, 7.5, 7.8, 8.5, 10.8%) from initial to eight months and C_1T_7 (3.5, 4.5, 4.8, 6.3, 6.5, 7.0, 7.3, 7.5, 8.8 and 11.0) from initial to nine months of storage. Even, C_1T_9 was also on par with C_1T_1 (4.3, 4.5, 5, 5.3, 6.0, 7.5, 7.8, 8.0, 8.5 and 12.0%) at zero, one, two, three, four, five, six, seven, eight and nine months of storage and C_1T_2 (6.5, 6.8, 7.0, 8.0, 8.5, 9.0, 9.5 and 12.3%) from second to nine months after storage and with C_2T_9 (12.5%) , C_2T_1 (12.5%), C_2T_8 (12.3%), C_2T_7 (12.8%) and C_2T_2 (12.8%) at nine months of storage.

4.1.4 Mean germination time (Table 4)

The data on mean germination time indicated a significant difference due to gamma irradiation dosages and seed treatment chemicals between the two crops.

Soybean seeds (C_1) recorded significantly lower mean germination time (1.49) compared to green gram (C_2) 1.88 immediately after imposition of treatments. Further, C_1 was able to maintain significantly lower mean germination time (1.69, 1.83 and 1.92) compared to C_2 (1.90, 1.95 and 2.01) at one, two and three months of storage. However, C_2 registered significantly lower mean germination time (2.08, 2.15, 2.18, 2.25, 2.38 and 2.55) compared to C_1 (2.39, 2.42, 2.45, 2.54, 2.61 and 2.74) from four to nine months after storage.

Compared to gamma irradiation dosages, seed treatment chemicals and control (1.68), T_9 was significantly superior in maintaining lower mean germination time (1.55) immediately after imposition of treatments. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant increase in mean germination time with an increase in gamma irradiation dosage wherein, T_6 recorded the highest mean germination time (1.87) compared to control (1.68). However, the low dosage (200Gy) did not increase the mean germination time (1.63) significantly compared to control (1.68).

Further, the mean germination time increased linearly up to nine months of storage. During the entire period of storage, T_9 recorded significantly lower mean germination time (1.56, 1.71, 1.80, 1.93, 1.98, 2.01, 2.04, 2.21 and 2.31) compared to control (1.78, 1.87, 1.99, 2.22, 2.25, 2.30, 2.34, 2.43 and 2.60) from one to nine months after storage,

Table 4. Influence of gamma irradiation and seed treatment chemicals on mean germination time of soybean and green gram

Treatments	Months after storage														
	Initial			1			2			3			4		
	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**
T_1	1.51	1.86	**1.68**	1.66	1.91	**1.78**	1.81	1.93	**1.87**	2.03	1.95	**1.99**	2.34	2.09	**2.22**
T_2	1.40	1.86	**1.63**	1.58	1.92	**1.75**	1.76	1.94	**1.85**	1.81	1.96	**1.88**	2.44	2.03	**2.23**
T_3	1.61	1.88	**1.74**	1.76	1.93	**1.84**	1.85	1.97	**1.91**	2.04	1.99	**2.01**	2.45	2.06	**2.26**
T_4	1.62	1.89	**1.76**	1.90	1.94	**1.92**	1.92	1.99	**1.95**	2.05	2.03	**2.04**	2.51	2.07	**2.29**
T_5	1.64	1.92	**1.78**	2.04	1.96	**2.00**	2.05	2.07	**2.06**	2.10	2.14	**2.12**	2.59	2.36	**2.47**
T_6	1.67	2.08	**1.87**	2.05	2.01	**2.03**	2.11	2.09	**2.10**	2.16	2.16	**2.16**	2.64	2.39	**2.52**
T_7	1.36	1.82	**1.59**	1.45	1.85	**1.65**	1.75	1.89	**1.82**	1.78	1.99	**1.88**	2.25	2.00	**2.12**
T_8	1.34	1.81	**1.58**	1.43	1.82	**1.63**	1.62	1.85	**1.74**	1.73	1.97	**1.85**	2.21	1.93	**2.07**
T_9	1.31	1.80	**1.55**	1.32	1.80	**1.56**	1.58	1.84	**1.71**	1.65	1.95	**1.80**	2.08	1.78	**1.93**
Mean	**1.49**	**1.88**		**1.69**	**1.90**		**1.83**	**1.95**		**1.92**	**2.01**		**2.39**	**2.08**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.02	0.05	0.04	0.12	0.03	0.10	0.02	0.05	0.05	0.15
T	0.04	0.10	0.08	0.24	0.07	0.20	0.03	0.10	0.11	0.32
C x T	0.05	0.15	0.12	0.36	0.10	0.30	0.05	0.14	0.15	0.45

Crops: C_1- Soybean C_2- Green gram

T_1 - Control T_3 - 400 Gy T_5 - 800 Gy T_7 - Malathion (2 g / kg of seed) T_9- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy T_4 - 600 Gy T_6 - 1000 Gy T_8 - Thiram (2 g / kg of seed)

Table 4. Influence of gamma irradiation and seed treatment chemicals on mean germination time of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2.38	2.12	**2.25**	2.42	2.19	**2.30**	2.47	2.22	**2.34**	2.54	2.32	**2.43**	2.59	2.61	**2.60**
T_2	2.46	2.08	**2.27**	2.48	2.08	**2.28**	2.55	2.17	**2.36**	2.60	2.30	**2.45**	2.64	2.58	**2.61**
T_3	2.49	2.11	**2.30**	2.51	2.16	**2.33**	2.68	2.26	**2.47**	2.69	2.49	**2.59**	2.75	2.62	**2.68**
T_4	2.56	2.32	**2.44**	2.58	2.35	**2.46**	2.71	2.41	**2.56**	2.72	2.53	**2.62**	2.89	2.69	**2.79**
T_5	2.60	2.37	**2.48**	2.63	2.45	**2.54**	2.79	2.53	**2.66**	2.82	2.62	**2.72**	3.10	2.73	**2.91**
T_6	2.69	2.46	**2.57**	2.75	2.48	**2.61**	2.80	2.56	**2.68**	2.83	2.63	**2.73**	3.30	2.82	**3.06**
T_7	2.27	2.04	**2.15**	2.30	2.06	**2.18**	2.39	2.13	**2.26**	2.50	2.29	**2.39**	2.56	2.36	**2.46**
T_8	2.22	1.99	**2.10**	2.24	2.01	**2.12**	2.27	2.11	**2.19**	2.46	2.13	**2.29**	2.46	2.34	**2.40**
T_9	2.09	1.87	**1.98**	2.13	1.89	**2.01**	2.18	1.90	**2.04**	2.32	2.10	**2.21**	2.39	2.23	**2.31**
Mean	**2.42**	**2.15**		**2.45**	**2.18**		**2.54**	**2.25**		**2.61**	**2.38**		**2.74**	**2.55**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.04	0.11	0.04	0.13	0.04	0.11	0.03	0.10	0.05	0.15
T	0.08	0.24	0.09	0.27	0.08	0.23	0.07	0.21	0.10	0.31
C x T	0.11	0.33	0.13	0.39	0.11	0.33	0.10	0.30	0.15	0.45

Crops: **C_1-** Soybean **C_2-** Green gram

T_1 - Control **T_3 -** 400 Gy **T_5 -** 800 Gy **T_7 -** Malathion (2 g / kg of seed) **T_9-** Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy **T_8 -** Thiram (2 g / kg of seed)

respectively. However, T_9 was on par with T_8 (1.58, 1.63, 1.74, 1.85, 2.10, 2.12, 2.19, 2.29 and 2.40) from zero to nine months of storage except at third month, T_7 (1.59, 1.65, 1.82, 2.12, 2.15, 2.18, 2.26, 2.39 and 2.46) respectively except at third month, T_2 (1.63, 1.75, 1.85, 2.23, 2.28 and 2.61) at initial, one, two, four, six and nine months of storage and T_1 (1.78, 2.22 and 2.60) at one, four and nine months after storage.

Among the interactions, C_1T_9 was able to maintain significantly lower mean germination time (1.31, 1.32, 1.58 and 1.65) at initial to three month of storage but from four to nine months of storage, C_2T_9 recorded lower mean germination time (1.78, 1.87, 1.89, 1.90, 2.10, and 2.23). However, C_1T_9 was on par with C_1T_8 (1.34, 1.43, 1.62), C_1T_7 (1.36, 1.45, 1.75) and C_1T_2 (1.40, 1.58 and 1.76) at initial, one and two months of storage, respectively. Even, C_1T_9 was on par with C_1T_1 (1.66 and1.81) at one and two months of storage. However, C_2T_9 was on par with C_2T_8 (1.93, 1.99, 2.01, 2.11, 2.13, 2.34), C_2T_7 (2.00, 2.04, 2.06, 2.13, 2.29, 2.36), C_2T_2 (2.03, 2.08, 2.08, 2.17, 2.30, 2.58), C_2T_1 (2.09, 2.12, 2.19, 2.22, 2.32 and 2.61) and C_1T_9 (2.08, 2.09, 2.13, 2.18, 2.32 and 2.39) from four to nine months of storage.

4.1.5 Germination rate index (Table 5)

The gamma irradiation dosages and seed treatment chemicals had a significant impact on germination rate index in both the crops.

On comparing the crops, C_1 evidenced significantly higher germination rate index (7417) compared to C_2 (7242) immediately after imposition of treatments. However, C_1 maintained significantly higher germination rate index (7089, 6789 and 6317) compared to C_2 (6681, 6469 and 6062) at one, two and three months of storage but from four month of storage, C_2 registered higher germination rate index (5858, 5195, 4687, 4418, 4171 and 3896) compared to C_1 (5314, 4869, 4515, 4329, 3977 and 3800).

Among the gamma irradiation dosages and seed treatment chemicals, there was a significant difference in germination rate index as observed in T_9 (8107) over all other treatments and control (7492) immediately after imposition of treatments. However, T_9

was on par with T_8 (7899). Further, exposing the seeds to the gamma irradiation (T_2 to T_6) showed a significant decrease in germination rate index with an increase in the gamma irradiation dosages wherein, T_6 recorded the lowest germination rate index (6521) compared to control (7492). Further, the germination rate index decreased linearly up to

Table 5. Influence of gamma irradiation and seed treatment chemicals on germination rate index of soybean and green gram

Treatments	**Months after storage**														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	7643	7341	**7492**	7277	6831	**7054**	6834	6531	**6682**	6512	6198	**6355**	5448	6025	**5736**
T_2	7475	7459	**7467**	7029	6677	**6853**	6639	6440	**6539**	6422	6134	**6278**	5171	6127	**5649**
T_3	7291	7033	**7162**	6871	6489	**6680**	6356	6351	**6354**	6246	5898	**6072**	5157	5778	**5467**
T_4	7061	6933	**6997**	6639	6313	**6476**	6257	6306	**6281**	6034	5703	**5869**	5037	5667	**5352**
T_5	6794	6434	**6614**	6419	6125	**6272**	6155	6035	**6095**	5793	5630	**5711**	4897	4843	**4870**
T_6	6626	6417	**6521**	6139	6079	**6109**	5870	5855	**5862**	5567	5402	**5484**	4866	5115	**4990**
T_7	7767	7645	**7706**	7651	7105	**7378**	7545	6943	**7244**	6632	6228	**6430**	5572	6228	**5900**
T_8	7955	7842	**7899**	7844	7152	**7498**	7585	6637	**7111**	6791	6536	**6663**	5752	6444	**6098**
T_9	8138	8075	**8107**	7937	7363	**7650**	7864	7128	**7496**	6862	6827	**6844**	5934	6496	**6215**
Mean	**7417**	**7242**		**7089**	**6681**		**6789**	**6469**		**6317**	**6062**		**5314**	**5858**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	42	125	88	263	26	78	37	111	53	160
T	88	265	186	558	56	166	79	236	113	340
C x T	125	375	264	792	79	235	111	333	160	480

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** - 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 5. Influence of gamma irradiation and seed treatment chemicals on germination rate index of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	4862	5188	**5025**	4584	4572	**4578**	4345	4516	**4431**	4129	4193	**4161**	4020	4010	**4015**
T_2	4837	5250	**5043**	4544	4701	**4622**	4319	4553	**4436**	4022	4293	**4157**	4045	4013	**4029**
T_3	4812	5166	**4989**	4555	4453	**4504**	4281	4379	**4330**	3888	4012	**3950**	3480	3837	**3658**
T_4	4804	4956	**4880**	4439	4041	**4240**	4238	3752	**3995**	3598	3729	**3663**	3477	3630	**3554**
T_5	4691	4555	**4623**	4178	3995	**4087**	4143	3684	**3913**	3354	3543	**3448**	3134	3214	**3174**
T_6	4555	4508	**4531**	3966	4829	**4397**	3701	3947	**3824**	3227	3442	**3334**	3029	3041	**3035**
T_7	4952	5406	**5179**	4675	4901	**4788**	4433	4766	**4599**	4375	4639	**4507**	4246	4311	**4278**
T_8	5130	5546	**5338**	4759	5100	**4930**	4641	4809	**4725**	4528	4736	**4632**	4246	4382	**4314**
T_9	5176	6184	**5680**	4938	5590	**5264**	4860	5364	**5112**	4675	4959	**4817**	4527	4631	**4579**
Mean	**4869**	**5195**		**4515**	**4687**		**4329**	**4418**		**3977**	**4171**		**3800**	**3896**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	93	278	40	119	22	65	28	85	29	87
T	197	589	84	252	46	138	60	180	61	184
C x T	278	834	119	357	65	196	85	255	87	261

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

nine months of storage. During the entire period of storage, T_9 recorded significantly higher germination rate index (7650, 7496, 6844, 6215, 5680, 5264, 5112, 4817 and 4579) compared to control (7054, 6682, 6355, 5736, 5025, 4578, 4431, 4161 and 4015) from one to nine months after storage, respectively. However, T_9 was on par with T_8 (7498, 6663, 6098 and 5338) at one, three, four and five months of storage and T_7 (7378, 5900 and 5179) at one, four and five months of storage.

Among the interactions, C_1T_9 registered significantly higher germination rate index (8138, 7937, 7864 and 6862) at initial, one, two and three months of storage. However, from fourth month of storage, C_2T_9 registered higher germination rate index (6496, 6184, 5590, 5364, 4959 and 4631). Further, C_1T_9 was on par with C_1T_8 (7955, 7844 and 6791), C_1T_7 (7767, 7651 and 6632), C_2T_9 (8075, 7363 and 6827), and C_2T_8 (7842, 7152 and 6536) at initial, one and three months of storage and C_1T_1 (7277) at one month of storage. However C_2T_9 was on par with C_2T_8 (6444, 5546 and 4736) at four, five and eight months of storage.

4.1.6 Peak value of germination (Table 6)

The peak value of germination was significantly influenced by the gamma irradiation dosage and seed treatment chemicals between the crops.

Soybean, C_1 recorded significantly higher peak value of germination (22.0) compared to green gram, C_2 (21.1) immediately after imposition of treatments. Further, C_1 maintained significantly higher peak value of germination (19.8, 17.8 and 16.3) compared to C_2 (19.2, 17.5 and 16.0) from one to three months after storage respectively. However, C_2 recorded significantly higher peak value of germination (15.9, 15.2, 14.6, 14.4, 13.4 and 12.5) compared to C_1 (14.8, 14.1, 13.6, 12.9, 12.3 and 11.6) from four to nine months, respectively. However, at three and five months of storage, the peak value of germination did not vary significantly.

Among gamma irradiation dosages and seed treatment chemicals, significantly higher peak value of germination (26.9) was recorded by T_9 compared to all other treatments and control (22.0) immediately after the imposition of treatments. Further, exposing the seeds to gamma irradiation (T_2- T_6) showed a significant decrease in peak value of germination with an increase in gamma irradiation dosage wherein, T_6 (1000Gy) recorded the lowest peak value (16.5) of germination compared to control (22.0) and all

Table 6. Influence of gamma irradiation and seed treatment chemicals on peak germination time of soybean and green gram

Treatments	Months after storage														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	22.7	21.3	**22.0**	22.2	18.4	**20.3**	20.1	16.6	**18.3**	16.4	15.8	**16.1**	14.8	15.5	**15.1**
T_2	22.6	21.4	**22.0**	20.5	18.8	**19.6**	17.8	17.0	**17.4**	16.5	16.7	**16.6**	13.9	16.4	**15.1**
T_3	22.2	20.3	**21.2**	18.6	18.5	**18.6**	16.5	16.9	**16.7**	15.5	13.7	**14.6**	13.5	14.6	**14.0**
T_4	20.6	19.8	**20.2**	16.3	17.8	**17.0**	14.7	16.3	**15.5**	13.5	13.4	**13.4**	13.3	13.7	**13.5**
T_5	17.4	19.1	**18.3**	14.2	16.6	**15.4**	12.7	15.8	**14.2**	12.1	12.9	**12.5**	11.8	13.3	**12.5**
T_6	14.4	18.6	**16.5**	12.0	15.8	**13.9**	11.4	15.1	**13.2**	11.3	12.5	**11.9**	11.1	12.9	**12.0**
T_7	23.4	22.1	**22.7**	23.8	21.0	**22.4**	21.0	17.6	**19.3**	17.7	17.4	**17.6**	15.5	16.5	**16.0**
T_8	26.2	22.3	**24.2**	24.8	21.3	**23.0**	21.4	17.9	**19.6**	19.7	17.6	**18.6**	17.5	16.6	**17.0**
T_9	28.3	25.5	**26.9**	26.3	24.5	**25.4**	24.5	24.2	**24.3**	24.2	23.8	**24.0**	22.5	23.5	**23.0**
Mean	**22.0**	**21.1**		**19.8**	**19.2**		**17.8**	**17.5**		**16.3**	**16.0**		**14.8**	**15.9**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.1	0.4	0.1	0.4	0.1	0.2	0.2	NS	0.3	0.9
T	0.3	0.8	0.3	0.9	0.2	0.5	0.4	0.8	0.6	1.9
C x T	0.4	1.2	0.4	1.2	0.3	0.7	0.5	1.1	0.9	2.7

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 - 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

Table 6. Influence of gamma irradiation and seed treatment chemicals on peak germination time of soybean and green gram *concluded*

Treatments	**Months after storage**														
	5			**6**			**7**			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	13.8	15.0	**14.4**	13.2	14.6	**13.9**	12.0	14.2	**13.1**	11.7	13.3	**12.5**	11.1	12.2	**11.7**
T_2	12.7	15.4	**14.0**	12.5	15.0	**13.7**	11.6	14.3	**12.9**	10.9	13.4	**12.2**	10.4	12.7	**11.6**
T_3	12.5	14.0	**13.3**	12.1	13.3	**12.7**	11.2	13.8	**12.5**	10.5	12.6	**11.6**	10.1	11.4	**10.7**
T_4	12.0	13.0	**12.5**	11.7	12.7	**12.2**	10.8	13.2	**12.0**	10.1	11.9	**11.0**	9.7	10.7	**10.2**
T_5	11.3	12.5	**11.9**	11.1	12.2	**11.6**	10.6	12.1	**11.3**	9.8	11.4	**10.6**	9.4	10.5	**9.9**
T_6	10.8	12.1	**11.4**	10.6	11.8	**11.2**	10.2	11.8	**11.0**	9.5	10.9	**10.2**	8.9	10.0	**9.5**
T_7	15.2	16.2	**15.7**	14.5	15.2	**14.9**	14.2	14.4	**14.3**	13.8	13.6	**13.7**	12.9	12.7	**12.8**
T_8	17.1	16.4	**16.7**	16.4	15.5	**15.9**	15.9	14.7	**15.3**	15.7	13.7	**14.7**	15.1	13.1	**14.1**
T_9	21.8	22.5	**22.1**	20.5	21.2	**20.8**	19.5	20.9	**20.2**	18.8	20.2	**19.5**	17.3	19.3	**18.3**
Mean	**14.1**	**15.2**		**13.6**	**14.6**		**12.9**	**14.4**		**12.3**	**13.4**		**11.6**	**12.5**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.4	NS	0.3	0.9	0.1	0.3	0.3	0.8	0.2	0.7
T	0.8	2.4	0.7	2.1	0.2	0.5	0.5	1.6	0.5	1.4
C x T	1.1	3.3	1.0	3.0	0.3	0.8	0.8	2.4	0.7	2.1

Crops: **C_1-** Soybean **C_2-** Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 -- 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

other treatments. The peak value of germination gradually decreased with the advancement of storage period from one to nine months of seed storage. However, the treatment T_9 recorded significantly peak value of germination (25.4, 24.3, 24.0, 23.0, 22.1, 20.8, 20.2, 19.5 and 18.3) from one to nine months of storage, compared to control (20.3, 18.3, 16.1, 15.1, 14.4, 13.9, 13.1, 12.5 and 11.7).

Among the interactions, C_1T_9 maintained significantly higher peak value of germination (28.3, 26.3, 24.5 and 24.2) from zero to three months of storage but from four to ninth month C_2T_9 maintained higher peak value of germination (23.5, 22.5, 21.2, 20.9, 20.2 and 19.3) respectively. However, C_1T_9 was on par with C_2T_9 (24.5, 24.2 and 23.8) at one, two and three months of seed storage. Further, C_2T_9 was on par with C_1T_9 (21.8, 20.5, 18.8 and 17.3) at five, six, eight and nine months of seed storage.

4.1.7 Shoot length (Table 7)

The shoot length was significantly influenced by gamma irradiation dosage and seed treatment chemicals between the crops.

Green gram (C_2) recorded significantly higher shoot length (16.34 cm) compared to soybean, C_1 (12.63 cm) immediately after imposition of treatments. However, C_2 was able to maintain higher shoot length (15.93, 14.44, 14.20, 14.07, 13.98, 13.69, 13.51, 13.27 and 12.68 cm) compared to C_1 (11.42, 10.77, 10.58, 10.49, 10.29, 10.07, 9.76, 9.62 and 9.43 cm) from one to nine months after storage.

Among the gamma irradiation dosage and seed treatment chemicals, significantly higher shoot length (16.56 cm) was recorded by T_9 compared to all other treatments and control (16.08 cm) immediately after imposition of treatments. However, T_9 was on par with T_8 (16.14 cm) and T_7 (16.15 cm). Further, exposing the seeds to gamma irradiation (T_2- T_6) showed a significant reduction in shoot length wherein, T_6 recorded the lowest shoot length (10.95 cm) compared to control (16.08 cm). Further, the shoot length decreased linearly with an increase in storage period from initial to nine months after storage. During the entire storage period (one to nine months), the treatment T_9 recorded significantly higher shoot length (15.88, 14.95, 14.71, 14.51, 14.40, 14.26, 14.13, 13.93 and 13.73 cm) compared to control (15.26, 14.54, 14.34, 14.20, 13.96, 13.79, 13.71, 13.38 and 13.34 cm). Further, T_9 was on par with T_8 (15.61, 14.66, 14.39, 14.33, 14.11, 13.83, 13.59 and 13.48 cm) and T_7 (15.51, 14.58, 14.54, 14.36, 14.18, 13.95, 13.36 and

Table 7. Influence of gamma irradiation and seed treatment chemicals on shoot length (cm) of soybean and green gram

Treatments	Months after storage														
	Initial			1			2			3			4		
	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**
T_1	14.50	17.65	**16.08**	13.35	17.18	**15.26**	12.70	16.38	**14.54**	12.55	16.13	**14.34**	12.33	16.08	**14.20**
T_2	13.48	18.05	**15.76**	12.18	18.00	**15.09**	11.33	17.00	**14.16**	11.15	16.55	**13.85**	11.48	16.43	**13.95**
T_3	11.75	16.23	**13.99**	10.83	15.75	**13.29**	10.35	14.95	**12.65**	10.08	14.78	**12.43**	9.93	14.58	**12.25**
T_4	10.68	15.23	**12.95**	9.85	14.53	**12.19**	9.38	12.35	**10.86**	9.15	12.08	**10.61**	9.13	11.88	**10.50**
T_5	10.13	13.45	**11.79**	8.10	13.00	**10.55**	7.63	10.50	**9.06**	7.43	10.25	**8.84**	7.30	10.10	**8.70**
T_6	9.50	12.40	**10.95**	7.50	11.95	**9.73**	7.03	8.98	**8.00**	6.80	8.75	**7.78**	6.75	8.70	**7.73**
T_7	14.38	17.93	**16.15**	13.60	17.43	**15.51**	12.60	16.55	**14.58**	12.68	16.40	**14.54**	12.48	16.25	**14.36**
T_8	14.58	17.70	**16.14**	13.75	17.48	**15.61**	12.70	16.63	**14.66**	12.50	16.28	**14.39**	12.43	16.23	**14.33**
T_9	14.73	18.40	**16.56**	13.65	18.10	**15.88**	13.25	16.65	**14.95**	12.85	16.58	**14.71**	12.60	16.43	**14.51**
Mean	**12.63**	**16.34**		**11.42**	**15.93**		**10.77**	**14.44**		**10.58**	**14.20**		**10.49**	**14.07**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.12	0.34		0.08	0.30		0.07	0.30		0.06	0.16		0.06	0.17	
T	0.25	0.72		0.17	0.49		0.14	0.40		0.12	0.33		0.13	0.37	
C x T	0.36	1.20		0.24	0.69		0.20	0.56		0.17	0.47		0.18	0.52	

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 7. Influence of gamma irradiation and seed treatment chemicals on shoot length (cm) of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	12.00	15.93	**13.96**	11.90	15.68	**13.79**	11.95	15.48	**13.71**	11.75	15.00	**13.38**	11.73	14.90	**13.34**
T_2	11.30	16.33	**13.81**	11.08	15.90	**13.49**	10.08	15.75	**12.91**	9.95	15.50	**12.73**	9.53	14.70	**12.11**
T_3	9.83	14.48	**12.15**	9.55	14.18	**11.86**	9.25	14.15	**11.70**	9.25	13.95	**11.60**	8.98	12.98	**10.98**
T_4	9.00	11.83	**10.41**	8.63	11.63	**10.13**	8.43	11.53	**9.98**	8.25	11.20	**9.73**	8.00	11.08	**9.54**
T_5	7.18	10.05	**8.61**	6.90	9.88	**8.39**	6.75	9.73	**8.24**	6.63	9.35	**7.99**	6.53	9.18	**7.85**
T_6	6.60	8.63	**7.61**	6.28	8.25	**7.26**	6.18	8.03	**7.10**	6.00	7.83	**6.91**	5.95	7.55	**6.75**
T_7	12.15	16.20	**14.18**	12.08	15.83	**13.95**	11.45	15.28	**13.36**	11.30	15.23	**13.26**	11.23	13.80	**12.51**
T_8	12.15	16.08	**14.11**	11.98	15.68	**13.83**	11.70	15.48	**13.59**	11.58	15.38	**13.48**	11.43	13.95	**12.69**
T_9	12.45	16.35	**14.40**	12.28	16.25	**14.26**	12.10	16.15	**14.13**	11.88	15.98	**13.93**	11.55	15.80	**13.73**
Mean	**10.29**	**13.98**		**10.07**	**13.69**		**9.76**	**13.51**		**9.62**	**13.27**		**9.43**	**12.68**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.07	0.20		0.13	0.37		0.12	0.33		0.13	0.38		0.13	0.36	
T	0.15	0.42		0.28	0.90		0.25	0.70		0.28	0.90		0.27	0.77	
C x T	0.21	0.59		0.39	1.20		0.35	1.20		0.40	1.20		0.38	1.20	

Crops: **C_1-** Soybean **C_2-** Green gram

T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy **T_7 -** Malathion (2 g / kg of seed) **T_9-** Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy **T_8 -** Thiram (2 g / kg of seed)

13.26 cm) from one to eight months of storage. Even, T_9 was on par with T_1 (16.08, 15.26, 14.20, 13.79, 13.71, 13.38 and 13.34 cm) from zero, one, four, six, seven, eight and nine months of storage and with T_2 (13.49 cm) at six month of storage.

Among the interactions, C_2T_9 recorded significantly higher shoot length (18.40 cm) compared to all other treatment combinations immediately after imposition of treatments. Similarly, C_2T_9 was able to maintain significantly higher shoot length (18.10, 16.65, 16.58, 16.43 16.35, 16.25, 16.15, 15.98 and 15.80 cm) from one to nine months of storage compared to other treatments. However, C_2T_9 was on par with C_2T_8 (17.70, 17.48, 16.63, 16.28, 16.23, 16.08, 15.68, 15.48 and 15.38 cm) and C_1T_7 (17.93, 17.43, 16.55, 16.40, 16.25, 16.20, 15.83, 15.28 and 15.23 cm) from initial to eight months after storage respectively. Further, C_2T_9 was also on par with C_1T_1 (17.65, 16.38, 16.13, 16.08, 15.93, 15.68, 15.48, 15.00 and 14.90 cm) at zero, two, three, four, five, six, seven, eight and nine months of storage and C_2T_2 (18.05, 16.55, 16.43, 16.33, 15.90, 15.75, 15.50 and 14.70 cm) at one, three, four, five, six, seven, eight and nine months of storage.

4.1.8 Root length (Table 8)

The influence of gamma irradiation and seed treatment chemicals between crops showed similar trend for root length as that of shoot length.

Between the crops studied, C_2 was significantly superior in maintaining higher root length (20.42 cm) compared to C_1 (16.16 cm) immediately after imposition of treatments. Further, C_2 maintained significantly higher root length (19.81, 18.00, 16.98, 16.58, 16.23, 16.03, 15.71, 15.48 and 15.20 cm) during the entire storage period (up to nine months) compared to C_1 (14.79, 14.29, 14.06, 13.81, 13.66, 13.49, 13.16, 12.58 and 12.16 cm).

Among gamma irradiation dosage and seed treatment chemicals, it was T_9 which recorded significantly higher root length (20.56 cm) compared control (19.39 cm) immediately after the imposition of treatments. However, T_9 was on par with T_8 (20.25 cm). There was a significant decrease in root length as the seeds were further exposed to higher gamma irradiation dosage (T_2- T_6) wherein, T_6 recorded the lowest root length (14.88 cm) compared to control (19.39 cm). Similarly, the root length went on decreased as the storage period advanced to nine months. The treatment, T_9 recorded significantly higher root length (19.75, 18.66, 18.05, 17.54, 17.45, 17.11, 16.79, 16.51 and 16.24 cm)

Table 8. Influence of gamma irradiation and seed treatment chemicals on root length (cm) of soybean and green gram

Treatments	**Months after storage**														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	17.48	21.30	**19.39**	15.58	20.75	**18.16**	15.43	18.83	**17.13**	15.03	17.58	**16.30**	14.63	17.35	**15.99**
T_2	16.28	21.85	**19.06**	15.25	20.92	**18.09**	14.70	19.63	**17.16**	14.60	18.43	**16.51**	14.48	18.33	**16.40**
T_3	15.63	20.18	**17.90**	14.78	19.63	**17.20**	14.23	18.33	**16.28**	14.10	17.60	**15.85**	13.98	16.60	**15.29**
T_4	14.55	19.18	**16.86**	13.80	18.63	**16.21**	13.25	16.23	**14.74**	12.90	15.05	**13.98**	12.73	14.95	**13.84**
T_5	14.00	17.43	**15.71**	12.05	16.88	**14.46**	11.50	14.38	**12.94**	11.35	13.35	**12.35**	11.23	13.25	**12.24**
T_6	13.38	16.38	**14.88**	11.45	15.83	**13.64**	10.90	12.85	**11.88**	10.65	12.40	**11.53**	10.53	11.60	**11.06**
T_7	17.68	22.33	**20.00**	16.10	21.30	**18.70**	15.55	20.33	**17.94**	15.35	19.13	**17.24**	15.20	18.93	**17.06**
T_8	17.98	22.53	**20.25**	17.03	21.98	**19.50**	16.53	20.73	**18.63**	16.18	19.60	**17.89**	15.73	18.98	**17.35**
T_9	18.50	22.63	**20.56**	17.13	22.38	**19.75**	16.58	20.75	**18.66**	16.43	19.68	**18.05**	15.85	19.23	**17.54**
Mean	**16.16**	**20.42**		**14.79**	**19.81**		**14.29**	**18.00**		**14.06**	**16.98**		**13.81**	**16.58**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.06	0.18		0.08	0.24		0.07	0.17		0.04	0.11		0.04	0.13	
T	0.13	0.38		0.14	0.42		0.13	0.36		0.08	0.24		0.09	0.27	
C x T	0.19	0.57		0.20	0.60		0.18	0.50		0.12	0.34		0.13	0.38	

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 8. Influence of gamma irradiation and seed treatment chemicals on root length (cm) of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	14.38	17.10	**15.74**	14.18	16.85	**15.51**	13.98	16.00	**14.99**	13.58	15.85	**14.71**	12.30	15.70	**14.00**
T_2	14.33	17.48	**15.90**	14.08	17.80	**15.94**	13.85	17.50	**15.68**	12.65	17.30	**14.98**	11.85	16.98	**14.41**
T_3	13.83	16.35	**15.09**	13.55	16.13	**14.84**	13.20	15.93	**14.56**	12.03	15.80	**13.91**	11.63	14.73	**13.18**
T_4	12.60	14.75	**13.68**	12.48	14.43	**13.45**	12.18	14.00	**13.09**	11.68	13.85	**12.76**	11.48	13.78	**12.63**
T_5	11.10	12.98	**12.04**	10.90	12.78	**11.84**	10.80	12.33	**11.56**	10.63	12.08	**11.35**	10.53	12.03	**11.28**
T_6	10.43	11.28	**10.85**	10.33	11.20	**10.76**	10.13	10.88	**10.50**	9.93	10.78	**10.35**	9.63	10.63	**10.13**
T_7	15.00	18.23	**16.61**	14.93	17.95	**16.44**	14.48	17.93	**16.20**	13.73	17.53	**15.63**	13.53	17.28	**15.40**
T_8	15.53	18.80	**17.16**	15.40	18.45	**16.93**	14.75	18.35	**16.55**	14.28	17.90	**16.09**	14.08	17.73	**15.90**
T_9	15.80	19.10	**17.45**	15.58	18.65	**17.11**	15.10	18.48	**16.79**	14.75	18.28	**16.51**	14.48	18.00	**16.24**
Mean	**13.66**	**16.23**		**13.49**	**16.03**		**13.16**	**15.71**		**12.58**	**15.48**		**12.16**	**15.20**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.05	0.15	0.07	0.19	0.18	0.51	0.15	0.42	0.16	0.48
T	0.11	0.31	0.14	0.39	0.38	1.08	0.31	0.88	0.34	1.02
C x T	0.15	0.44	0.20	0.56	0.54	1.62	0.44	1.25	0.44	1.24

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

compared to control (18.16, 17.13, 16.30, 15.99, 15.74, 15.51, 14.99, 14.71 and 14.00 cm) from one to nine months of storage respectively. However, T_9 was on par with T_8 (19.50, 18.63, 17.89, 17.35, 17.16, 16.93, 16.55, 16.09 and 15.90 cm) from one to nine months of storage. Further, T_9 was also on par with T_7 (16.20, 15.63 and 15.40 cm) from seven to nine months of storage.

Interaction of crops with gamma irradiation and seed treatment chemicals revealed that, C_2T_9 was superior in recording significantly higher root length (22.63 cm) compared to all other treatment combinations immediately after imposition of treatments. During the entire period of storage, C_2T_9 also maintained higher root length (22.38, 20.75, 19.68, 19.23, 19.10, 18.65, 18.48, 18.28 and 18.00 cm). But, C_2T_9 was on par with C_2T_8 (22.53, 21.98, 20.73, 19.60, 18.98, 18.80, 18.45, 18.35, 17.90 and17.73 cm) from initial to nine months of storage.

4.1.9 Seedling dry weight (Table 9)

The seedling dry weight was significantly influenced by gamma irradiation and seed treatment chemicals in both crops.

Between the crops, C_2 recorded significantly higher seedling dry weight (0.384 g) compared to C_1 (0.379 g) immediately after imposition of treatments. However, C_2 maintained significantly higher seedling dry weight (0.374, 0.367, 0.355, 0.347, 0.337, 0.328, 0.318, 0.306 and 0.293 g) compared to C_1 (0.367, 0.362, 0.352, 0.343, 0.334, 0.323, 0.314, 0.303 and 0.290 g) from one to nine months after storage.

The seedling dry weight of 0.418 g was recorded by T_9 which was significantly higher than all other treatments and control (0.398 g) immediately after the imposition of treatments. However, T_9 was on par with T_8 which recorded 0.414 g of seedling dry weight. By exposing the seeds to gamma irradiation (T_2- T_6) showed a significantly decrease in seedling dry weight, wherein, T_6 recorded the lowest seedling dry weight (0.307 g) compared to control (0.398 g).The seedling dry weight decreased further as the time elapsed from zero to nine month of storage. The treatment, T_9 recorded significantly higher seedling dry weight (0.406, 0.400, 0.386, 0.380, 0.368, 0.363, 0.354, 0.343 and 0.333 g) compared to control (0.387, 0.380, 0.366, 0.360, 0.351, 0.339, 0.319, 0.307 and 0.291 g) from one to nine months of seed storage. However, T_9 was on par with T_8 (0.403, 0.394, 0.385, 0.375, 0.361, 0.351 0.349, 0.337 and 0.324 g) at one, two, three, four, five,

Table 9. Influence of gamma irradiation and seed treatment chemicals on seedling dry weight (g) of soybean and green gram

Treatments	Months after storage														
	Initial			1			2			3			4		
	C$_1$	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**
T$_1$	0.395	0.402	**0.398**	0.384	0.390	**0.387**	0.380	0.381	**0.380**	0.363	0.369	**0.366**	0.359	0.360	**0.360**
T$_2$	0.386	0.404	**0.395**	0.376	0.394	**0.385**	0.369	0.384	**0.376**	0.366	0.373	**0.369**	0.353	0.362	**0.358**
T$_3$	0.381	0.391	**0.386**	0.371	0.381	**0.376**	0.365	0.377	**0.371**	0.357	0.366	**0.362**	0.348	0.360	**0.354**
T$_4$	0.373	0.370	**0.371**	0.362	0.360	**0.361**	0.360	0.351	**0.355**	0.351	0.332	**0.341**	0.345	0.324	**0.334**
T$_5$	0.337	0.338	**0.337**	0.327	0.328	**0.327**	0.325	0.325	**0.325**	0.315	0.311	**0.313**	0.303	0.307	**0.305**
T$_6$	0.299	0.315	**0.307**	0.289	0.305	**0.297**	0.279	0.302	**0.290**	0.273	0.298	**0.286**	0.266	0.286	**0.276**
T$_7$	0.411	0.406	**0.409**	0.390	0.398	**0.394**	0.386	0.389	**0.387**	0.373	0.374	**0.373**	0.364	0.363	**0.363**
T$_8$	0.415	0.414	**0.414**	0.403	0.404	**0.403**	0.397	0.391	**0.394**	0.385	0.386	**0.385**	0.372	0.377	**0.375**
T$_9$	0.418	0.418	**0.418**	0.405	0.407	**0.406**	0.399	0.402	**0.400**	0.385	0.388	**0.386**	0.376	0.384	**0.380**
Mean	**0.379**	**0.384**		**0.367**	**0.374**		**0.362**	**0.367**		**0.352**	**0.355**		**0.343**	**0.347**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.007	0.021		0.008	0.024		0.006	0.018		0.005	0.015		0.002	0.006	
T	0.016	0.045		0.017	0.047		0.013	0.036		0.010	0.027		0.005	0.014	
C x T	0.022	0.066		0.024	0.072		0.018	0.054		0.014	0.042		0.007	0.020	

Crops: **C$_1$**- Soybean **C$_2$**- Green gram

T$_1$ - Control **T$_3$ -** 400 Gy **T$_5$ --** 800 Gy **T$_7$ -** Malathion (2 g / kg of seed) **T$_9$-** Malathion + Thiram (each 2 g / kg of seed)

T$_2$ - 200 Gy **T$_4$ -** 600 Gy **T$_6$ -** 1000 Gy **T$_8$ -** Thiram (2 g / kg of seed)

Table 9. Influence of gamma irradiation and seed treatment chemicals on seedling dry weight (g) of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	0.350	0.351	**0.351**	0.334	0.345	**0.339**	0.326	0.312	**0.319**	0.317	0.297	**0.307**	0.303	0.279	**0.291**
T_2	0.348	0.357	**0.352**	0.333	0.348	**0.340**	0.324	0.323	**0.323**	0.313	0.306	**0.310**	0.296	0.287	**0.292**
T_3	0.344	0.325	**0.335**	0.331	0.306	**0.318**	0.317	0.296	**0.307**	0.304	0.291	**0.298**	0.286	0.271	**0.278**
T_4	0.338	0.312	**0.325**	0.327	0.299	**0.313**	0.306	0.293	**0.299**	0.285	0.288	**0.286**	0.277	0.267	**0.272**
T_5	0.296	0.302	**0.299**	0.292	0.287	**0.289**	0.288	0.284	**0.286**	0.274	0.278	**0.276**	0.271	0.263	**0.267**
T_6	0.264	0.282	**0.273**	0.263	0.279	**0.271**	0.252	0.268	**0.260**	0.249	0.262	**0.255**	0.238	0.260	**0.249**
T_7	0.352	0.357	**0.355**	0.336	0.357	**0.346**	0.334	0.355	**0.344**	0.326	0.335	**0.331**	0.306	0.331	**0.318**
T_8	0.354	0.368	**0.361**	0.337	0.366	**0.351**	0.335	0.364	**0.349**	0.328	0.346	**0.337**	0.314	0.335	**0.324**
T_9	0.358	0.378	**0.368**	0.356	0.370	**0.363**	0.343	0.366	**0.354**	0.333	0.353	**0.343**	0.322	0.344	**0.333**
Mean	**0.334**	**0.337**		**0.323**	**0.328**		**0.314**	**0.318**		**0.303**	**0.306**		**0.290**	**0.293**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.005	0.016	0.003	0.009	0.006	0.017	0.002	0.006	0.003	0.008
T	0.011	0.032	0.006	0.018	0.010	0.028	0.005	0.013	0.004	0.011
C x T	0.016	0.046	0.009	0.026	0.014	0.042	0.007	0.019	0.005	0.015

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 - 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

six, seven, eight and nine months after storage. Even T_9 was on par with T_7 (0.409, 0.394, 0.387, 0.373, 0.363, 0.355, 0.346, 0.344, 0.331) at one, two, three, four, five, six, seven and eight months after storage, T_2 (0.395, 0.385, 0.376, 0.369,0.352) and T_1 (0.398, 0.387, 0.380, 0.366, 0.351) at initial, one, two, three, and five months of storage, T_3 (0.386, 0.376, 0.371 and 0.362) at initial, one, two and three months of storage and T_4 (0.361) one time months of storage.

Among interactions, C_2T_9 recorded significantly higher seedling dry weight (0.418 g) compared to all other treatment combination immediately after imposition of gamma irradiation and seed treatment chemicals. Similarly, from one to nine months of seed storage, C_2T_9 maintained higher seedling dry matter (0.407, 0.402, 0.388, 0.384, 0.378, 0.370, 0.366, 0.353 and 0.344 g). However, C_2T_9 was on par with C_2T_8 (0.414, 0.404, 0.391, 0.386, 0.377, 0.368, 0.366, 0.364, 0.346 and 0.335 g) at zero, one, two, three, four, five, six, seven, eight and nine months of seed storage, C_2T_7 (0.406, 0.398, 0.389, 0.374, 0.357, 0.357, 0.355, 0.335 and 0.331) zero, one, two, three, five, six, seven, eight and nine, C_2T_1 (0.402, 0.390, 0.381, 0.369, 0.351 and 0.345) at zero, one, two, three, five, six months of storage, C_2T_2 (0.404, 0.394, 0.384, 0.373,0.357 and 0.348) at zero, one, two, three, five and six months of storage, Further, C_2T_9 was also on par with C_1T_9 (0.418, 0.405, 0.399, 0.385, 0.376, 0.358, 0.356, and 0.343 g) at initial, one, two three, four, five, six and seven month of storage and C_1T_1 (0.395, 0.384, 0.380, 0.363 0.350, 0.334 and 0.326) at zero, one, two, three, five, six and seven months of storage.

4.1.10 Seedling vigour index (Table 10)

The seedling vigour index was significantly influenced in both the crops due to gamma irradiation and seed treatment chemicals.

Between the crops under study, C_2 registered significantly higher seedling vigour index (3065) compared to C_1 (2490) immediately after imposition of treatments. Accordingly, from one to nine months of storage, C_2 maintained significantly higher seedling vigour index (2923, 2620, 2472, 2374, 2283, 2212, 2147, 2067 and 1979) compared to C_1 (2238, 2061, 1987, 1873, 1795, 1721, 1624, 1527 and 1410).

Among the gamma irradiation dosage and seed treatment chemicals, T_9 recorded significantly higher seedling vigour index (3343) compared to all other treatments and control (3135) immediately after the imposition of treatments. Further, exposing the seeds

Table 10. Influence of gamma irradiation and seed treatment chemicals on seedling vigour index of soybean and green gram

Treatments	Months after storage														
	Initial			1			2			3			4		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2941	3330	**3135**	2639	3195	**2917**	2511	2940	**2725**	2405	2789	**2597**	2208	2675	**2441**
T_2	2530	3432	**2981**	2298	3320	**2809**	2066	3086	**2576**	2001	2919	**2460**	1951	2799	**2375**
T_3	2236	3066	**2651**	2028	2901	**2464**	1885	2678	**2282**	1821	2516	**2169**	1755	2391	**2073**
T_4	2012	2822	**2417**	1857	2519	**2188**	1676	2136	**1906**	1593	1962	**1777**	1540	1898	**1719**
T_5	1810	2403	**2106**	1482	2240	**1861**	1311	1816	**1563**	1267	1686	**1476**	1199	1622	**1410**
T_6	1694	2168	**1931**	1378	2076	**1727**	1205	1572	**1389**	1146	1476	**1311**	1101	1389	**1245**
T_7	2989	3409	**3199**	2740	3253	**2997**	2533	3061	**2797**	2474	2932	**2703**	2317	2823	**2570**
T_8	3050	3402	**3235**	2847	3331	**3089**	2645	3110	**2878**	2556	2952	**2754**	2378	2833	**2606**
T_9	3149	3536	**3343**	2878	3471	**3174**	2714	3179	**2946**	2619	3017	**2818**	2411	2940	**2675**
Mean	**2490**	**3065**		**2238**	**2923**		**2061**	**2620**		**1987**	**2472**		**1873**	**2374**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	13	38	11	31	11	32	10	28	10	27
T	28	81	23	66	24	69	21	60	20	58
C x T	40	115	33	93	34	97	30	84	29	82

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy **T_7 -** Malathion (2 g / kg of seed) **T_9-** Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy **T_8 -** Thiram (2 g / kg of seed)

Table 10. Influence of gamma irradiation and seed treatment chemicals on seedling vigour index of soybean and green gram *concluded*

Treatments	Months after storage														
	5			6			7			8			9		
	C$_1$	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**	**C$_1$**	**C$_2$**	**Mean**
T$_1$	2089	2582	**2336**	1999	2503	**2251**	1940	2409	**2174**	1806	2295	**2051**	1645	2258	**1952**
T$_2$	1883	2661	**2272**	1822	2611	**2217**	1666	2559	**2112**	1564	2475	**2019**	1400	2375	**1887**
T$_3$	1691	2310	**2000**	1625	2228	**1926**	1517	2159	**1838**	1414	1996	**1705**	1290	1857	**1574**
T$_4$	1485	1821	**1653**	1427	1742	**1584**	1349	1683	**1516**	1254	1641	**1447**	1191	1601	**1396**
T$_5$	1150	1564	**1357**	1115	1506	**1310**	1081	1450	**1266**	1053	1398	**1225**	980	1356	**1168**
T$_6$	1067	1330	**1199**	1036	1274	**1155**	990	1227	**1109**	929	1206	**1067**	880	1150	**1015**
T$_7$	2200	2686	**2443**	2106	1274	**2358**	1962	2532	**2247**	1839	2441	**2140**	1703	2283	**1993**
T$_8$	2262	2738	**2500**	2154	2654	**2404**	2008	2567	**2297**	1907	2489	**2198**	1768	2320	**2044**
T$_9$	2330	2860	**2595**	2214	2781	**2498**	2101	2718	**2410**	1977	2664	**2320**	1828	2616	**2222**
Mean	**1795**	**2283**		**1721**	**2212**		**1624**	**2147**		**1527**	**2067**		**1410**	**1979**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	9	24	13	38	16	49	16	47	16	44
T	18	52	28	81	35	99	35	99	33	94
C x T	26	73	40	114	49	143	49	140	47	132

Crops: **C$_1$**- Soybean **C$_2$**- Green gram

T$_1$ - Control **T$_3$ -** 400 Gy **T$_5$ --** 800 Gy **T$_7$ -** Malathion (2 g / kg of seed) **T$_9$-** Malathion + Thiram (each 2 g / kg of seed)

T$_2$ - 200 Gy **T$_4$ -** 600 Gy **T$_6$ -** 1000 Gy **T$_8$ -** Thiram (2 g / kg of seed) to gamma irradiation (T_2- T_6) showed a significant decrease in seedling vigour index wherein, T_6 recorded the lowest seedling vigour index (1931) compared to control (3135). The seedling vigour index linearly decreased with an increase in storage period from zero to nine months of storage. But, T_9 recorded significantly higher seedling vigour index (3174, 2946, 2818, 2675, 2595, 2498, 2410, 2320 and 2222) compared to control (2917, 2725, 2597, 2441, 2336, 2251, 2174, 2051 and 1952) from one to nine months of storage, respectively. However, T_9 was on par with T_8 (2878) at second month of storage.

Among the interactions, C_2T_9 recorded significantly higher seed vigour index (3536) compared to all other treatments immediately after imposition of treatments. Meanwhile, C_2T_9 was able to maintain significantly higher seedling vigour (3471, 3179, 3017, 2940, 2860, 2781, 2718, 2664 and 2616) during the entire storage period. However, C_2T_9 was on par with C_2T_2 (3432 and 3086) at zero and two months after storage and with C_2T_8 (3110 and 2952) at two and three months after storage.

4.1.11 Seed infection percentage (Table 11)

The seed infection varied significantly due to gamma irradiation and seed treatment chemicals between the two crops.

Soybean (C_1) recorded significantly lower seed infection (13.6%) compared to green gram, C_2 (17.6%) immediately after imposition of treatments. However, C_1 was able to maintain lower seed infection (16.7, 20.9, 23.3, 26.0, 28.9, 31.6, 39.1, 43.6 and 48.4%) compared to C_2 (26.0, 32.7, 47.1, 59.8, 64.0, 66.7, 72.0, 74.7 and 78.2%) from one to nine months after storage, respectively.

Among the gamma irradiation dosage and seed treatment chemicals, T_9 recorded significantly lower seed infection (4.0%) compared to all other treatments and control (30.0%) immediately after imposition of treatments. However, T_9 was on par with T_8 (6.0%) and T_7 (9.0%). Further, exposing the seeds to the gamma irradiation (T_2 to T_6) showed a significant decrease in seed infection with an increase in the gamma irradiation dosage wherein, T_6 recorded the lowest seed infection (12.0%) compared to control

(30.0%). Further, the seed infection increased linearly up to nine months of seed storage. During the entire period of storage, T_9 recorded significantly lower seed infection (7.0, 11.0, 20.0, 26.0, 29.0, 31.0, 39.0, 46.0 and 50.0%) compared to control (33.0, 37.0, 51.0, 57.0, 63.0, 64.0, 71.0, 73.0 and 77.0%) from one to nine months after storage,

Table 11. Influence of gamma irradiation and seed treatment chemicals on seed infection (%) of soybean and green gram

Treatments	**Months after storage**														
	Initial			**1**			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	26.0 (30.6)	34.0 (35.6)	**30.0 (33.1)**	28.0 (31.7)	38.0 (38.0)	**33.0 (34.8)**	30.0 (32.9)	44.0 (41.5)	**37.0 (37.2)**	34.0 (35.6)	68.0 (55.6)	**51.0 (45.6)**	36.0 (36.9)	78.0 (62.6)	**57.0 (49.7)**
T_2	22.0 (27.9)	26.0 (30.6)	**24.0 (29.3)**	26.0 (29.7)	32.0 (34.4)	**29.0 (32.1)**	34.0 (35.6)	42.0 (40.4)	**38.0 (38.0)**	36.0 (36.8)	56.0 (48.4)	**46.0 (42.6)**	40.0 (39.1)	72.0 (58.1)	**56.0 (48.6)**
T_3	20.0 (26.4)	22.0 (27.9)	**21.0 (27.2)**	22.0 (27.3)	30.0 (33.1)	**26.0 (30.4)**	28.0 (31.9)	40.0 (39.2)	**34.0 (35.5)**	32.0 (34.0)	64.0 (53.1)	**48.0 (43.6)**	38.0 (38.0)	72.0 (58.6)	**55.0 (48.3)**
T_4	16.0 (23.4)	20.0 (26.6)	**18.0 (25.0)**	20.0 (26.4)	34.0 (35.6)	**27.0 (31.0)**	26.0 (30.9)	36.0 (36.7)	**31.0 (33.7)**	28.0 (31.7)	60.0 (50.8)	**44.0 (41.2)**	30.0 (33.1)	64.0 (53.1)	**47.0 (43.1)**
T_5	14.0 (21.9)	18.0 (25.1)	**16.0 (23.2)**	18.0 (24.2)	28.0 (31.9)	**23.0 (28.0)**	22.0 (27.8)	34.0 (35.6)	**28.0 (31.7)**	24.0 (29.2)	42.0 (40.4)	**33.0 (34.8)**	26.0 (30.5)	62.0 (51.9)	**44.0 (41.2)**
T_6	10.0 (18.3)	14.0 (21.9)	**12.0 (20.1)**	16.0 (22.9)	26.0 (30.5)	**21.0 (26.7)**	20.0 (26.1)	26.0 (30.6)	**23.0 (28.4)**	22.0 (27.9)	36.0 (36.7)	**29.0 (32.3)**	24.0 (29.3)	52.0 (46.1)	**38.0 (37.7)**
T_7	8.0 (16.4)	10.0 (18.3)	**9.0 (17.4)**	8.0 (15.9)	18.0 (25.1)	**13.0 (20.5)**	12.0 (20.3)	32.0 (34.3)	**22.0 (27.3)**	12.0 (20.3)	34.0 (35.6)	**23.0 (28.0)**	14.0 (21.9)	52.0 (46.2)	**33.0 (34.0)**
T_8	4.0 (8.2)	8.0 (16.4)	**6.0 (12.4)**	8.0 (15.9)	18.0 (25.1)	**13.0 (20.5)**	10.0 (18.3)	24.0 (29.0)	**17.0 (23.7)**	14.0 (21.5)	32.0 (34.4)	**23.0 (27.9)**	14.0 (21.9)	46.0 (42.7)	**30.0 (32.3)**
T_9	2.0 (5.8)	6.0 (14.0)	**4.0 (9.9)**	4.0 (11.5)	10.0 (18.3)	**7.0 (14.9)**	6.0 (14.0)	16.0 (23.6)	**11.0 (18.8)**	8.0 (16.4)	32.0 (34.9)	**20.0 (25.4)**	12.0 (20.0)	40.0 (39.2)	**26.0 (29.6)**
Mean	**13.6 (19.9)**	**17.6 (24.1)**		**16.7 (22.9)**	**26.0 (30.2)**		**20.9 (26.4)**	**32.7 (34.5)**		**23.3 (28.2)**	**47.1 (43.3)**		**26.0 (31.0)**	**59.8 (50.9)**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	1.0	2.9	1.5	4.4	1.2	3.5	1.1	3.3	1.3	3.8
T	2.0	6.1	3.1	9.3	2.4	7.3	2.3	7.0	2.7	8.1
C x T	2.9	8.7	4.4	13.2	3.5	10.5	3.3	9.9	3.8	11.4

Crops: **C_1-** Soybean **C_2-** Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 11. Influence of gamma irradiation and seed treatment chemicals on seed infection (%) of soybean and green gram *concluded*

Treatments	**Months after storage**														
	5			**6**			**7**			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	44.0 (41.5)	82.0 (64.9)	**63.0 (53.2)**	46.0 (42.7)	82.0 (65.2)	**64.0 (53.9)**	54.0 (47.3)	88.0 (69.7)	**71.0 (58.5)**	56.0 (48.4)	90.0 (71.6)	**73.0 (60.0)**	64.0 (53.2)	90.0 (72.4)	**77.0 (62.8)**
T_2	42.0 (40.4)	80.0 (63.5)	**61.0 (51.9)**	44.0 (41.3)	82.0 (65.2)	**63.0 (53.3)**	52.0 (46.1)	84.0 (66.4)	**68.0 (56.3)**	54.0 (47.3)	86.0 (68.1)	**70.0 (57.7)**	58.0 (49.8)	88.0 (70.0)	**73.0 (59.9)**
T_3	40.0 (39.2)	76.0 (62.1)	**58.0 (50.7)**	42.0 (40.4)	78.0 (62.2)	**60.0 (51.3)**	44.0 (41.5)	80.0 (63.5)	**62.0 (52.5)**	48.0 (43.8)	82.0 (64.9)	**65.0 (54.4)**	56.0 (48.5)	84.0 (66.4)	**70.0 (57.5)**
T_4	32.0 (34.4)	66.0 (54.4)	**49.0 (44.4)**	34.0 (35.6)	74.0 (59.3)	**54.0 (47.5)**	42.0 (40.4)	76.0 (60.7)	**59.0 (50.5)**	46.0 (42.7)	78.0 (62.2)	**62.0 (52.4)**	54.0 (47.3)	80.0 (63.5)	**67.0 (55.4)**
T_5	28.0 (31.7)	66.0 (54.3)	**47.0 (43.0)**	32.0 (34.3)	70.0 (57.1)	**51.0 (45.7)**	44.0 (41.5)	70.0 (56.9)	**57.0 (49.2)**	48.0 (43.8)	74.0 (59.5)	**61.0 (51.7)**	52.0 (46.1)	78.0 (62.2)	**65.0 (54.2)**
T_6	26.0 (30.5)	60.0 (50.3)	**43.0 (40.6)**	28.0 (31.9)	62.0 (51.9)	**45.0 (41.9)**	30.0 (33.2)	66.0 (54.3)	**48.0 (43.8)**	40.0 (39.1)	70.0 (57.1)	**55.0 (48.1)**	44.0 (41.5)	74.0 (59.8)	**59.0 (50.6)**
T_7	16.0 (23.4)	54.0 (47.4)	**35.0 (35.4)**	20.0 (26.6)	54.0 (47.3)	**37.0 (36.9)**	34.0 (35.6)	64.0 (53.1)	**49.0 (44.3)**	36.0 (36.7)	66.0 (54.3)	**51.0 (45.5)**	40.0 (39.2)	72.0 (58.0)	**56.0 (48.6)**
T_8	18.0 (25.1)	48.0 (43.8)	**33.0 (34.4)**	22.0 (27.9)	52.0 (46.1)	**37.0 (37.0)**	32.0 (34.4)	62.0 (52.0)	**47.0 (43.2)**	34.0 (35.6)	64.0 (53.1)	**49.0 (44.4)**	36.0 (36.9)	70.0 (56.9)	**53.0 (46.9)**
T_9	14.0 (21.9)	44.0 (41.5)	**29.0 (31.7)**	16.0 (23.4)	46.0 (42.6)	**31.0 (33.0)**	20.0 (26.6)	58.0 (49.6)	**39.0 (38.1)**	30.0 (33.2)	62.0 (51.9)	**46.0 (42.6)**	32.0 (34.4)	68.0 (55.6)	**50.0 (45.0)**
Mean	**28.9 (32.0)**	**64.0 (53.6)**		**31.6 (33.8)**	**66.7 (55.2)**		**39.1 (38.5)**	**72.0 (58.5)**		**43.6 (41.2)**	**74.7 (60.3)**		**48.4 (44.1)**	**78.2 (62.7)**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	1.4	4.2	1.4	4.1	0.6	1.9	0.9	2.8	1.3	4.0
T	3.0	9.0	2.9	8.6	1.4	4.1	2.0	6.0	2.8	8.5
C x T	4.2	12.6	4.1	12.3	1.9	5.7	2.8	8.4	4.0	12.0

Crops: **C_1**- Soybean **C_2**- Green gram
T_1 - Control **T_2** - 200 Gy **T_3** - 400 Gy **T_4** - 600 Gy **T_5** - 800 Gy **T_6** - 1000 Gy **T_7** - Malathion (2 g / kg of seed) **T_8** - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

respectively. However, T_9 was on par with T_8 (13.0, 17.0, 23.0, 30.0, 33.0, 37.0, 49.0 and 53.0%) from one to nine months after storage except at seventh month of storage, respectively and T_7 (13.0, 23.0, 33.0, 35.0, 37.0, 51.0 and 56.0%) from one to nine months after storage except at two and seventh month of storage, respectively.

Among the interactions, C_1T_9 maintained significantly lower seed infection during the entire period of seed storage (2.0, 4.0, 6.0, 8.0, 12.0, 14.0, 16.0, 20.0, 30.0 and 32.0%). However, C_1T_9 was on par with C_1T_8 (4.0, 8.0, 10.0, 14.0, 14.0, 18.0, 22.0, 34.0 and 36.0%), C_1T_7 (8.0, 8.0, 12.0, 12.0, 14.0, 16.0, 20.0, 36.0 and 40.0%) from initial to nine months after storage except at seven month of storage, respectively and C_1T_6 (10.0, 16.0, 24.0, 26.0, 28.0 and 44.0%) at initial, one, four, five, six and nine months of storage.

4.1.12 Insect egg percentage (Table 12)

The insect eggs were not noticed during the entire month of seed storage in soybean. However, the insect eggs on green gram seeds were noticed from seventh month of storage.

Among the gamma irradiation and seed treatment chemicals, the insect eggs were not at all noticed in the treatments T_2 to T_6 up to seven months of storage. However, T_1 (control) recorded significantly higher insect egg (1.34, 1.66 and 1.78%) at seven, eight and nine months after storage, respectively. However, T_6 recorded the lowest insect egg (0.0, 0.10 and 0.30%) during seven, eight and nine months after seed storage, respectively.

Among the interactions, C_2T_1 showed significantly higher insect eggs (2.68, 3.33 and 3.55%) compared to all other treatments from seven to nine month of storage.

4.1.13a Seed damage percentage (Table 13)

The seed damage was not at all noticed till ninth month of seed storage in soybean. However, in green gram the seed damage was noticed from seventh month after storage.

Among the gamma irradiation and seed treatment chemicals, the seed damage was not noticed at all in the treatments from T_2 to T_6 up to seventh months of storage. However, T_1 (control) recorded significantly higher seed damage with pin hole seeds (1.66, 1.83 and 2.08%) at seven, eight and nine months after storage, respectively.

Table 12. Influence of gamma irradiation and seed treatment chemicals on insect egg (%) of soybean and green gram

Treatments	**Months of storage**								
	7			**8**			**9**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	0.00	2.68	**1.34**	0.00	3.33	**1.66**	0.00	3.55	**1.78**
T_2	0.00	0.00	**0.00**	0.00	1.00	**0.50**	0.00	1.55	**0.78**
T_3	0.00	0.00	**0.00**	0.00	0.65	**0.33**	0.00	1.23	**0.61**
T_4	0.00	0.00	**0.00**	0.00	0.45	**0.23**	0.00	1.10	**0.55**
T_5	0.00	0.00	**0.00**	0.00	0.33	**0.16**	0.00	0.75	**0.38**
T_6	0.00	0.00	**0.00**	0.00	0.20	**0.10**	0.00	0.60	**0.30**
T_7	0.00	0.95	**0.48**	0.00	1.40	**0.70**	0.00	1.75	**0.88**
T_8	0.00	1.40	**0.70**	0.00	1.60	**0.80**	0.00	2.00	**1.00**
T_9	0.00	1.15	**0.58**	0.00	1.25	**0.63**	0.00	1.70	**0.85**
Mean	**0.00**	**0.69**		**0.00**	**1.13**		**0.00**	**1.58**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.01	0.04	0.02	0.06	0.02	0.05
T	0.03	0.08	0.04	0.12	0.04	0.10
C x T	0.04	0.11	0.06	0.17	0.05	0.15

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** – 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Table 13. Influence of gamma irradiation and seed treatment chemicals on seed damage (%) and weight loss (%) of soybean and green gram

Treatments	Months after storage									Weight loss		
	7			8			9					
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	0.00	3.33	**1.66**	0.00	3.65	**1.83**	0.00	4.15	**2.08**	0.00	5.30	**2.65**
T_2	0.00	0.00	**0.00**	0.00	1.13	**0.56**	0.00	2.25	**1.13**	0.00	3.55	**1.78**
T_3	0.00	0.00	**0.00**	0.00	1.00	**0.50**	0.00	1.95	**0.98**	0.00	2.70	**1.35**
T_4	0.00	0.00	**0.00**	0.00	0.88	**0.44**	0.00	1.75	**0.88**	0.00	2.40	**1.20**
T_5	0.00	0.00	**0.00**	0.00	0.70	**0.35**	0.00	1.00	**0.50**	0.00	2.15	**1.08**
T_6	0.00	0.00	**0.00**	0.00	0.48	**0.24**	0.00	0.73	**0.36**	0.00	1.40	**0.70**
T_7	0.00	1.10	**0.55**	0.00	1.40	**0.70**	0.00	2.48	**1.24**	0.00	3.45	**1.73**
T_8	0.00	1.63	**0.81**	0.00	1.85	**0.93**	0.00	2.70	**1.35**	0.00	3.85	**1.93**
T_9	0.00	0.75	**0.38**	0.00	1.58	**0.79**	0.00	2.55	**1.28**	0.00	3.25	**1.63**
Mean	**0.00**	**0.76**		**0.00**	**1.41**		**0.00**	**2.17**		**0.00**	**3.12**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.01	0.02	0.02	0.06	0.01	0.04	0.03	0.09
T	0.02	0.04	0.04	0.12	0.03	0.08	0.06	0.18
C x T	0.02	0.06	0.06	0.17	0.04	0.11	0.09	0.26

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

Further, with an increase in the gamma irradiation dosage, the seed damage (%) decreased further wherein, T_6 recorded the lowest seed damage (0.0, 0.24, 0.36%) at seven, eight and nine months after seed storage respectively.

Among the interactions, C_2T_1 (3.33, 3.65 and 4.15%) showed significantly higher seed damage compared to all other treatments from seven to nine month of storage.

4.1.13b Per cent weight loss (Table 13)

The seed weight loss was significantly influenced by seed treatment chemicals and gamma irradiation dosage in both the crops.

Between the crops, the per cent weight loss was not at all noticed in soybean compared to green gram (3.12) whereas, the seed weight loss was noticed in all the treatments. T_1 (control) recorded significantly higher seed weight loss (2.65%) after nine months of storage. Further, with an increase in gamma irradiation dosage, the seed weight loss went on decreased linearly wherein, T_6 recorded the lowest seed weight loss (0.70%) nine months after storage.

4.1.14 Dehydrogenase enzyme activity (Table 14)

The dehydrogenase enzyme activity (OD value) was significantly influenced by gamma irradiation and seed treatment chemicals between the two crops.

Between the two crops under study, C_1 registered significantly higher dehydrogenase enzyme activity (2.690) compared to C_2 (2.384) immediately after imposition of treatments. Accordingly, at two months of storage, C_1 recorded significantly higher dehydrogenase enzyme activity (1.836) compared to C_2 (1.476). However, from fourth month of storage, C_2 reported higher dehydrogenase enzyme activity (0.785, 0.438 and 0.204) compared to C_1 (0.402, 0.251 and 0.181) from four to nine months respectively.

Comparing the treatments, T_9 was significantly superior in recording higher dehydrogenase enzyme activity (3.447) compared to other treatments and control (2.563) immediately after imposition of treatments. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant decrease in dehydrogenase enzyme activity with an increase in gamma irradiation dosage wherein, T_6 recorded the lowest dehydrogenase enzyme activity (2.055) compared to control (2.563). The dehydrogenase

Table 14. Influence of gamma irradiation and seed treatment chemicals on de-hydrogenase enzyme activity of soybean and green gram

Treatments	Months after storage														
	0			2			4			6			8		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	2.709	2.417	**2.563**	1.848	1.491	**1.670**	0.329	0.733	**0.531**	0.258	0.464	**0.361**	0.195	0.210	**0.203**
T_2	2.637	2.361	**2.499**	1.808	1.478	**1.643**	0.344	0.673	**0.508**	0.239	0.417	**0.328**	0.183	0.190	**0.187**
T_3	2.501	2.333	**2.417**	1.793	1.437	**1.615**	0.344	0.662	**0.503**	0.228	0.407	**0.317**	0.171	0.182	**0.177**
T_4	2.494	1.978	**2.236**	1.757	1.425	**1.591**	0.361	0.652	**0.507**	0.223	0.405	**0.314**	0.164	0.179	**0.171**
T_5	2.468	1.880	**2.174**	1.696	1.406	**1.551**	0.375	0.608	**0.491**	0.200	0.385	**0.292**	0.133	0.166	**0.149**
T_6	2.335	1.774	**2.055**	1.450	1.207	**1.328**	0.387	0.582	**0.484**	0.191	0.359	**0.275**	0.126	0.157	**0.141**
T_7	2.709	2.544	**2.626**	1.908	1.567	**1.737**	0.445	0.768	**0.607**	0.277	0.466	**0.371**	0.204	0.239	**0.221**
T_8	2.828	2.808	**2.818**	2.129	1.623	**1.876**	0.455	0.861	**0.658**	0.290	0.495	**0.392**	0.209	0.252	**0.230**
T_9	3.533	3.362	**3.447**	2.138	1.651	**1.894**	0.581	1.524	**1.052**	0.355	0.546	**0.450**	0.243	0.262	**0.252**
Mean	**2.690**	**2.384**		**1.836**	**1.476**		**0.402**	**0.785**		**0.251**	**0.438**		**0.181**	**0.204**	

Factors	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%
C	0.062	0.176	0.046	0.132	0.021	0.058	0.010	0.028	0.003	0.007
T	0.131	0.373	0.098	0.280	0.044	0.124	0.021	0.059	0.005	0.015
C x T	0.186	0.558	0.139	0.417	0.062	0.175	0.029	0.087	0.008	0.024

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 -- 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

enzyme activity decreased linearly up to eight months of seed storage irrespective of the dosage and treatments. During the entire period of storage, T_9 recorded significantly higher dehydrogenase enzyme activity (1.894, 1.052, 0.450 and 0.252) compared to control (1.670, 0.531, 0.361 and 0.203) from two to eight months after storage, respectively. However, T_9 was on par with T_8 (1.876 and 0.392) at two and six months of storage, T_7 (1.737), T_3 (1.615), T_2 (1.643) and T_1 (1.670) at two months of storage.

Among the interactions, C_1T_9 recorded significantly higher dehydrogenase enzyme activity (3.533) compared to all other treatment combinations immediately after the imposition of the treatments. Even at two month of storage, C_1T_9 has maintained higher dehydrogenase enzyme activity (2.138). From fourth month of storage, C_2T_9 maintained higher dehydrogenase enzyme activity (1.524, 0.546 and 0.262). However, C_1T_9 was on par with C_1T_8 (2.129), C_1T_7 (1.908), C_1T_4 (1.757), C_1T_3 (1.793), C_1T_2 (1.808), C_1T_1 (1.848) at two month of storage and C_2T_9 (3.362) at initial month of storage. Whereas, C_2T_9 was on par with C_2T_8 (0.495 and 0.252), C_2T_7 (0.466 and 0.239) at six and eight months after storage. Even, C_2T_9 was on par with C_2T_1 (0.464) at six month of storage and C_1T_9 (0.243) at eight month of storage.

4.1.15 Alpha amylase enzyme activity (Table 15)

The alpha amylase enzyme activity was significantly influenced in both the crops due to gamma irradiation and seed treatment chemicals.

Soybean C_1, recorded significantly higher amylase activity (26.34 mm) compared to green gram, C_2 (26.05 mm) immediately after imposition of treatments. However, C_1 was significantly superior in maintaining higher alpha amylase enzyme activity (25.64 mm) compared to C_2 (24.96 mm) at two, months after storage, but from four month of storage, C_2 recorded significantly higher alpha amylase enzyme activity (24.31, 23.09 and 22.13 mm) compared to C_1 (22.14, 21.41 and 20.46 mm) at four, six and eight month of storage respectively.

Among the gamma irradiation dosages and seed treatment chemicals, T_9 reported significantly higher alpha amylase activity (28.50 mm) compared to all other treatments and control (26.60 mm) immediately after imposition of treatments. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant decrease in alpha amylase enzyme activity with an increase in gamma irradiation dosages wherein, T_6 recorded the

Table 15. Influence of gamma irradiation and seed treatment chemicals on alpha- amylase activity (mm) of soybean and green gram

Treatments	**Months after storage**														
	0			**2**			**4**			**6**			**8**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	26.25	26.95	**26.60**	25.75	25.35	**25.55**	23.35	24.85	**24.10**	21.85	22.55	**22.20**	20.85	21.50	**21.18**
T_2	25.95	27.05	**26.50**	25.65	25.65	**25.65**	21.05	25.05	**23.05**	20.70	23.30	**22.00**	19.65	21.70	**20.68**
T_3	25.75	26.85	**26.30**	25.25	25.00	**25.13**	20.75	24.25	**22.50**	20.35	22.75	**21.55**	19.10	21.95	**20.53**
T_4	25.70	24.45	**25.08**	24.85	24.25	**24.55**	20.15	23.75	**21.95**	19.90	22.05	**20.98**	18.15	21.25	**19.70**
T_5	25.55	24.55	**25.05**	24.60	24.05	**24.33**	20.05	22.50	**21.28**	19.35	21.30	**20.33**	19.15	20.55	**19.85**
T_6	25.45	21.85	**23.65**	24.10	20.35	**22.23**	18.80	19.45	**19.13**	18.05	19.10	**18.58**	17.85	18.50	**18.18**
T_7	26.70	27.40	**27.05**	26.50	26.10	**26.30**	23.75	25.75	**24.75**	23.00	25.05	**24.03**	22.05	24.25	**23.15**
T_8	27.05	27.05	**27.05**	26.85	26.65	**26.75**	24.85	26.20	**25.53**	24.50	25.40	**24.95**	22.50	24.45	**23.48**
T_9	28.70	28.30	**28.50**	27.25	27.20	**27.23**	26.55	26.95	**26.75**	24.95	26.30	**25.63**	24.85	25.05	**24.95**
Mean	**26.34**	**26.05**		**25.64**	**24.96**		**22.14**	**24.31**		**21.41**	**23.09**		**20.46**	**22.13**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.06	0.17	0.04	0.13	0.04	0.12	0.04	0.13	0.02	0.07
T	0.12	0.35	0.09	0.27	0.09	0.26	0.09	0.27	0.05	0.14
C x T	0.17	0.50	0.13	0.38	0.12	0.37	0.13	0.38	0.07	0.20

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** – 800 Gy **T_7** - Malathion (2 g / kg of seed) **T_9**- Malathion + Thiram (each 2 g / kg of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy **T_8** - Thiram (2 g / kg of seed)

lowest amylase activity (23.65 mm) compared to control (26.60 mm). However, the dosage (200 Gy) did not decreases the alpha amylase activity (26.50 mm) significantly compared to the control (26.60 mm). Further, the amylase activity decreased linearly up to eight months of seed storage. During the entire period of storage, T_9 recorded significantly higher amylase activity (27.23, 26.75, 25.63 and 24.95 mm) compared to control (25.55, 24.10, 22.20 and 21.18 mm) at two, four, six and eight months of storage, respectively.

Among the interactions, C_1T_9 was able to maintain significantly alpha amylase activity (28.70 and 27.25 mm) at initial and second month after storage but from fourth month C_2T_9 maintained significantly higher alpha amylase activity (26.95, 26.30 and 25.05 mm) respectively. However, C_1T_9 was on par with C_2T_9 (28.30 and 27.20 mm) at initial and second month of storage. However, C_2T_9 was on par with C_1T_9 (24.85 mm) at eight month of storage.

4.1.16 Electrical conductivity (Table 16)

The electrical conductivity of seed leacheates was significantly influenced by gamma irradiation and seed treatment chemicals in both the crops.

Comparing the crops, soybean (C_1) recorded significantly lower electrical conductivity (0.472 dSm^1) compared to green gram, C_2 (0.509 dSm^{-1}) immediately after imposition of treatments. However, C_1 maintained significantly lower electrical conductivity (0.483, 0.496, 0.639 and 0.684 dSm^{-1}) compared to C_2 (0.522, 0.533, 0.725 and 0.766 dSm^{-1}) during the entire storage period.

The electrical conductivity of 0.414 dSm^{-1} was recorded by T_9 which was significantly lower compared to all other treatments and control (0.480 dSm^{-1}) immediately after the imposition of treatments. Further, exposing the seed to gamma irradiation (T_2- T_6) there was a significant increase in the electrical conductivity of seed leachate wherein, T_6 recorded significantly higher electrical conductivity (0.533 dSm^{-1}) compared to control (0.480 dSm^{-1}). The electrical conductivity increased from initial to nine months after storage irrespective of the treatments. However, the treatment, T_9 registered significantly lower electrical conductivity (0.425, 0.438, 0.615 and 0.655 dSm^{-1}) from two to eight month of storage compared to control (0.497, 0.530, 0.666 and

Table 16. Influence of gamma irradiation and seed treatment chemicals on electrical conductivity (dSm^{-1}) of soybean and green gram

Treatments	**Months after storage**														
	0			**2**			**4**			**6**			**8**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	0.461	0.499	**0.480**	0.484	0.510	**0.497**	0.497	0.564	**0.530**	0.638	0.693	**0.666**	0.678	0.734	**0.706**
T_2	0.473	0.520	**0.497**	0.490	0.531	**0.511**	0.503	0.523	**0.513**	0.648	0.702	**0.675**	0.666	0.738	**0.702**
T_3	0.485	0.540	**0.513**	0.496	0.551	**0.524**	0.508	0.543	**0.526**	0.658	0.721	**0.689**	0.687	0.756	**0.721**
T_4	0.493	0.552	**0.523**	0.504	0.563	**0.534**	0.517	0.575	**0.546**	0.666	0.767	**0.716**	0.693	0.786	**0.739**
T_5	0.508	0.553	**0.531**	0.519	0.569	**0.544**	0.532	0.577	**0.555**	0.675	0.808	**0.742**	0.745	0.836	**0.791**
T_6	0.513	0.554	**0.533**	0.524	0.572	**0.548**	0.540	0.582	**0.561**	0.678	0.828	**0.753**	0.821	0.890	**0.856**
T_7	0.479	0.477	**0.478**	0.472	0.488	**0.480**	0.485	0.500	**0.493**	0.636	0.679	**0.658**	0.652	0.724	**0.688**
T_8	0.441	0.459	**0.450**	0.452	0.470	**0.461**	0.465	0.483	**0.474**	0.588	0.663	**0.625**	0.620	0.722	**0.671**
T_9	0.398	0.431	**0.414**	0.409	0.442	**0.425**	0.421	0.454	**0.438**	0.567	0.662	**0.615**	0.596	0.713	**0.655**
Mean	**0.472**	**0.509**		**0.483**	**0.522**		**0.496**	**0.533**		**0.639**	**0.725**		**0.684**	**0.766**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.001	0.003	0.001	0.003	0.001	0.002	0.005	0.014	0.007	0.021
T	0.003	0.007	0.002	0.007	0.002	0.005	0.010	0.029	0.015	0.043
C x T	0.004	0.010	0.003	0.009	0.002	0.007	0.014	0.041	0.021	0.063

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 -- 800 Gy
T_6 - 1000 Gy
T_7 - Malathion (2 g / kg of seed)
T_8 - Thiram (2 g / kg of seed)
T_9- Malathion + Thiram (each 2 g / kg of seed)

0.706 dSm^{-1}). Further, T_9 was on par with T_8 (0.625 and 0.671 dSm^{-1}) at six and eight months after storage and with T_7 (0.688 dS^{-1}) at eight months of storage.

Among the interactions, C_1T_9 registered significantly lower electrical conductivity (0.398 dSm^{-1}) compared to all other treatments immediately after imposition of treatments. Similarly, C_1T_9 maintained lower electrical conductivity (0.596 dSm^{-1}) during the entire period of storage. But, C_1T_9 was on par with C_1T_8 (0.588, 0.620 dSm^{-1}) at six and eight months of storage respectively and with C_1T_7 (0.652 dSm^{-1}) at eight months of storage.

4.2 Experiment 2: Influence of mid storage gamma irradiation and fumigation on seed quality of soybean and green gram

4.2.1 Seed germination (Table 17)

The seed germination (%) varied significantly due to mid storage gamma irradiation and fumigation between the two crops.

Soybean, C_1 (82.9 and 65.3%) recorded significantly higher seed germination compared to green gram, C_2 (82.5 and 62.6%) respectively at one and two times mid storage irradiation and fumigation but at third and fourth month mid storage irradiation and fumigation, C_2 recorded numerically higher seed germination (59.9 and 51.7%) respectively compared to C_1 (56.7 and 50.8%). However, at one time exposure to gamma irradiation and fumigation, the seed germination (%) did not vary significantly.

Among the mid storage gamma irradiation and fumigation treatments, T_7 (fumigation) recorded significantly higher seed germination (89.8, 85.4, 77.6, 71.4%) due to one, two, three and four times exposure to mid storage imposition of treatments. However, T_7 was on par with T_1 (88.8, 85.0, 76.9 and 71.1%) at one, two, three and four time exposures respectively.

Among the interactions, C_1T_7 recorded significantly higher seed germination (93.0, and 88.0%) at one and two times mid storage exposure to gamma irradiation and fumigation compared all other treatment combinations. However, C_2T_7 recorded significantly higher seed germination (78.0 and 74.0%) respectively, at third and fourth exposure. Further, C_1T_7 was on par with C_1T_1 (92.0 and 87.3%) at one and two times exposure respectively. While, C_2T_7 was on par with C_2T_1 (77.0 and 73.8%) at three and four times exposure, respectively and C_1T_1 (76.8%) at three times exposure.

Table 17. Influence of mid storage gamma irradiation and fumigation on seed germination (%) of soybean and green gram

Treatments	Number of exposure to gamma irradiation and fumigation at three months interval											
	1			2			3			4		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	92.0 *(73.6)	85.5 (67.6)	**88.8 (70.6)**	87.3 (69.1)	82.8 (65.4)	**85.0 (67.3)**	76.8 (61.2)	77.0 (61.3)	**76.9 (61.2)**	68.5 (55.8)	73.8 (59.2)	**71.1 (57.5)**
T_2	85.0 (67.2)	86.0 (68.0)	**85.5 (67.6)**	67.0 (54.9)	66.0 (54.3)	**66.5 (54.6)**	59.3 (50.3)	66.3 (54.5)	**62.8 (52.4)**	53.3 (46.8)	53.8 (47.1)	**53.5 (47.0)**
T_3	81.8 (64.7)	84.3 (66.6)	**83.0 (65.7)**	62.0 (51.9)	58.0 (49.6)	**60.0 (50.8)**	54.0 (47.3)	59.3 (50.3)	**56.6 (48.8)**	48.8 (44.3)	45.0 (42.1)	**46.9 (43.2)**
T_4	79.8 (63.3)	82.0 (64.9)	**80.9 (64.1)**	57.0 (49.0)	52.3 (46.3)	**54.6 (47.6)**	45.8 (42.3)	52.3 (46.3)	**49.0 (44.4)**	44.5 (41.6)	41.3 (39.9)	**42.9 (40.9)**
T_5	75.0 (60.0)	77.8 (61.8)	**76.4 (60.9)**	50.3 (45.1)	50.0 (45.0)	**50.1 (45.1)**	43.5 (41.2)	46.5 (43.0)	**45.0 (42.1)**	38.5 (38.3)	38.3 (38.2)	**38.4 (38.3)**
T_6	74.0 (59.3)	75.3 (60.1)	**74.6 (59.7)**	45.8 (42.5)	46.3 (42.8)	**46.0 (42.7)**	40.3 (39.4)	40.0 (39.2)	**40.1 (39.3)**	33.5 (35.3)	35.8 (36.7)	**34.6 (36.0)**
T_7	93.0 (74.7)	86.5 (68.4)	**89.8 (71.6)**	88.0 (69.7)	82.9 (65.5)	**85.4 (67.6)**	77.2 (61.4)	78.0 (62.0)	**77.6 (61.7)**	68.9 (56.1)	74.0 (59.3)	**71.4 (57.7)**
Mean	**82.9 (66.1)**	**82.5 (65.4)**		**65.3 (54.6)**	**62.6 (52.7)**		**56.7 (49.1)**	**59.9 (50.9)**		**50.8 (45.5)**	**51.7 (46.1)**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	NS	0.3	0.7	0.2	0.6	0.2	0.5
T	0.5	1.3	0.5	1.4	0.4	1.1	0.3	1.0
C x T	0.6	1.9	0.7	2.0	0.6	1.6	0.5	1.4

*Figures in the parenthesis indicate angular transformed values

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_2** - 200 Gy **T_3** - 400 Gy **T_4** - 600 Gy **T_5** -- 800 Gy **T_6** - 1000 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)

4.2.2 Abnormal seedlings (Table 18)

The Abnormal seedlings (%) varied significantly between the two crops due to mid storage gamma irradiation and fumigation.

Upon comparing the crops, C_2 recorded significantly lower abnormal seedlings (5.8, 11.4, 16.0 and 19.6%) compared to C_1 (6.5, 15.1, 19.3 and 23.4%) respectively at one, two, three and four times mid storage gamma irradiation and fumigation.

Among repeated gamma irradiation and fumigation treatments, significantly lower abnormal seedling (1.1, 2.5, 8.4 and 11.4%) was recorded by T_7 compared to all other treatments at one, two, three and four times mid storage exposure to gamma irradiation and fumigation respectively. However, T_7 was on par with T_1 (1.5, 8.8 and 12.0%) at one, three and four times exposure, respectively.

Among the interactions, C_2T_7 recorded significantly lower abnormal seedlings (0.5, 2.0, 7.3 and 11.3%) respectively at one, two, three and four times mid storage exposure to gamma irradiation and fumigation compared to all other treatment combinations respectively. However, C_2T_7 was on par with C_2T_1 (1.0, 7.8 and 11.5%) respectively at one, three and four times exposure compared to all other treatment combinations. Further, C_2T_7 was also on par with C_2T_2 (2.0%) at one times exposure. Even, C_2T_7 was on par with C_1T_7 (1.8, 3.0 and 11.5%) at one, two and four times exposure and with C_1T_1 (2.0 and 12.5%) at one and four times exposure.

4.2.3 Dead seeds (Table 19)

The data on dead seed (%) indicated a significant difference between the two crops and mid storage gamma irradiation and fumigation.

Between the crops, C_1 recorded significantly lower dead seed (6.3, 14.4, 17.7 and 22.9%) compared to C_2 (8.4, 18.4, 22.1 and 27.0%) respectively at one, two, three and four times exposure to mid storage gamma irradiation and fumigation. Among the gamma irradiation and fumigation treatments, significantly lower dead seeds (5.5, 7.4, 8.5 and

11.9%) were recorded by T_7 compared to all other treatments at one, two, three and four times mid storage exposure to gamma irradiation and fumigation, respectively. However, T_7 was on par with T_1 (5.8, 8.0, 9.5 and 12.3%) respectively during the same period

Table 18. Influence of mid storage gamma irradiation and fumigation on abnormal seedling (%) of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2.0	1.0	**1.5**	5.3	4.0	**4.6**	9.8	7.8	**8.8**	12.5	11.5	**12.0**
T_2	4.5	2.0	**3.3**	14.3	7.8	**11.0**	17.8	14.5	**16.1**	22.3	17.0	**19.6**
T_3	5.5	4.3	**4.9**	16.0	10.5	**13.3**	19.5	16.3	**17.9**	24.5	20.0	**22.3**
T_4	7.3	8.5	**7.9**	18.0	15.3	**16.6**	23.0	19.0	**21.0**	27.0	24.3	**25.6**
T_5	9.5	10.8	**10.1**	21.3	18.5	**19.9**	25.3	21.5	**23.4**	30.8	25.0	**27.9**
T_6	14.8	13.3	**14.0**	28.0	22.0	**25.0**	30.3	25.8	**28.0**	35.5	28.3	**31.9**
T_7	1.8	0.5	**1.1**	3.0	2.0	**2.5**	9.5	7.3	**8.4**	11.5	11.3	**11.4**
Mean	**6.5**	**5.8**		**15.1**	**11.4**		**19.3**	**16.0**		**23.4**	**19.6**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.6	0.2	0.7	0.2	0.7	0.3	0.8
T	0.4	1.1	0.5	1.3	0.5	1.3	0.5	1.5
C x T	0.5	1.5	0.6	1.8	0.6	1.8	0.8	2.1

Crops: **C_1-** Soybean **C_2-** Green gram
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

Table 19. Influence of mid storage gamma irradiation and fumigation on dead seed (%) of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	4.3	7.3	**5.8**	5.3	10.8	**8.0**	7.8	11.3	**9.5**	12.0	12.5	**12.3**
T_2	5.8	8.0	**6.9**	9.8	16.8	**13.3**	14.3	22.8	**18.5**	21.0	27.3	**24.1**
T_3	7.0	8.5	**7.8**	16.5	19.8	**18.1**	19.3	24.5	**21.9**	26.8	31.5	**29.1**
T_4	7.3	8.5	**7.9**	18.0	21.3	**19.6**	22.8	26.8	**24.8**	28.0	34.5	**31.3**
T_5	7.5	9.0	**8.3**	21.3	23.5	**22.4**	25.8	28.0	**26.9**	30.0	35.3	**32.6**
T_6	8.3	10.3	**9.3**	25.0	26.5	**25.8**	27.5	30.8	**29.1**	31.0	36.0	**33.5**
T_7	4.0	7.0	**5.5**	4.8	10.0	**7.4**	6.5	10.5	**8.5**	11.6	12.3	**11.9**
Mean	**6.3**	**8.4**		**14.4**	**18.4**		**17.7**	**22.1**		**22.9**	**27.0**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.2	0.6	0.3	0.8	0.3	0.8	0.3	1.0
T	0.4	1.1	0.5	1.4	0.5	1.5	0.6	1.8
C x T	0.6	1.2	0.7	2.0	0.7	2.1	0.9	2.6

Crops: **C_1**- Soybean **C_2**- Green gram
T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

Among the interactions, C_1T_7 recorded significantly lower dead seed (4.0, 4.8, 6.5 and 11.6%) respectively at one, two, three and four times mid storage exposure to gamma irradiation and fumigation compared to all other treatment combinations. However, C_1T_7 was on par with C_1T_1 (4.3, 5.3, 7.8 and 12.0%) respectively during the same period. Even, C_1T_7 was on par with C_2T_1 (12.5) and C_2T_7 (12.3) at four times exposure.

4.2.4 Mean germination time (20)

The mean germination time was significantly influenced by mid storage gamma irradiation and fumigation between the two crops.

Among the two crops, soybean (C_1) registered significantly lower mean germination time (1.54 and 2.52) compared to green gram, C_2 (1.90 and 2.54) respectively, at one and two times mid storage exposure to gamma irradiation and fumigation respectively. However, C_2 recorded significantly lower mean germination time (2.70 and 2.90) compared to C_1 (2.80 and 2.95) at three and four times exposure. While, the mean germination time did not vary significantly due to two time exposure.

Among the repeated gamma irradiation and fumigation treatments, T_7 recorded significantly lower mean germination time (1.59, 1.69, 2.29 and 2.51) at one, two, three and four times mid storage exposure to gamma irradiation and fumigation, respectively. However, T_7 was on par with T_1 (1.68 and 2.30) at one and three times exposure and with T_2 (1.63) at one time exposure.

Among the interactions, C_1T_7 recorded significantly lower mean germination time (1.36 and 1.49) respectively at one and two times mid storage exposure to gamma irradiation and fumigation. While, at three and four times exposure C_2T_7 recorded significantly lower mean germination time (2.19 and 2.44). Further, C_1T_7 was on par with C_1T_1 (1.51) and C_1T_2 (1.40) at one time exposure. While, C_2T_7 was on par with C_1T_1 (2.19) at three time exposure.

4.2.5 Germination rate index (Table 21)

The germination rate index was significantly influenced by mid storage gamma irradiation and fumigation treatments between the two crops.

Upon comparing crops, C_1 reported significantly higher germination rate index (7237 and 6706) compared with C_2 (7037 and 6131) respectively, at one and two times

Table 20. Influence of mid storage gamma irradiation and fumigation on mean germination time of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	1.51	1.86	**1.68**	2.03	1.95	**1.99**	2.42	2.19	**2.30**	2.59	2.61	**2.60**
T_2	1.40	1.86	**1.63**	2.54	2.52	**2.53**	2.65	2.57	**2.61**	2.74	2.67	**2.70**
T_3	1.62	1.88	**1.75**	2.62	2.64	**2.63**	2.75	2.68	**2.71**	2.89	2.75	**2.82**
T_4	1.62	1.89	**1.76**	2.75	2.80	**2.77**	2.84	3.03	**2.94**	3.03	3.19	**3.11**
T_5	1.64	1.92	**1.78**	2.97	2.92	**2.94**	3.03	3.06	**3.05**	3.17	3.26	**3.21**
T_6	1.67	2.08	**1.88**	3.28	3.11	**3.19**	3.52	3.17	**3.35**	3.69	3.40	**3.54**
T_7	1.36	1.82	**1.59**	1.49	1.89	**1.69**	2.39	2.19	**2.29**	2.57	2.44	**2.51**
Mean	**1.54**	**1.90**		**2.52**	**2.54**		**2.80**	**2.70**		**2.95**	**2.90**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.02	0.06	0.02	NS	0.01	0.04	0.01	0.03
T	0.04	0.11	0.04	0.12	0.03	0.08	0.02	0.05
C x T	0.05	0.15	0.06	0.17	0.04	0.11	0.03	0.08

Crops: **C_1-** Soybean **C_2-** Green gram NS – Non significant
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

Table 21. Influence of mid storage gamma irradiation and fumigation on germination rate index of soybean and green gram

Treatments	Number of exposure to gamma irradiation and fumigation at three months interval											
	1			2			3			4		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	7643	7341	**7492**	6512	6198	**6355**	4584	4572	**4578**	4020	4010	**4015**
T_2	7475	7459	**7467**	7258	6634	**6946**	4842	5237	**5039**	4182	4435	**4308**
T_3	7291	7033	**7162**	7035	6261	**6648**	4703	4950	**4826**	4066	4291	**4178**
T_4	7061	6933	**6997**	6765	5976	**6370**	4475	4737	**4606**	3860	4000	**3930**
T_5	6794	6434	**6614**	5949	5666	**5807**	4283	4710	**4496**	3708	3924	**3816**
T_6	6626	6417	**6521**	5683	5139	**5411**	4160	4673	**4417**	3527	3678	**3603**
T_7	7767	7645	**7706**	7744	7042	**7393**	5236	5646	**5441**	4631	4773	**4702**
Mean	**7237**	**7037**		**6706**	**6131**		**4612**	**4932**		**3999**	**4158**	

Factors	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%
C	53	161	23	71	25	76	38	115
T	99	302	43	133	47	143	70	216
C x T	140	420	61	187	66	202	100	300

Crops: **C_1-** Soybean **C_2-** Green gram
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

exposure to mid storage gamma irradiation and fumigation. However, at three and four times exposure, C_2 recorded higher germination rate index (4932 and 4158) compared to C_1 (4612 and 3999) respectively.

Among the gamma irradiation and fumigation treatments, T_7 recorded significantly higher germination rate index (7706, 7393, 5441 and 4702) at one, two, three and four times imposition of the treatments respectively.

Among the interactions, C_1T_7 recorded significantly higher germination rate index (7767 and 7744) respectively at one and two times exposure to mid storage gamma irradiation and fumigation compared to all other treatment combinations. However, at three and four time exposure, C_2T_7 recorded significantly higher germination rate index (5646 and 4773) respectively. Further, C_1T_7 was on par with C_1T_1 (7643), C_1T_2 (7475), C_2T_2 (7459) and C_2T_7 (7645) at one time exposure. While, C_2T_7 was on par with C_1T_7 (4631) at fourth time exposure.

4.2.6 Peak value of germination (Table 22)

The Peak value of germination was significantly influenced by mid storage gamma irradiation and fumigation between the two crops.

Within the two crops, C_1 registered significantly higher peak value of germination (20.5 and 15.5) compared to C_2 (20.3 and 14.4) respectively, at one and two times mid storage exposure to gamma irradiation and fumigation. However, at three and four times exposure, C_2 reported significantly higher peak value of germination (12.6 and 9.7) compared to C_1 (10.8 and 8.0) respectively. However, at one time exposure to gamma irradiation and fumigation, the peak value of germination did not vary significantly.

Among the gamma irradiation and fumigation treatments, T_7 recorded significantly higher peak value of germination (22.7, 19.6, 14.5 and 12.1) at one, two, three and four times mid storage exposure to gamma irradiation and fumigation respectively. However, T_7 was on par with T_1 (22.0, 13.9 and 11.7) at one, three and four times exposure, T_2 (22.0 and 10.3) at one and four times exposure and T_3 (21.2) at one time exposure to mid storage gamma irradiation.

Among the interactions, C_1T_7 recorded significantly higher peak value of germination (23.4 and 20.2) at one and two times exposure to mid storage gamma irradiation and fumigation. However, at three and four time's exposure, C_2T_7 registered

Table 22. Influence of mid storage gamma irradiation and fumigation on peak value of germination of soybean and green gram

<table>
<tr><th rowspan="3">Treatments</th><th colspan="12">Number of exposure to gamma irradiation and fumigation at three months interval</th></tr>
<tr><th colspan="3">1</th><th colspan="3">2</th><th colspan="3">3</th><th colspan="3">4</th></tr>
<tr><th>C_1</th><th>C_2</th><th>Mean</th><th>C_1</th><th>C_2</th><th>Mean</th><th>C_1</th><th>C_2</th><th>Mean</th><th>C_1</th><th>C_2</th><th>Mean</th></tr>
<tr><td>T_1</td><td>22.7</td><td>21.3</td><td>22.0</td><td>16.4</td><td>15.8</td><td>16.1</td><td>13.2</td><td>14.6</td><td>13.9</td><td>11.1</td><td>12.2</td><td>11.7</td></tr>
<tr><td>T_2</td><td>22.6</td><td>21.4</td><td>22.0</td><td>15.9</td><td>15.3</td><td>15.6</td><td>10.7</td><td>13.1</td><td>11.9</td><td>8.0</td><td>12.6</td><td>10.3</td></tr>
<tr><td>T_3</td><td>22.2</td><td>20.3</td><td>21.2</td><td>15.5</td><td>14.5</td><td>15.0</td><td>10.1</td><td>12.5</td><td>11.3</td><td>7.3</td><td>10.8</td><td>9.0</td></tr>
<tr><td>T_4</td><td>20.6</td><td>19.8</td><td>20.2</td><td>14.7</td><td>13.6</td><td>14.2</td><td>9.9</td><td>11.8</td><td>10.8</td><td>6.7</td><td>8.7</td><td>7.7</td></tr>
<tr><td>T_5</td><td>17.4</td><td>19.1</td><td>18.3</td><td>13.3</td><td>11.7</td><td>12.5</td><td>9.4</td><td>10.7</td><td>10.0</td><td>6.0</td><td>5.8</td><td>5.9</td></tr>
<tr><td>T_6</td><td>14.4</td><td>18.6</td><td>16.5</td><td>12.5</td><td>10.9</td><td>11.7</td><td>8.6</td><td>9.9</td><td>9.3</td><td>5.7</td><td>4.9</td><td>5.3</td></tr>
<tr><td>T_7</td><td>23.4</td><td>22.1</td><td>22.7</td><td>20.2</td><td>19.0</td><td>19.6</td><td>13.5</td><td>15.5</td><td>14.5</td><td>11.5</td><td>12.8</td><td>12.1</td></tr>
<tr><td>Mean</td><td>20.5</td><td>20.3</td><td></td><td>15.5</td><td>14.4</td><td></td><td>10.8</td><td>12.6</td><td></td><td>8.0</td><td>9.7</td><td></td></tr>
<tr><td>Factors</td><td colspan="2">S.Em±</td><td colspan="1">C.D. at 1%</td><td colspan="2">S.Em±</td><td colspan="1">C.D. at 1%</td><td colspan="2">S.Em±</td><td colspan="1">C.D. at 1%</td><td colspan="2">S.Em±</td><td colspan="1">C.D. at 1%</td></tr>
<tr><td>C</td><td colspan="2">0.4</td><td>NS</td><td colspan="2">0.3</td><td>0.9</td><td colspan="2">0.2</td><td>0.7</td><td colspan="2">0.4</td><td>1.1</td></tr>
<tr><td>T</td><td colspan="2">0.7</td><td>2.0</td><td colspan="2">0.5</td><td>1.6</td><td colspan="2">0.6</td><td>1.8</td><td colspan="2">0.7</td><td>2.1</td></tr>
<tr><td>C x T</td><td colspan="2">0.9</td><td>2.5</td><td colspan="2">0.7</td><td>2.2</td><td colspan="2">0.8</td><td>2.3</td><td colspan="2">1.0</td><td>3.0</td></tr>
</table>

Crops: **C_1-** Soybean **C_2-** Green gram NS – Non significant
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

significantly higher peak value of germination (15.5 and 12.8) respectively. Further, C_1T_7 was on par with C_2T_7 (22.1 and 19.0) at one and two times exposure, C_2T_2 (21.4), C_2T_1 (21.3), C_1T_3 (22.2), C_1T_2 (22.6) and C_1T_1 (22.7) at one time exposure. However, C_2T_7 was on par with C_1T_7 (13.5 and 11.5), C_1T_1 (13.2 and 11.1) at three and four times exposure.

4.2.7 Shoot length (Table 23)

The shoot length was significantly influenced by mid storage gamma irradiation and fumigation in both the crops.

Within the crops, C_2 recorded significantly higher shoot length (15.82, 10.29, 9.28 and 7.80 cm) compared to C_1 (12.10, 8.09, 6.30 and 5.71 cm) respectively, at one, two, three and four times mid storage gamma irradiation and fumigation.

Among the mid storage gamma irradiation and fumigation treatments, significantly higher shoot length (16.20, 14.73, 13.89 and 13.56 cm) was recorded by T_7 at one, two, three and four times mid storage exposure to gamma irradiation and fumigation respectively. However, T_7 was on par with T_1 (16.08, 14.33, 13.79 and 13.34 cm) respectively at one, two, three and four times exposure and T_2 (15.76) at one time exposure.

Among the interactions, C_2T_7 recorded significantly higher shoot length (17.75, 16.35, 15.80 and 15.25 cm) respectively at one, two, three and four times mid storage exposure to gamma irradiation and fumigation compared to all other treatment combinations. However, C_2T_7 was on par with C_2T_1 (17.65, 16.15, 15.68 and 14.95 cm) at one, two, three and four times exposure respectively.

4.2.8 Root length (Table 24)

Similar trend as that of shoot length was noticed was root length due to mid storage gamma irradiation and fumigation in both the crops.

Between the crops, C_2 recorded significantly higher root length (19.78, 9.68, 8.94 and 7.83 cm) compared to C_1 (15.66, 8.02, 6.66 and 5.68 cm) respectively, at one, two, three and four times mid storage gamma irradiation and fumigation.

Among the repeated gamma irradiation and fumigation treatments, significantly higher root length (20.23, 17.81, 16.59 and 15.05 cm) was recorded by T_7 compared to all

Table 23. Influence of mid storage gamma irradiation and fumigation on shoot length (cm) of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	14.50	17.65	**16.08**	12.50	16.15	**14.33**	11.90	15.68	**13.79**	11.73	14.95	**13.34**
T_2	13.48	18.05	**15.76**	9.28	13.23	**11.25**	7.48	11.25	**9.36**	5.33	8.78	**7.05**
T_3	11.75	16.23	**13.99**	7.95	10.48	**9.21**	5.63	9.35	**7.49**	4.75	7.00	**5.88**
T_4	10.68	15.23	**12.95**	6.28	7.15	**6.71**	3.88	6.28	**5.08**	3.43	4.85	**4.14**
T_5	10.13	13.45	**11.79**	4.30	5.18	**4.74**	1.95	4.18	**3.06**	1.80	2.78	**2.29**
T_6	9.50	12.40	**10.95**	3.23	3.50	**3.36**	1.30	2.43	**1.86**	1.08	0.98	**1.03**
T_7	14.65	17.75	**16.20**	13.10	16.35	**14.73**	11.98	15.80	**13.89**	11.88	15.25	**13.56**
Mean	**12.10**	**15.82**		**8.09**	**10.29**		**6.30**	**9.28**		**5.71**	**7.80**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.14	0.40	0.12	0.34	0.09	0.26	0.09	0.27
T	0.26	0.74	0.22	0.64	0.17	0.49	0.18	0.51
C x T	0.37	1.20	0.32	0.91	0.24	0.70	0.25	0.72

Crops: **C_1**- Soybean **C_2**- Green gram
T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

Table 24. Influence of mid storage gamma irradiation and fumigation on root length (cm) of soybean and green gram

Treatments	Number of exposure to gamma irradiation and fumigation at three months interval											
	1			2			3			4		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	17.48	21.30	**19.39**	15.03	17.58	**16.30**	14.18	16.90	**15.54**	12.33	15.70	**14.01**
T_2	16.28	21.85	**19.06**	7.93	10.55	**9.24**	5.75	10.15	**7.95**	4.95	9.18	**7.06**
T_3	15.63	20.18	**17.90**	6.15	8.35	**7.25**	4.95	7.30	**6.13**	3.45	5.80	**4.63**
T_4	14.55	19.18	**16.86**	4.75	5.78	**5.26**	3.75	5.15	**4.45**	3.03	4.60	**3.81**
T_5	14.00	17.43	**15.71**	3.20	3.90	**3.55**	1.83	3.45	**2.64**	1.55	2.45	**2.00**
T_6	13.38	16.38	**14.88**	2.33	2.75	**2.54**	0.95	1.65	**1.30**	0.53	0.95	**0.74**
T_7	18.30	22.15	**20.23**	16.75	18.88	**17.81**	15.23	17.95	**16.59**	13.95	16.15	**15.05**
Mean	**15.66**	**19.78**		**8.02**	**9.68**		**6.66**	**8.94**		**5.68**	**7.83**	

Factors	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%
C	0.07	0.21	0.20	0.56	0.05	0.13	0.09	0.26
T	0.14	0.39	0.37	1.05	0.09	0.25	0.17	0.49
C x T	0.19	0.56	0.52	1.50	0.12	0.35	0.24	0.69

Crops: **C_1**- Soybean **C_2**- Green gram
T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

other treatments at one, two, three and four times mid storage gamma irradiation and fumigation respectively.

Among the interactions, C_2T_7 was significantly better in recording higher root length (22.15, 18.88 and 17.95 and 16.15 cm) respectively at one, two three and four times exposure to mid storage gamma irradiation and fumigation. However, C_2T_7 was on par with C_2T_1 (17.58 and 15.70 cm) at two and four times exposure respectively and with C_2T_2 (21.85 cm) at one time exposure.

4.2.9 Seedling dry weight (Table 25)

The data on seedling dry weight was significantly influenced by mid storage gamma irradiation and fumigation between the crops.

On comparing the crops, C_2 recorded significantly higher seedling dry weight (0.375, 0.268, 0.240 and 0.199 g) compared to C_1 (0.368, 0.262, 0.214 and 0.186 g) respectively, at one, two, three and four times mid storage gamma irradiation and fumigation respectively.

Among the repeated gamma irradiation and fumigation treatments, significantly higher seedling dry weight (0.409, 0.387, 0.362 and 0.323 g) was recorded by T_7 compared to all other treatments and control (0.398, 0.366, 0.339 and 0.291 g) at one, two, three and four times mid storage gamma irradiation and fumigation respectively.

Among the interactions, C_2T_7 (0.411, 0.398, 0.366 and 0.346 g) recorded significantly higher seedling dry weight at one, two, three and four times mid storage exposure to gamma irradiation and fumigation respectively. However, C_2T_7 was on par with C_1T_7 (0.406 g) and C_2T_2 (0.404 g) at one time exposure.

4.2.10 Seedling vigour index (Table 26)

Crops showed a significant difference with respect to seedling vigour index due to exposing the seeds to mid storage gamma irradiation and fumigation.

On comparing the crops, C_2 recorded significantly higher seedling vigour index (2953, 1398, 1185 and 968) compared to C_1 (2327, 1188, 894 and 692) respectively, due to one, two, three and four times mid storage gamma irradiation and fumigation.

Table 25. Influence of mid storage gamma irradiation and fumigation on seedling dry weight (g) of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	0.395	0.402	**0.398**	0.363	0.369	**0.366**	0.334	0.345	**0.339**	0.303	0.279	**0.291**
T_2	0.386	0.404	**0.395**	0.286	0.297	**0.291**	0.256	0.266	**0.261**	0.226	0.215	**0.221**
T_3	0.381	0.391	**0.386**	0.244	0.265	**0.255**	0.193	0.237	**0.215**	0.165	0.184	**0.174**
T_4	0.373	0.370	**0.371**	0.217	0.216	**0.216**	0.156	0.186	**0.171**	0.136	0.156	**0.146**
T_5	0.337	0.338	**0.337**	0.194	0.176	**0.185**	0.114	0.153	**0.133**	0.103	0.135	**0.119**
T_6	0.299	0.315	**0.307**	0.154	0.156	**0.155**	0.087	0.126	**0.107**	0.066	0.076	**0.071**
T_7	0.406	0.411	**0.409**	0.376	0.398	**0.387**	0.358	0.366	**0.362**	0.300	0.346	**0.323**
Mean	**0.368**	**0.375**		**0.262**	**0.268**		**0.214**	**0.240**		**0.186**	**0.199**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.001	0.003	0.001	0.001	0.004	0.011	0.002	0.004
T	0.002	0.005	0.002	0.003	0.007	0.021	0.003	0.008
C x T	0.003	0.007	0.003	0.004	0.010	0.030	0.004	0.012

Crops: **C_1**- Soybean　**C_2**- Green gram
T_1 - Control　**T_3** - 400 Gy　**T_5** -- 800 Gy　T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy　**T_4** - 600 Gy　**T_6** - 1000 Gy

Table 26. Influence of mid storage gamma irradiation and fumigation on seedling vigour index of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2941	3330	**3135**	2405	2789	**2597**	1999	2503	**2251**	1645	2258	**1952**
T_2	2530	3432	**2981**	1147	1569	**1358**	877	1269	**1073**	548	964	**756**
T_3	2236	3066	**2651**	875	1092	**983**	626	899	**763**	400	576	**488**
T_4	2012	2822	**2417**	629	675	**652**	400	523	**461**	287	390	**339**
T_5	1810	2403	**2106**	378	453	**416**	176	331	**254**	129	200	**165**
T_6	1694	2168	**1931**	254	289	**271**	90	165	**127**	54	69	**62**
T_7	3065	3452	**3258**	2626	2918	**2772**	2122	2604	**2363**	1780	2322	**2051**
Mean	**2327**	**2953**		**1188**	**1398**		**898**	**1185**		**692**	**968**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	16	46	16	45	9	27	8	23
T	30	86	30	85	18	51	15	43
C x T	43	122	42	120	25	72	21	61

Crops: **C_1**- Soybean **C_2**- Green gram
T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

Among the gamma irradiation and fumigation treatments, significantly higher seedling vigour index (3258, 2772, 2363 and 2051) was recorded by T_7 at one, two, three and four times mid storage gamma irradiation and fumigation respectively.

Among the interactions, C_2T_7 recorded significantly higher seedling vigour index (3452, 2918, 2604 and 2322) at one, two, three and four time's exposure mid storage gamma irradiation and fumigation respectively. However, C_2T_7 was on par with C_2T_1 (3330) and C_2T_2 (3432) at one time exposure respectively.

4.2.11 Seed infection (Table 27)

The seed infection (%) varied significantly between the two crops due to mid storage gamma irradiation and fumigation treatments.

Upon comparing the crops, C_1 recorded significantly lower seed infection (18.9, 18.4, 15.9 and 15.6%) compared to C_2 (23.8, 23.4, 22.9 and 21.5%) respectively at one, two, three and four times mid storage gamma irradiation and fumigation, respectively.

Among the gamma irradiation and fumigation treatments, T_6 recorded significantly lower seed infection (12.0, 8.5, 5.8 and 1.8%) respectively at one, two, three and four time's imposition of the treatments. However, T_6 was on par with T_5 (8.0%) at three times mid storage gamma irradiation and fumigation.

Among the interactions, C_1T_6 recorded significantly lower seed infection (10.0, 8.5, 5.5 and 1.5%) at one, two, three and four times mid storage exposure to gamma irradiation and fumigation, respectively compared to all other treatment combinations. However, C_1T_6 was on par with C_1T_5 (14.0, 13.0, 7.5 and 3.5%) respectively, at one, two, three and four times exposure, C_1T_4 (10.0 and 6.0%) at three and four times exposure respectively and C_1T_3 (8.0%) at four times exposure. Further, C_1T_6 was also on par with C_2T_6 (14.0, 8.5, 6.0 and 2.0%) at one, two and three and four times exposure, C_2T_5 (11.5, 8.5 and 4.5%) at two, three and four times exposure respectively and C_2T_4 (11.0 and 7.5%) at three and four times exposure, respectively.

4.2.12 Dehydrogenase enzyme activity (Table 28)

The dehydrogenase enzyme activity (OD value) was significantly influenced by mid storage gamma irradiation and fumigation treatments in both the crops.

Table 27. Influence of mid storage gamma irradiation and fumigation on seed infection (%) of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	26.0 *(30.6)	34.0 (35.6)	**30.0 (33.1)**	34.0 (35.6)	68.0 (55.6)	**51.0 (45.6)**	46.0 (42.7)	82.0 (65.2)	**64.0 (53.9)**	64.0 (53.2)	90.0 (72.9)	**77.0 (62.3)**
T_2	22.0 (27.9)	26.0 (30.6)	**24.0 (29.3)**	20.0 (26.5)	20.0 (26.6)	**20.0 (26.5)**	13.5 (21.5)	17.0 (24.3)	**15.3 (22.9)**	10.5 (18.9)	14.5 (22.4)	**12.5 (20.6)**
T_3	20.0 (26.4)	22.0 (27.9)	**21.0 (27.2)**	18.0 (25.1)	16.5 (24.0)	**17.3 (24.5)**	11.5 (19.8)	12.5 (20.7)	**12.0 (20.3)**	8.0 (16.4)	10.5 (18.9)	**9.3 (17.6)**
T_4	16.0 (23.4)	20.0 (26.6)	**18.0 (25.0)**	14.5 (22.4)	14.5 (22.4)	**14.5 (22.4)**	10.0 (18.4)	11.0 (19.3)	**10.5 (18.9)**	6.0 (14.1)	7.5 (15.9)	**6.8 (15.0)**
T_5	14.0 (21.9)	18.0 (25.1)	**16.0 (23.5)**	13.0 (21.1)	11.5 (19.8)	**12.3 (20.4)**	7.5 (15.9)	8.5 (16.9)	**8.0 (16.4)**	3.5 (10.8)	4.5 (12.2)	**4.0 (11.5)**
T_6	10.0 (18.3)	14.0 (21.9)	**12.0 (20.1)**	8.5 (16.9)	8.5 (16.9)	**8.5 (16.9)**	5.5 (13.5)	6.0 (14.1)	**5.8 (13.8)**	1.5 (6.9)	2.0 (7.9)	**1.8 (7.4)**
T_7	24.5 (29.7)	32.5 (34.7)	**28.5 (32.2)**	21.0 (27.2)	24.5 (29.7)	**22.8 (28.4)**	17.5 (24.7)	23.5 (29.0)	**20.5 (26.9)**	15.5 (23.2)	21.5 (27.9)	**18.5 (25.4)**
Mean	**18.9 (25.5)**	**23.8 (28.9)**		**18.4 (25.0)**	**23.4 (27.8)**		**15.9 (22.4)**	**22.9 (27.1)**		**15.6 (20.5)**	**21.5 (25.3)**	
Factors	**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**		**S.Em±**	**C.D. at 1%**	
C	0.6	1.9		0.6	1.7		0.7	2.1		0.8	2.6	
T	1.2	3.6		1.0	3.2		1.3	4.0		1.6	4.8	
C x T	1.7	5.1		1.5	4.5		1.8	5.6		2.2	6.8	

*Figures in the parenthesis indicate angular transformed value

Crops: **C_1-** Soybean **C_2-** Green gram
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

Table 28. Influence of mid storage gamma irradiation and fumigation on dehydrogenase enzyme activity (OD value) of soybean and green gram

Treatments	Number of exposure to gamma irradiation and fumigation at three months interval											
	1			2			3			4		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	2.709	2.417	**2.563**	1.524	0.459	**0.992**	0.258	0.464	**0.361**	0.134	0.383	**0.258**
T_2	2.637	2.361	**2.499**	1.373	0.450	**0.912**	0.205	0.404	**0.304**	0.082	0.204	**0.143**
T_3	2.501	2.333	**2.417**	1.348	0.445	**0.897**	0.151	0.387	**0.269**	0.063	0.188	**0.126**
T_4	2.494	1.978	**2.236**	1.349	0.436	**0.893**	0.139	0.354	**0.246**	0.058	0.167	**0.112**
T_5	2.468	1.880	**2.174**	1.237	0.425	**0.831**	0.134	0.349	**0.241**	0.051	0.153	**0.102**
T_6	2.335	1.774	**2.054**	1.241	0.361	**0.801**	0.130	0.345	**0.237**	0.040	0.139	**0.089**
T_7	2.720	2.544	**2.632**	2.236	1.499	**1.867**	0.267	0.483	**0.375**	0.231	0.406	**0.319**
Mean	**2.552**	**2.184**		**1.473**	**0.582**		**0.183**	**0.398**		**0.094**	**0.234**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.001	0.004	0.005	0.017	0.006	0.017	0.006	0.017
T	0.003	0.008	0.010	0.031	0.010	0.032	0.010	0.032
C x T	0.004	0.011	0.014	0.044	0.015	0.045	0.015	0.045

Crops: **C_1-** Soybean
C_2- Green gram
T_1 - Control
T_2 - 200 Gy
T_3 - 400 Gy
T_4 - 600 Gy
T_5 -- 800 Gy
T_6 - 1000 Gy
T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)

Within the two crops, C_1 registered significantly higher dehydrogenase enzyme activity (2.552 and 1.473) compared to C_2 (2.184 and 0.582) respectively at one and two times mid storage gamma irradiation and fumigation. While at three and four times exposure, C_2 reported higher dehydrogenase enzyme activity (0.398 and 0.234) compared to C_1 (0.183 and 0.094) respectively.

Among the gamma irradiation and fumigation treatments, T_7 recorded significantly higher dehydrogenase enzyme activity (2.632, 1.867, 0.375 and 0.319) compared to control (2.563, 0.992, 0.361 and 0.258) respectively at one, two, three and four times mid storage exposure to gamma irradiation and fumigation. However, T_7 was on par with T_1 (0.361) at three times exposure.

Among the interactions, C_1T_7 recorded significantly higher dehydrogenase enzyme activity (2.720 and 2.236) respectively at one and two times mid storage exposure to gamma irradiation and fumigation. While, C_2T_7 reported significantly higher dehydrogenase enzyme activity (0.483 and 0.406) at three and four times exposures, respectively. However, C_1T_7 was on par with C_1T_1 (2.709) at one time exposure and C_2T_7 with C_2T_1 (0.464 and 0.383) at three and four times exposure, respectively.

4.2.13 Alpha amaylase enzyme activity (Table 29)

The alpha amaylase enzyme activity (mm) was also significantly influenced by mid storage gamma irradiation and fumigation in both the crops.

Among the two crops, C_1 registered significantly higher alpha amaylase enzyme activity (26.03 and 23.09 mm) compared to C_2 (25.49 and 21.66 mm) respectively, at one and two times mid storage exposure to gamma irradiation and fumigation. However, C_2 reported significantly higher alpha amaylase enzyme activity (19.44 and 16.90 mm) compared to C_1 (17.09 and 14.21 mm) at three and four time exposure respectively.

Among the repeated gamma irradiation and fumigation treatments, T_7 recorded significantly higher alpha amaylase enzyme activity (27.40, 25.85, 22.08 and 21.78 mm) compared to control (26.60, 23.90, 21.78 and 18.30 mm) respectively at one, two, three and four times mid storage exposure to gamma irradiation and fumigation. However, T_7 - was on par with T_1 (21.78) at three times exposure.

Among the interactions, C_1T_7 recorded significantly higher alpha amaylase enzyme activity (27.55 and 25.90 mm) respectively at one and two times mid storage

Table 29. Influence of mid storage gamma irradiation and fumigation on alpha amylase enzyme activity of soybean and green gram

Treatments	**Number of exposure to gamma irradiation and fumigation at three months interval**											
	1			**2**			**3**			**4**		
	C_1	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**	**C_1**	**C_2**	**Mean**
T_1	26.25	26.95	**26.60**	25.35	22.45	**23.90**	21.00	22.55	**21.78**	16.35	20.25	**18.30**
T_2	25.95	27.05	**26.50**	23.55	23.30	**23.43**	18.40	21.15	**19.78**	15.35	18.85	**17.10**
T_3	25.75	26.85	**26.30**	22.65	21.00	**21.83**	17.40	20.10	**18.75**	14.85	17.10	**15.98**
T_4	25.70	24.45	**25.08**	22.10	20.95	**21.53**	16.65	18.85	**17.75**	12.65	15.90	**14.28**
T_5	25.55	24.05	**24.80**	21.20	19.95	**20.58**	13.20	16.35	**14.78**	10.60	13.30	**11.95**
T_6	25.45	21.85	**23.65**	20.90	18.20	**19.55**	11.40	14.50	**12.95**	8.00	11.05	**9.53**
T_7	27.55	27.25	**27.40**	25.90	25.80	**25.85**	21.55	22.60	**22.08**	21.70	21.85	**21.78**
Mean	**26.03**	**25.49**		**23.09**	**21.66**		**17.09**	**19.44**		**14.21**	**16.90**	

Factors	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**	**S.Em±**	**C.D. at 1%**
C	0.05	0.15	0.31	0.95	0.23	0.71	0.13	0.40
T	0.09	0.29	0.58	1.78	0.43	1.33	0.24	0.75
C x T	0.13	0.40	0.82	2.40	0.61	1.80	0.34	1.06

Crops: **C_1-** Soybean **C_2-** Green gram
T_1 - Control **T_3 -** 400 Gy **T_5 --** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

exposure to gamma irradiation and fumigation but at three and four times exposure, C_2T_7 (22.60 and 21.85 mm) recorded significantly higher alpha amylase enzyme activity respectively. However, C_1T_7 was on par with C_2T_7 (27.25 and 25.80 mm) at one and two time's exposure. While, C_2T_7 was on par with C_2T_1 (22.55 mm), C_2T_2 (21.15 mm) C_1T_7 (21.55 mm) and C_1T_1 (21.00 mm) at three times exposure.

4.2.14 Electrical conductivity (Table 30)

The electrical conductivity (dSm^{-1}) of seed leachates was significantly influenced by mid storage gamma irradiation and fumigation treatments between the crops.

Soybean (C_1) recorded significantly lower electrical conductivity (0.483, 0.621, 0.756 and 0.823 dSm^{-1}) compared to green gram, C_2 (0.528, 0.642, 0.791 and 1.057 dSm^{-1}) respectively, at one, two, three and four times mid storage gamma irradiation and fumigation.

Comparing the treatments, T_7 was significantly superior in maintaining lower electrical conductivity (0.465, 0.487, 0.628 and 0.678 dSm^{-1}) respectively at one, two, three and four mid storage gamma irradiation and fumigation respectively.

Among the interactions, C_1T_7 recorded significantly lower electrical conductivity (0.449, 0.469, 0.590 and 0.644 dSm^{-1}) at one, two, three and four times exposure to mid storage gamma irradiation and fumigation, respectively compared to all other treatments. However, C_1T_7 was on par with C_1T_1 (0.461 and 0.659 dSm^{-1}) at one and four times exposure.

Table 30. Influence of mid storage gamma irradiation and fumigation on electric conductivity (dSm^{-1}) of soybean and green gram

Treatments	Number of exposure to gamma irradiation and fumigation at three months interval											
	1			2			3			4		
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean
T_1	0.461	0.499	**0.480**	0.572	0.629	**0.600**	0.638	0.693	**0.666**	0.659	0.875	**0.767**
T_2	0.473	0.520	**0.497**	0.614	0.652	**0.633**	0.750	0.772	**0.761**	0.840	0.974	**0.907**
T_3	0.485	0.540	**0.513**	0.652	0.663	**0.658**	0.773	0.793	**0.783**	0.881	1.111	**0.996**
T_4	0.493	0.552	**0.523**	0.666	0.671	**0.669**	0.819	0.856	**0.837**	0.904	1.137	**1.020**
T_5	0.508	0.553	**0.531**	0.688	0.683	**0.685**	0.844	0.875	**0.859**	0.910	1.237	**1.073**
T_6	0.513	0.554	**0.533**	0.687	0.691	**0.689**	0.880	0.884	**0.882**	0.926	1.355	**1.141**
T_7	0.449	0.480	**0.465**	0.469	0.504	**0.487**	0.590	0.667	**0.628**	0.644	0.712	**0.678**
Mean	**0.483**	**0.528**		**0.621**	**0.642**		**0.756**	**0.791**		**0.823**	**1.057**	

Factors	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%	S.Em±	C.D. at 1%
C	0.002	0.006	0.003	0.009	0.003	0.009	0.007	0.019
T	0.004	0.011	0.006	0.016	0.006	0.017	0.013	0.036
C x T	0.006	0.018	0.008	0.023	0.008	0.024	0.018	0.051

Crops: **C_1-** Soybean **C_2-** Green gram
T_1 - Control **T_3 -** 400 Gy **T_5 -** 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4 -** 600 Gy **T_6 -** 1000 Gy

Discussion

V. DISCUSSION

Ageing is a common phenomenon in all the living entities as a result progressive decline in all the vital events occur culminating to death at the end. Seed being a living entity is not an exception to this and seed ageing is affected by many factors *viz*., environmental, genetic, initial seed quality, moisture content, storage containers *etc*., The process of ageing in seeds involves deterioration of many systems within the tissues. As it has been found in many other species with time, the tissues become leakier and thus results in membrane damage and enzyme inactivation (Deepak, 2012). Further, as seeds approach death, they are likely to produce abnormal seedlings, but some species are capable of producing hard, impermeable seed coats (Ellis and Pieta, 1992).

Seed storage environment play an important role in maintenance of seed quality. If is not well then the seeds are more prone for infestation and infection thereby it enhance aging process alarmingly leading to death of seed within a short span of time. Several techniques *viz.*, physical, chemical and biochemical have been practiced to slow down this ageing process *vis-a-vis* maintenance of seed quality during storage. But none of them are proved so effective in controlling insect infestation, infection, weight loss and ultimately the longevity of various crop seeds. Therefore, a new kind of approach is very much required to overcome these challenges during seed/food grain storage.

Irradiation is an ionic, no-heat process that continues to receive attention as a preservation and functional modification agent. In comparison with other physical modification methods, irradiation treatment is rapid, convenient and more extensive because of their easy availability and power of penetration (Delia *et al.*, 2013). However, the morphological, structural and functional changes in crop plants depend on the strength and duration of exposure of these gamma rays. Hence, the gamma radiation is a technology with immense applications in agriculture, industry and medicine. In agriculture it is being utilised in solving various problems such as reduction of post-harvest losses through suppressing sprouting and contamination, eradication or control of insect pests, reduction of food-borne diseases, extension of shelf life and breeding of high performance well adopted and disease resistant agricultural crop varieties. Although it's potential exploitation in Seed Science Research is limited but is gaining importance recently to augment the need of seed and food industries.

Radiation technology such as gamma irradiation is an effective disinfection treatment for stored product insect pests. Ionizing radiation has been suggested as useful alternative to methyl bromide, as there is no development of insect resistance and absence of residue in treated food and no significant loss of nutrients in commodities (Lapidot *et al*., 1991). In view of global trends towards a cleaner agriculture, irradiation strategy is becoming popular as a phytosanitary treatment worldwide due to its positive attributes to facilitate trade through, effective means for minimizing post harvest losses, fast and easy application, non use of chemicals and wide application compared to other phytosanitory treatments (Richard and Patrick, 2014) of fresh commodities as it is generally less damaging than alternative temperature and fumigation treatments (Hallman, 2011).

In any seed production programme, storage of seeds from harvest to next planting assumes greater importance. Soybean and green gram predominantly are the two pulse crops which are to be stored for nearly 8-10 months after harvest until next season. Therefore, storage of these seeds in good condition is of prime importance as the old "seed saved is seed produced" an adage still holds good even for today's modern agriculture.

Hence, an attempt was made to study the effect of gamma irradiation and seed treatment with fungicides and insecticides on seed quality and storability of soybean and green gram, so also to find out the effect of mid storage exposure to gamma irradiation and fumigation on seed quality during storage. The results obtained from the present study are discussed in this chapter.

5.1 Physiological and biochemical changes in soybean and green gram as influenced by gamma irradiation and seed treatment chemicals

In the present study, during initial storage period (up to three months) soybean registered significantly higher values for seed germination and enzyme activities compared to green gram. However, after four months of storage soybean lost the germination very rapidly compared to that of green gram. This might be due to weak structure of soybean seed; inherently short lived and easily subjected to damage (Delouche and Baskin1973). Under storage soybean seed loose their quality faster than any other crop seed except for shelled peanuts (Delouche, 1982).

Irrespective of the treatments imposed, the germination potential of seeds of both the crops decreased with the advancement of storage period. Between the crops, soybean

recorded higher seed germination (85.5 and 79.2%) at initial and three months after storage compared to green gram (83.0 and 78.4%) respectively. Later from four to nine months of storage, green gram recorded highest seed germination (76.6 and 70.2%) compared to soybean (75.9 and 64.5%). The results are in conformity with Kumar *et al.* (2004); Selvaraju and Krishnaswamy (2005) who also reported decrease in germination potential of rice seeds with the advancement in storage period. This variation in storability between the crops was due to genetic control of a particular crop seed to resist deterioration during storage. Similarly, Yogalakshmi *et al.* (1996) noticed genotypic variations between the crops for their storability in rice. Decrease in germination potential during storage was mainly due to age induced phenomenon in most kind of seeds which is inevitable, irreversible and increase in membrane leakage as reported by Abdul- Baki and Anderson (1973). Deterioration in seed quality is associated with decrease in seedling length, dry matter production and vigour index with the advancement of storage period (Singh *et al.*, 2004).

The results of the present study revealed that, among different treatments (exposing the seeds to different doses of gamma rays and seed treatment with fungicides and insecticides) significantly higher seed germination (90.5 and 73.8%) was recorded by the treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (88.8 and 71.1%) at initial and nine months after storage, respectively. This may be due to better protection of seeds by both the combination of insecticide (melathion) and fungicide (thiram) when used at optimum dose. These results are in line with the earlier findings of Ravikumar *et al*. (1987) who reported that soybean seeds treated with melathion (2 g/ kg of seed) or in combination with fungicide (thiram @ 2 g/kg of seed) prevented the insect infestation and thereby registering higher seed germination. Similarly, Anahousur and Bidari (1973) reported higher seed germination in soybean by treating the seeds with thiram (2 g/ kg of seed) even six months after storage. In the same line, Casela *et al*. (1979) in soybean and Radhakrishanan *et al*. (1983) in pigeon pea reported higher seed germination due to seed treatment with thiram (2 g/ kg of seed) and 5 per cent dust formulation of malathion, respectively.

Further, exposing seeds to gamma irradiation (T_2- T_6) showed a significant reduction in seed germination with an increasing gamma irradiation dosage. Almost a linear relationship between germination and dosage of radiation was noticed. The

treatment, T_6 recorded the lowest seed germination (74.6 and 59.9%) compared to control (88.8 and 71.1%) at initial and nine months after storage, respectively (Fig. 1 and Plate 2-3).

This might be due to the result of greater loss of leachates mainly because of enhanced membrane permeability (Krishnaswamy and Seshu., 1989). Leaching of electrolytes was more in seeds exposed to higher dose of gamma irradiation than lower dosage which reduced the germinability and accompanied with reduction in the activities of dehydrogenase and alpha amylase enzyme activity. Further, it might also due to accumulation of non-volatile growth inhibitors in irradiated seeds (Rajarajeshwari *et al*., 2011). Similarly, Meckelvie, (1977) reported that increasing doses of gamma irradiation progressively reduced the vigour of seedlings root growth being more affected by irradiation the shoot. Irradiation restricts the root growth possibly due to inhibition of cell division (Rajarajeshwari, 2011). Muhammad Amjad and Muhammad Akbar (2002) reported higher EC values from the seeds exposed to gamma irradiation than unexposed seeds. Similarly, Lokesha *et al*. (1992) stated that the higher inhibitory effect on germination at higher dosage of gamma rays could be due to several reasons like histological and cytological changes, disruption and disorganization of seed layer and generation of free radicals resulting in metabolic disorders in the germinating seeds that is directly proportional to the intensity of expose to gamma rays. Similarly, Uma and Salimath (2001) reported a significantly reduction in seed germination potential of cowpea seeds with an increase in the irradiation dosage (10 Kr to 60 Kr). Likewise, Narayan *et al.* (2014) noticed decrease in germination percentage with an increase in gamma irradiation dosage from 200 to 800 Gy and also reported that the regeneration potential of callus derived from primary leaves of treated seeds increased at lower dosage of gamma irradiation (200 to 400 Gy). In the same line, Ariramana *et al.* (2014) in pigeon pea, Monica and Seetharaman (2014) in *Lablab purpureus* and Dhulgande *et al.* (2015) in pea reported inhibition of seed germination and seedling growth at higher doses/ concentrations of mutagens. Ludvik (2014) stated that the seeds treated with 0.4K Gy had significantly lower germination rate.

Irrespective of the crops, the abnormal seedlings (%) and dead seeds (%) increased with the advancement of storage period. However, between the crops, soybean registered significantly higher abnormal seedlings (5.4 and 15.0%) compared to green gram (4.8 and 13.2%) respectively, during initial and nine months of storage period.

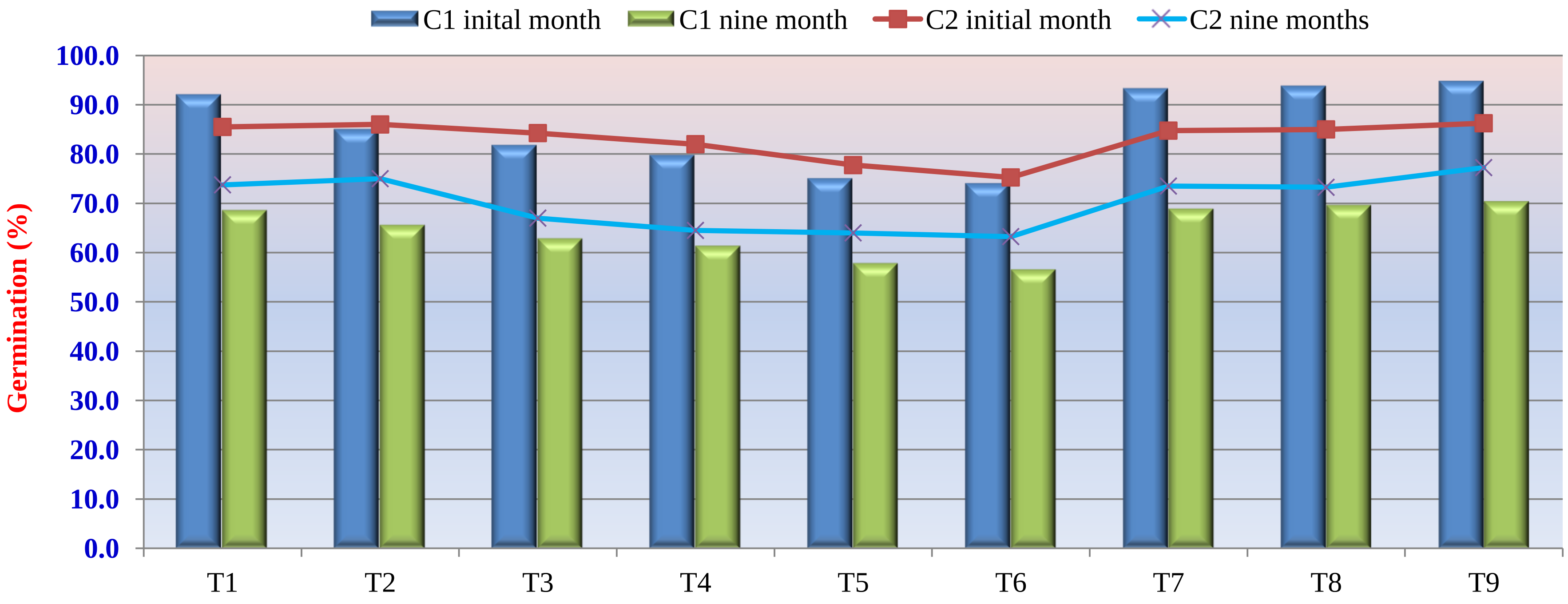


Fig. 1. Influence of gamma irradiation and seed treatment chemicals on seed germination (%) of soybean and green gram

C_1- Soybean

C_2- Green gram

T_1- Control

T_2- 200 Gy

T_3- 400 Gy

T_4- 600 Gy

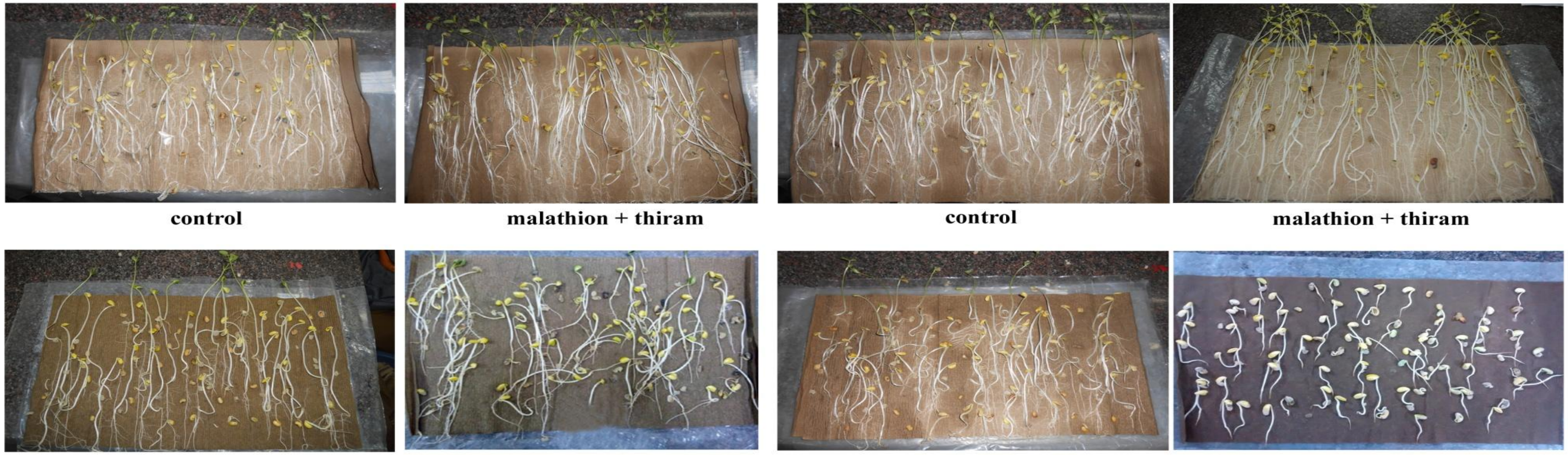
T_5- 800 Gy

T_6- 1000 Gy

T_7- Malathion (2g/ kg of seed)

T_8- Thiram (2g / kg of seed

T_9- Malathion+Thiram (each 2g / kg of seed)



control

malathion + thiram

control

malathion + thiram

200 Gy

1000 Gy

200 Gy

1000 Gy

Initial month

Nine months after storage

Plate 2. Influence of gamma irradiation and seed treatment chemicals on seed germination (%) of soybean during storage

control malathion + thiram control malathion + thiram

200 Gy 1000 Gy 200 Gy 1000 Gy

Initial month Nine months after storage

Plate 3. Influence of gamma irradiation and seed treatment chemicals on seed germination (%) of green gram during storage

While, significantly higher dead seeds were recorded by green gram (8.2 and 14.0%) compared to soybean (5.5 and 13.1%), respectively at initial and nine months after storage. This variation in response by the crops as a result of exposure to gamma irradiation and seed treatment chemicals may be because of differences in genotypic response and also due to inherent genetic composition to withstand the impact of imposed treatment and also ageing. The present results are in conformity with the findings of Cheema and Atta (2003) who also reported varietal differences in radio sensitivity to gamma irradiation in three different basmati rice cultivars.

From the present study, significantly lower abnormal seedlings (1.3 and 11.1%) and dead seeds (5.0 and 11.5%) were noticed in treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (1.5 and 12.0%) and (5.8 and 12.3%) at initial and nine months after storage respectively. Further, a significant and drastic increase (Fig. 2) in the abnormal seedlings (%) and dead seeds (%) were noticed with an increase in gamma radiation dosage (T_2 to T_6). This might be due to gamma irradiation induced oxidative stress with over production of reactive oxygen species (ROS) such as super oxide radical, hydroxyl radical and hydrogen peroxide which reacts rapidly with almost all structural and functional organic molecules including proteins, lipids and nucleic acids causing disturbance in cellular metabolism (Salter and Hewitt., 1992). Similarly, Muhammad Amjad and Muhammad Akbar (2002) also noticed increase in abnormal seedlings with an increase in irradiation dose.

The mean germination time increased with advancement of storage period in both the crops. However, soybean registered lower mean germination time (1.49 and 1.92) at initial and three months of storage compared to green gram (1.88 and 2.01) respectively but from fourth month of storage green gram recorded lower mean germination time (2.08 and 2.55) compared to soybean (2.39 and 2.74) at four and nine months of storage respectively. Among the treatments, significantly lower mean germination time (1.55 and 2.31) was noticed in combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (1.68 and 2.60) at initial and nine months after storage respectively. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant increase in the mean germination time (Fig. 3) with an increase in gamma irradiation. This may ascribed to histological, cytological changes, disruption and disorganization of seed layer and also generation of free radicals resulting in metabolic disorders in the germinating seeds (Lokesha *et al.*, 1992) and inhibitory effect of gamma rays on seed germination (Majeed *et al.* 2010). These results are also in line with the findings of Majeed *et al.* (2010) who found that the mean germination time of *Lepidum sativam* was significantly delayed at higher dose of gamma rays.

The peak value of germination, germination rate index and seedling vigour index declined with the progress of storage period in both the crops but the extent of variation was not similar. Between the crops, soybean recorded the highest peak value (22.0 and 16.3) and germination rate index (7417 and 6317) at initial and three months of storage compared to green gram (21.1 and 16.0) and (7242 and 6062) respectively, but from fourth month of storage green gram recorded the highest peak value (15.9 and 12.5) and germination rate index (5858 and 3896) compared to soybean (14.8 and 11.6) and (5314 and 3800) respectively. This is due to higher initial food reserves which showed rapid and fast germination (Kavitha, 2002). Similarly, Chandrababa *et al.* (1990) in green gram and black gram reported positive correlation between seed size and germination. While, Roy *et al.* (2008) reported increase in germination rate with increase in seed size.

From the present study, it was observed that, treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) recorded significantly higher germination rate index (8107 and 4579) compared to all other treatments and control (7492 and 4015) at initial and nine months after storage respectively. Similarly, the peak value of germination was also significantly higher in treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) 26.9 and 18.3 compared to all other treatments control 22.0 and 11.7. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in germination rate index and peak value of germination with an increase in gamma radiation dosage wherein, 1000Gy (T_6) recorded the least germination rate index (6521 and 3035) and peak value of germination (16.5 and 9.5) compared to control (7492 and 4015) and (22.0 and 11.7) respectively. These varied physiological changes might be due to radiation induce plant sensitivity to gamma rays which in turn might have reduced the synthesis of endogenous growth regulators, especially cytokinins, (Kiong *et al*., 2008) thereby reduced the germination parameters with corresponding decline in growth of the plants. These results are in line with the earlier findings of Cheema and Atta (2003) who reported decrease in peak value of germination with an increase in gamma dose. Similarly, Aparna *et al*. (2013) reported significant decrease in speed of germination, mean daily germination, peak and germination value with an increase in radiation dose.

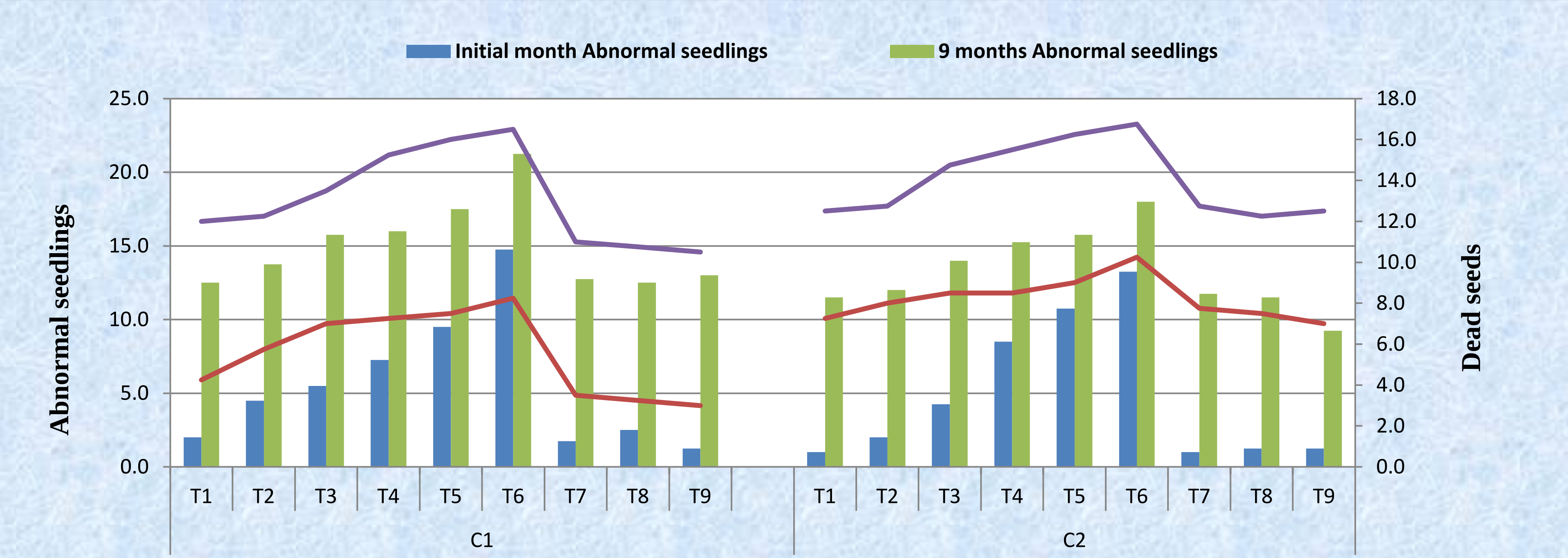


Fig. 2. Influence of gamma irradiation and seed treatment chemicals on abnormal seedlings (%) and dead seeds (%) of soybean and green gram

C_1- Soybean **C_2**- Green gram

T_1- Control T_3- 400 Gy T_5- 800 Gy T_7- Malathion (2g/ kg of seed) T_9- Malathion+Thiram (each 2g / kg of seed)
T_2- 200 Gy T_4- 600 Gy T_6- 1000 Gy T_8- Thiram (2g / kg of seed)

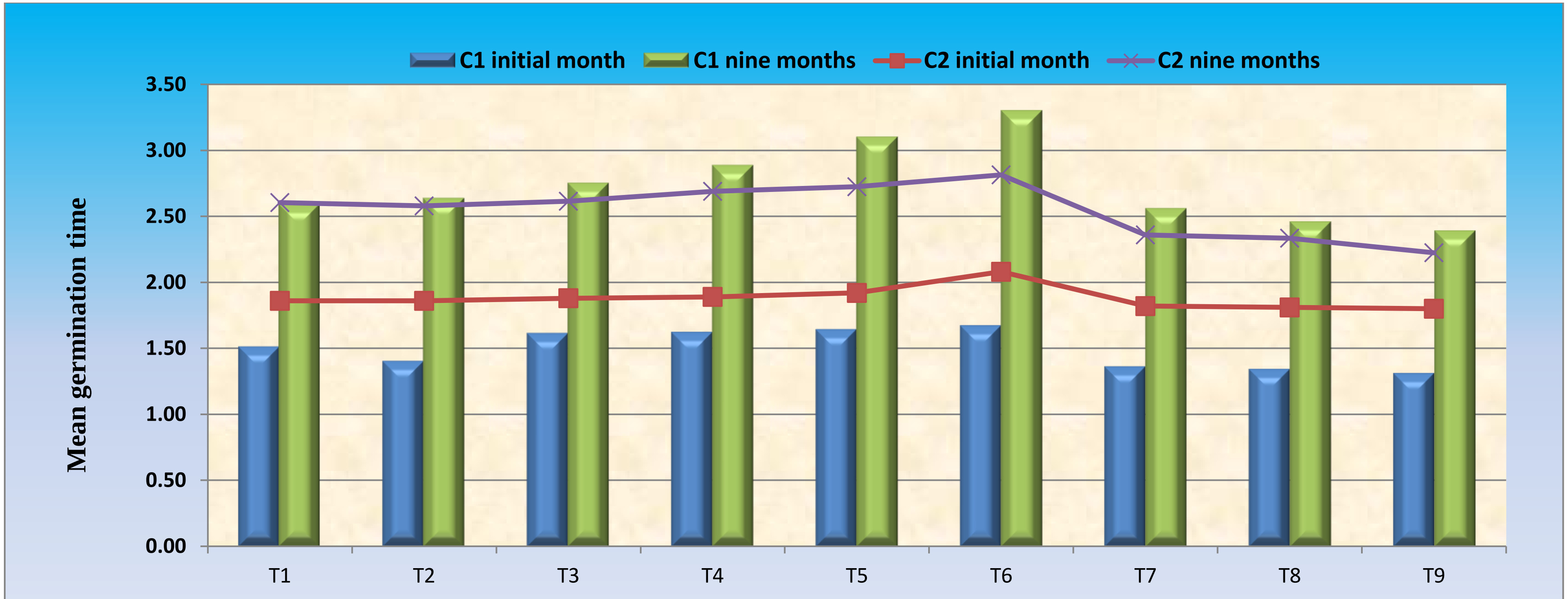


Fig. 3. Influence of gamma irradiation and seed treatment chemicals on mean germination time of soybean and green gram

C_1- Soybean **C_2**- Green gram

T_1- Control
T_2- 200 Gy
T_3- 400 Gy
T_4- 600 Gy
T_5- 800 Gy
T_6- 1000 Gy
T_7- Malathion (2g/ kg of seed)
T_8- Thiram (2g / kg of seed)
T_9- Malathion+Thiram (each 2g / kg of seed)

In our present study, green gram registered highest shoot length (16.34 and 12.68) and root length (20.42 and 15.20) compared to soybean (12.63 and 9.43) and (16.16 and 12.16) at initial and nine month of storage respectively. This might be due to the sensitive nature of soybean crop to with stand the imposed gamma irradiation treatment and there by registering lesser shoot and root length (Delouche and Baskin., 1973). However, the root length, shoot length, seedling dry weight and seedling vigour index decreased with the advancement of storage. Similar decrease in root length in paddy with the advancement of storage period and variation among the varieties were reported by Pameri *et al*. (2016).

Among the different treatments, significantly higher shoot (16.56 and 13.73 cm) and root (20.56 and 16.24 cm) length were recorded by treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (16.08 and 13.34 cm) and (19.39 and 14.00 cm) at initial and nine months after storage, respectively. This might be due to the influence of fungicides which might have increased phenol production and total sugars (Sindhan *et al*., 1996). The results are in line with the findings of Choudury *et al*. (2011) who also reported significantly higher root and shoot length due to seed treatment with thiram and bavistin each at one gram per kg of seed. Similarly, Ravikumar *et al*. (1987) reported that soybean seeds treated with malathion (10 g/ kg of seed) or in combination with thiram (2 g/ kg of seed) prevented insect infestation and recorded higher shoot length. Similarly, Biradar (2001) reported higher shoot length in soybean due to seed treatment with malathion (10 g/ kg of seed) compared to control even at the end of ten months of storage.

Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in shoot and root length with an increase in gamma radiation dosage (Fig. 4) This was probably due to reduced mitotic activity of the meristematic tissues (Shakoor *et al*., 1978 and Khalil *et al*., 1986). Reduction in seedling growth at higher dosage of irradiation might be attributed to the changes in the level of auxin and ascorbic acid contents and physiological and biochemical disturbances (Gunekal and Sparrow, 1954), changes in the enzyme activity (Alduous and Stewart, 1952), chromosomal breakage and mitotic inhibition (Sparrow and Vans, 1961) and inhibition of DNA synthesis (Mikaelson, 1968). These results are in line with the findings of Uma and Salimath (2001) who reported a significant reduction in root and shoot length of cowpea seeds with an increase in the irradiation dosage (10 Kr to 60 Kr) and Aparna *et al*. (2013) in groundnut seeds at

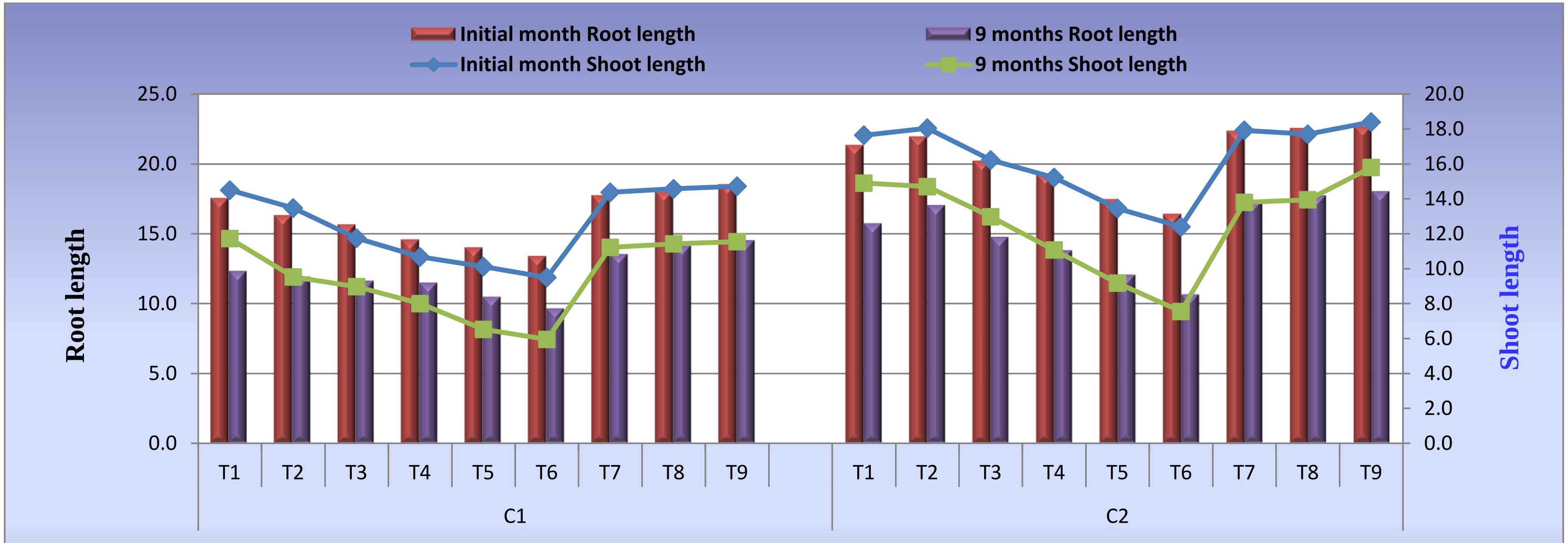


Fig. 4. Influence of gamma irradiation and seed treatment chemicals on shoot length (cm) and root length (cm) of soybean and green gram

C_1- Soybean

C_2- Green gram

T_1- Control

T_2- 200 Gy

T_3- 400 Gy

T_4- 600 Gy

T_5- 800 Gy

T_6- 1000 Gy

T_7- Malathion (2g/ kg of seed)

T_8- Thiram (2g / kg of seed)

T_9- Malathion+Thiram (each 2g / kg of seed)

higher gamma. Similarly, Borzouei *et al*. (2010) reported decrease in root and shoot length in two wheat genotypes (Roshan and T-65-58-8) with an increase in gamma irradiation dosage (0, 100 and 200 Gy).

In the present study, green gram proved best in storage capacity as it maintained significantly higher seedling dry weight (0.384 g) and seedling vigour index (3065). This might be due to higher shoot and root length registered in our study by green gram which has a direct correlation with seedling dry weight and seedling vigour index. However, irrespective of the crops, the seedling dry weight and seedling vigour index decreased with the advancement of storage period. Similar decrease in seedling dry weight and seedling vigour index in paddy with the advancement of storage period and variation among the varieties were reported by Pameri *et al.* (2016).

Among the different treatments (exposing the seeds to different dosage of gamma rays and seed treatment with fungicide and insecticide) significantly higher seedling dry weight (0.418 and 0.333 g) was recorded by treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (0.398 and 0.291 g) at initial and nine months after storage respectively. Similarly, T_9 also recorded significantly higher seedling vigour index (3343 and 2222) compared to all other treatments and control (3135 and 1952) at initial and nine months after storage. This might be due to longer shoot and root length recorded by T_9 in our study which had a direct correlation with seedling dry weight and seedling vigour index. The fungicide prevented the seed deterioration by reducing the fungal invasion and favoured the seed germination and other quality parameters (Sundaresh *et al.*, 1987). The results are in line with the findings of Basavaraj *et al*. (2008) who reported that onion seeds coated with polymer (12 ml) + thiram (2 g/ kg of seed) recorded higher seedling dry weight and seedling vigour index. Similarly, Ravikumar *et al*. (1987) reported that soybean seeds treated with melathoin (10 g/ kg of seed) or in combination with thiram (2 g/ per kg of seed) recorded significantly higher seedling dry weight and vigour index. Similarly, Shivagouda *et al*. (2014) recorded significantly higher seedling dry weight and seedling vigour index by treating pigeon pea seeds with thiram (3 g/ kg of seed). However, Hunje *et al*. (1990) reported adverse effect on seedling vigour index of cowpea seeds treated with malathion (10 g / kg of seeds) and thiram (2 g/ kg of seed) or both malathion and thiram in different combinations during six months storage.

Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in seedling dry weight and seedling vigour index (Fig. 5) with an increase in gamma radiation dosage. This reduction in seedling dry weight and seedling vigour index at higher dosage might be due to shorter root and shoot length registered in our study which had a direct correlation with dry weight and seedling vigour index. Due to inhibition of mitosis and enzyme activities it is more likely that reserve food was utilized less efficiently at higher dose of irradiation which might have resulted in significant reduction of seedling fresh and dry weight (Alduous and Stewert, 1952). The other causes for reduction in dry matter may be due to inhibition of cell elongation. The results are in line with the findings of Veeresh *et al*. (1995) who recorded lower shoot fresh weight of winged bean at higher dose. Similarly, Kon *et al*. (2007) reported reduction in shoot dry weight of long beans when exposed to higher gamma radiation dose. So also, Aparna *et al*. (2013) in groundnut and Radha and Uma (2015) in finger millet reported reduction in seedling vigour index at higher dosage.

Irrespective of the crops, the seed infection per cent (*Aspergillus niger, Aspergillus flavus, Rhizactonia solania* and *Rhizophus* spp) increased with the advancement of storage period. However, among the crops, green gram (17.6 and 78.2%) registered significantly higher seed infection compared to soybean (13.6 and 48.4%) respectively, during initial and nine months of storage period.

Significantly lower seed infection (4.0 and 50.0%) was recorded by treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (30.0 and 77.0%) at initial and nine months after storage, respectively. This might be due to the fungicidal effect on production of pectolytic and cellulolytic enzymes by the fungi and thereby reducing the incidence of fungal pathogen

(Mehta *et al*., 1990). The results are in line with the earlier findings of Choudury *et al*. (2011) who reported low seed infection in rice seeds treated with thiram and carbendazim (each at 1 g/ kg of seed). Similarly, Vamadevappa (1998) observed complete protection of soybean seeds from different fungal species by seed treatment with thiram (2 g/ kg of seed).

Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in seed infection with an increase in gamma radiation dosage, but the seed infection increased with the storage period (Fig. 6). Irradiation at higher dose, though

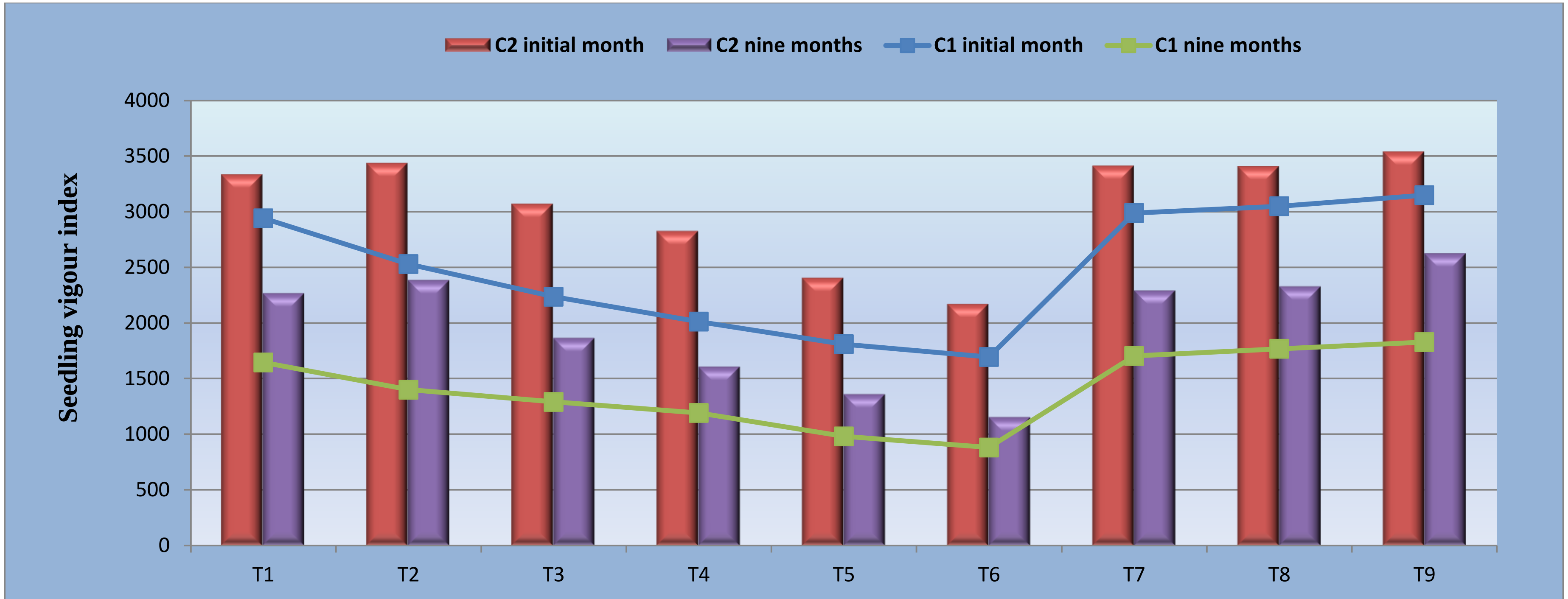


Fig. 5. Influence of gamma irradiation and seed treatment chemicals on seedling vigour index of soybean and green gram

C_1- Soybean

C_2- Green gram

T_1- Control
T_2- 200 Gy
T_3- 400 Gy
T_4- 600 Gy
T_5- 800 Gy
T_6- 1000 Gy
T_7- Malathion (2g/ kg of seed)
T_8- Thiram (2g / kg of seed)
T_9- Malathion+Thiram (each 2g / kg of seed)

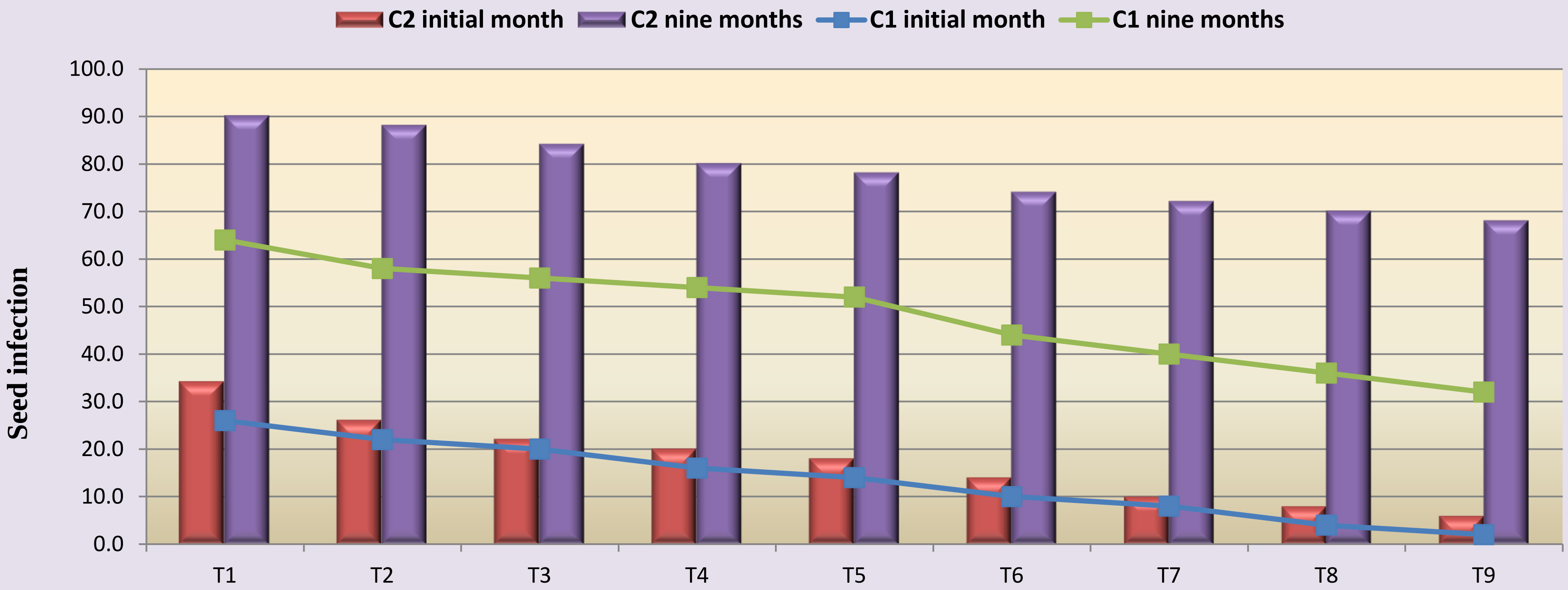


Fig. 6. Influence of gamma irradiation and seed treatment chemicals on seed infection (%) of soybean and green gram

C_1- Soybean

C_2- Green gram

T_1- Control

T_2- 200 Gy

T_3- 400 Gy

T_4- 600 Gy

T_5- 800 Gy

T_6- 1000 Gy

T_7- Malathion (2g/ kg of seed)

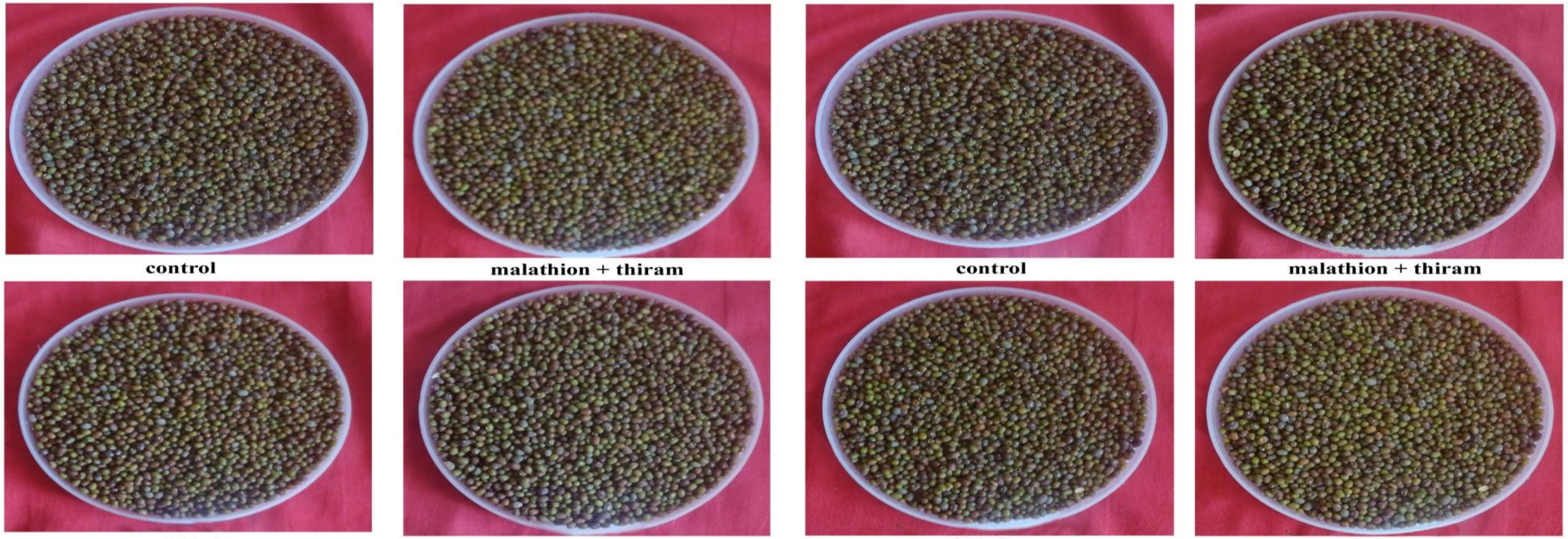
T_8- Thiram (2g / kg of seed)

T_9- Malathion+Thiram (each 2g / kg of seed)

found more effective in decontaminating microbial infection, but negatively affected the seed germination efficiency in addition to impairment of metabolic activities of the seeds (Maity *et al*., 2004). The results are in line with the findings of Mahrous (2007) who reported that gamma irradiation of *Aspergillus flavus* infected soybean seeds at a dosage of 1 KGy was sufficient to inhibit fungus growth and afflatoxin production. Similarly, Maity *et al*. (2009) concluded that the fungal growth and their population of gamma treated rice seeds decreased significantly with an increase in irradiation dose and storage time.

In the present study, insect eggs and seed damage in soybean were not noticed from initial to nine months of storage. However, in case of green gram insect eggs and seed damage were observed from seventh month onwards which increased up to nine months after storage (Plate 4) in all the treatments. Although, insect eggs and seed damage were even noticed in irradiated seeds from eighth month after storage but the percentage of this decreased with an increase in dosage (Fig. 7). Whereas, in treatments T_7, T_8 and T_9 insect eggs and seed damage were noticed at lower percentage compared to control from seventh month of storage. Significantly higher weight loss was noticed in green gram which went on decreasing with an increase in the dosage of gamma irradiation and the least was recorded in 1000 Gy (0.70%).

However, in treatments T_7, T_8 and T_9 the weight loss was lowest compared to control. This might be due to treating the seeds with insecticide and fungicide might have inhibited hatching of eggs resulting no emergence of adults and thereby absence of pinholes on seeds. The results are in line with Pramanik and Sardar (2006) who carried out the laboratory experiment to assess the effectiveness of Nogos, Malathion, Sevin and Limper on lentil, gram, grass pea, green gram and black gram seeds with eggs of pulse beetle, *Callosobruchus chinensis* L. The insecticides sprayed on seeds with eggs inhibited their hatching and resulted in significantly lowest rate of adult emergence. They reported 26.35-100 per cent reduction in seed damage and 40-100 per cent weight loss in insecticides treated seeds of five different types of pulses with highest reduction in seed damage and weight loss was observed with Nogos and malathion treatments. Similarly, Pathania and Thakur (2012) reported 100 per cent mortality due to seed treatment with malathion (0.5%) and also by minimizing oviposition, seed damage and weight loss.



control

malathion + thiram

control

malathion + thiram

200 Gy

1000 Gy

200 Gy

1000 Gy

Seven months after storage

Nine months after storage

Plate 4. Influence of gamma irradiation and seed treatment chemicals on seed damage of green gram during storage

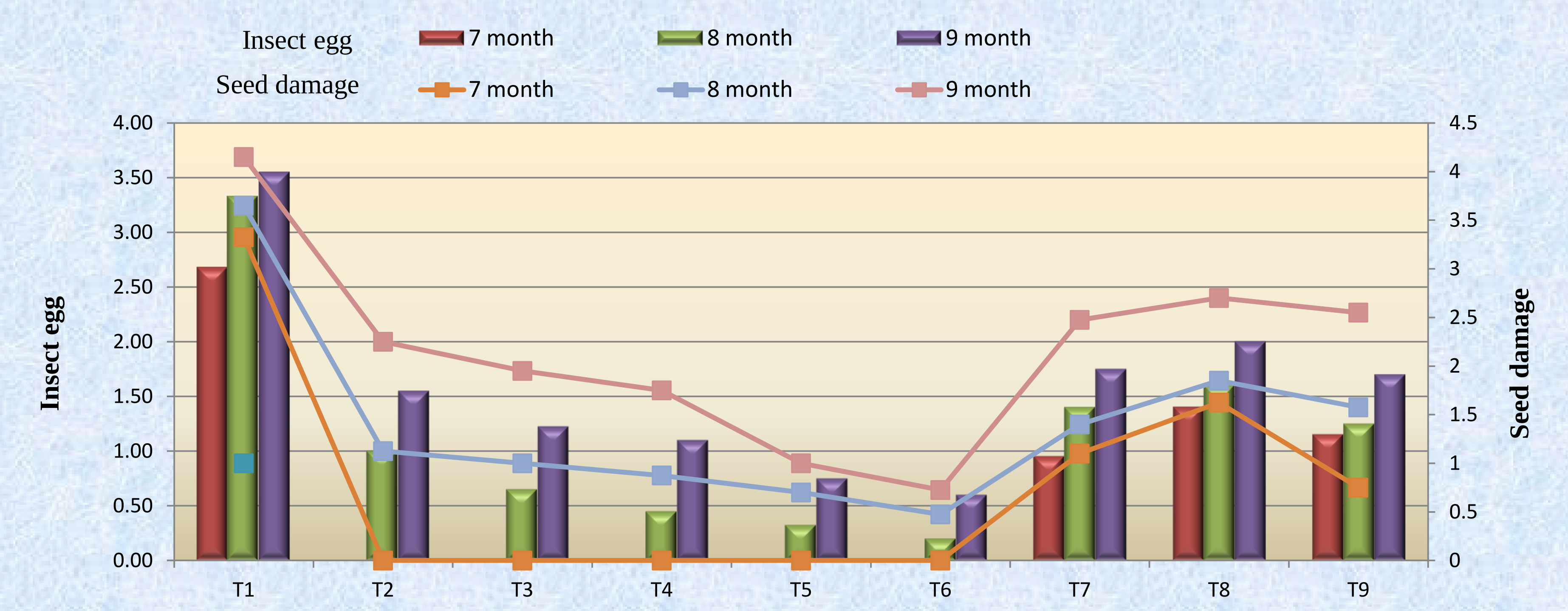


Fig. 7. Influence of gamma irradiation and seed treatment chemicals on insect egg (%) and seed damage (%) of green gram

C_1- Soybean **C_2-** Green gram

T_1- Control
T_2- 200 Gy
T_3- 400 Gy
T_4- 600 Gy
T_5- 800 Gy
T_6- 1000 Gy
T_7- Malathion (2g/ kg of seed)
T_8- Thiram (2g / kg of seed)
T_9- Malathion+Thiram (each 2g / kg of seed)

Among the different treatements, the insect eggs (%), seed damage (%) and weight loss (%) were noticed at lowest percentage in the treatments T_7, T_8 and T_9 from seven to nine month of storage. The results are in line with findings of Pramanik and Sardhar (2006) who reported lower number of emerged adults, reduction in seed damage and weight loss in insecticide treated seeds of green gram and bengal gram. Similarly, Radhakrishnan *et al*. (1983) reported 90 per cent pulse bruchid mortality with dust formulation of five per cent melathion. Pathania and Thakur (2012) also reported that seeds treated with malathion (0.5%) was most effective resulting in 100 per cent adult mortality after seven days of exposure and was also proved best in minimizing the oviposition, seed damage and weight loss.

Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in insect egg (%), seed damage (%) and per cent weight loss with an increase in gamma radiation dosage even after nine months of storage. This might be due to the action of gamma irradiation as it acts as an effective disinfecting agent for seeds and thereby control the insects which lead to complete mortality of insects and also prevented hatching of eggs on seed leading to neither damage nor reduction in weight loss of the seed. The results are in line with the findings of Richard and Patrick (2014) who reported 100 per cent mortality of *Sitophilus zeamays* and *Callosobruchus maculatus* when exposed to gamma radiation at 300 Gy and 500 Gy. In the same line, Byun *et al*. (1988) evaluated the effect of gamma irradiation for controlling infestation of rice weevil (*Sitophilus oryzae*) and observed complete mortality of egg and larval stages at 0.05 kGy. While, Kareem and Baki (2013) observed severe reduction in fecundity and fertility of pest of rice in 25 days old larvae treated with a gamma dose of 80 Gy.

The dehydrogenase enzyme activity is a good and stable metabolic marker to estimate the degree of vigour in seeds (Saxena *et al.*, 1987) and have positive association with vigour and viability of seeds (Halder and Gupta, 1982 and Rudrapal and Basu, 1982). In our present study, the dehydrogenase enzyme activity decreased with the advancement of storage period due to the inability of the seed tissues to reduce tetrazolium chloride to insoluble formazan as revealed by Raja (2003) in paddy and Anuradha *et al.* (2010) in bengal gram.

Between the crops, soybean recorded higher dehydrogenase enzyme activity (2.690 and 1.836 OD value) and alpha amylase enzyme activity (26.34 and 25.64 mm) at initial and two months after storage compared to green gram (2.384 and 1.476 OD value) and (26.05 and 24.96 mm) respectively, but from fourth month of storage green gram recorded higher dehydrogenase enzyme (0.785 and 0.204 OD value) and alpha amylase enzyme activity (24.31 and 22.13) at four and eight months of storage compared to soybean (0.402 and 0.181 OD value) and (22.14 and 20.46 mm), respectively. This might be due to age induced deterioration which is a common phenomenon in any living entity and difference in genotypic response may be due to variation in inherent genotypic composition to withstand the impact of ageing. The results of the present study are in conformity with the findings of Khidrapure (2015) and Nagrajaiah (2014) in paddy who reported low dehydrogenase and alpha amylase enzyme activities with the advancement of storage period.

Significantly higher dehydrogenase enzyme activity (3.447 and 0.252 OD value) was recorded by treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (2.563 and 0.203 mm) at initial and eight months after storage respectively. Similarly, the alpha amylase enzyme activity was also higher in T_9 (28.50 and 24.95 mm) compared to all other treatments and control (26.60 and 21.18 mm) at initial and nine months after storage respectively. Further, exposing the seeds to gamma irradiation (T_2 to T_6) showed a significant reduction in dehydrogenase and alpha amylase activity with an increase in gamma radiation dosage (Fig. 8 and Plate 5-6). This may be due to decline in the activity of amylases in seed which reduces the rate of starch hydrolysis and would thus be expected to slow down the germination process (Koksel *et al.*, 1998). These results are in line with the findings of Ivan *et al.* (2012) who reported that irradiation of malt caused a significant reduction in alpha and beta amylase activity. Similarly, Delia *et al.* (2013) noticed that the biochemical differences based on photosynthetic pigment content revealed an inverse relationship to the dosage of exposure.

Deterioration alters the semi-permeable property of the membrane and its integrity**.** The electrical conductivity of seed leachate was found to be a good index of seed viability (Mathews and Bradnock, 1968), vigour (Grabe, 1967) and deterioration (Hibbard and Miller, 1928). Membrane integrity of seed has a greater influence on seed performance (Tappel, 1965 and Berjack, 1968). Electrical conductivity of seed leachate, leaching of sugars and amino acids are negatively associated with membrane integrity and so with germination and vigour (Delouche and Baskin, 1973; Bhaskaran, 1995 and Sabirahamed, 2003). In the present study, the electrical conductivity of seed leachates increased with an increase in storage period. Between the crops, green gram (0.509 and

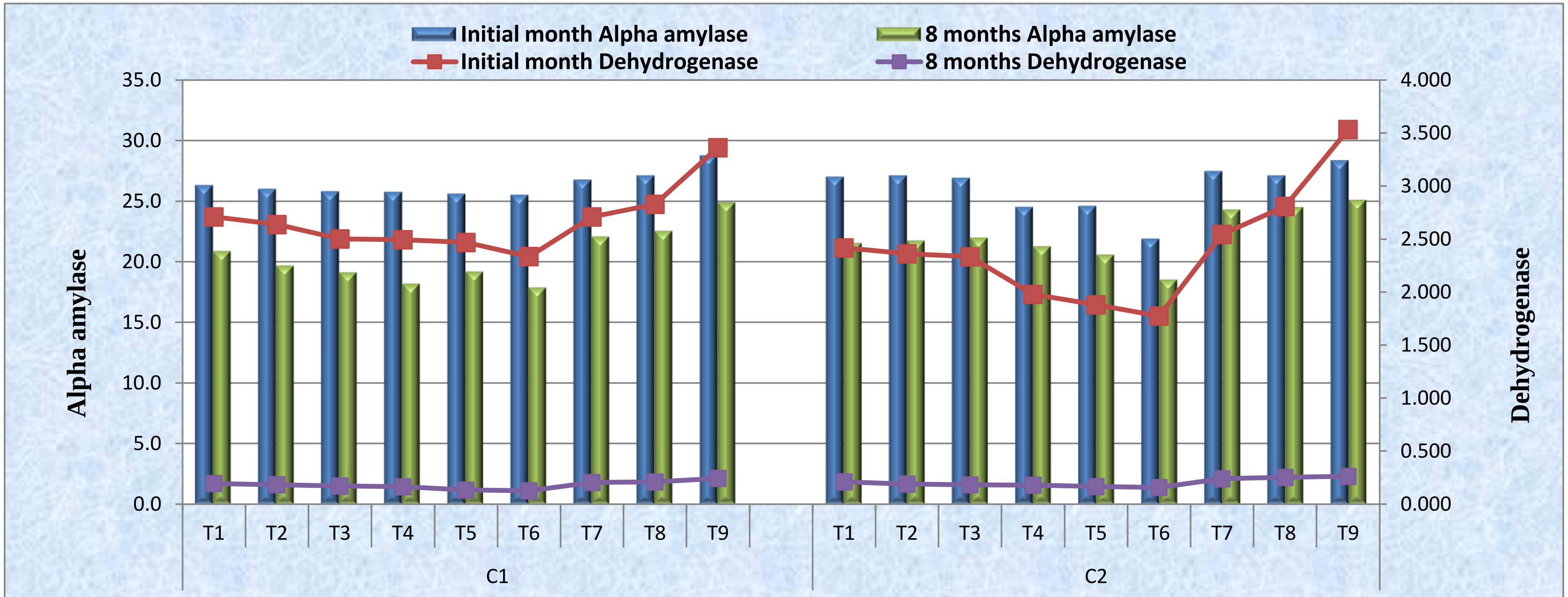


Fig. 8. Influence of gamma irradiation and seed treatment chemicals on alpha amylase activity (mm) and dehydrogenase activity of soybean and green gram

C_1- Soybean

C_2- Green gram

T_1- Control

T_2- 200 Gy

T_3- 400 Gy

T_4- 600 Gy

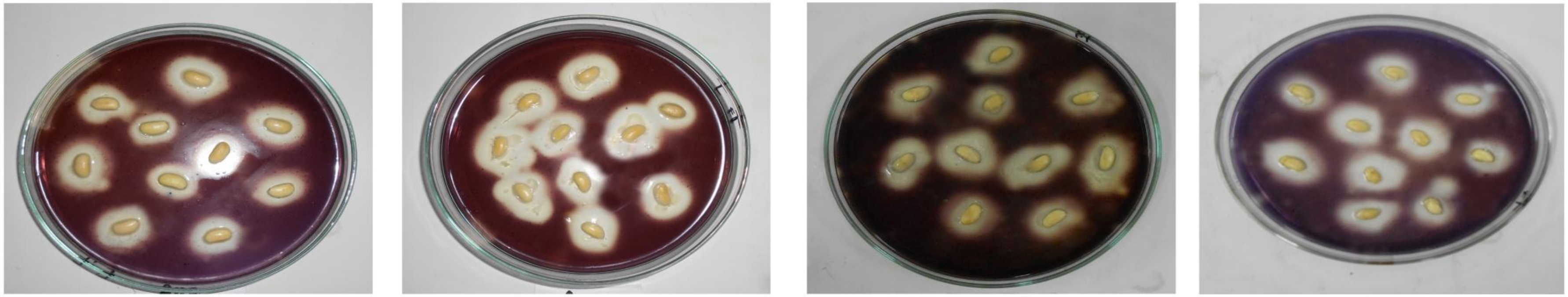
T_5- 800 Gy

T_6- 1000 Gy

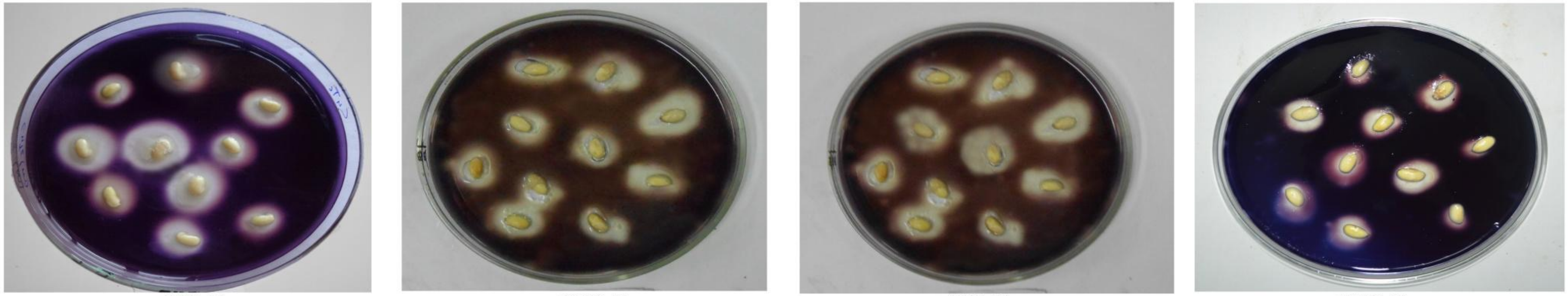
T_7- Malathion (2g/ kg of seed)

T_8- Thiram (2g / kg of seed)

T_9- Malathion+Thiram (each 2g / kg of seed)



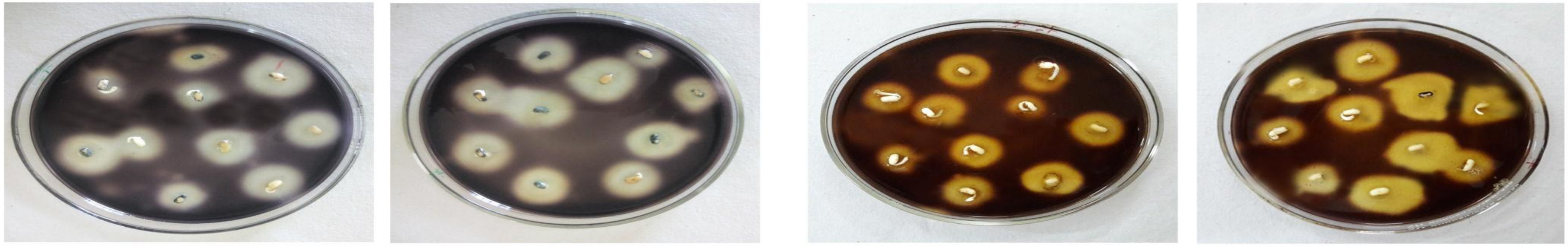
control **malathion + thiram** **control** **malathion + thiram**



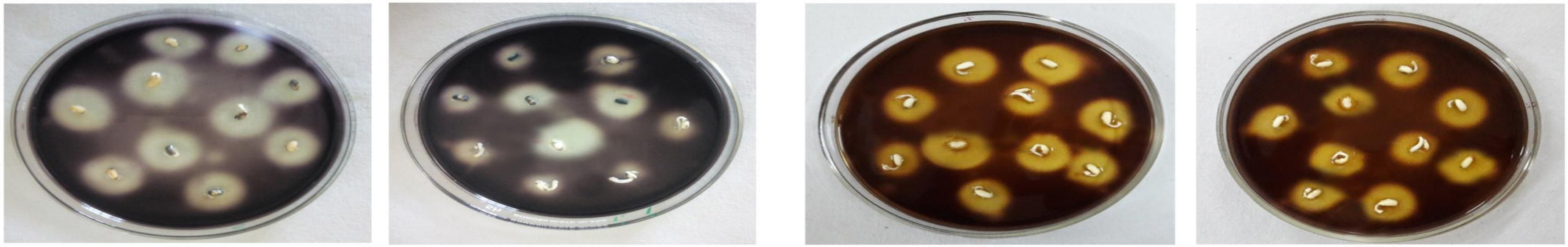
200 Gy **1000 Gy** **200 Gy** **1000 Gy**

Initial month **Eight months after storage**

Plate 5. Influence of gamma irradiation and seed treatment chemicals on alpha amylase enzyme activity (mm) of soybean during storage



control malathion + thiram control malathion + thiram



200 Gy 1000 Gy 200 Gy 1000 Gy

Initial month Eight months after storage

Plate 6. Influence of gamma irradiation and seed treatment chemicals on alpha amylase enzyme activity (mm) of green gram during storage

0.766 dSm^{-1}) released more electrolytes compared to soybean (0.472 and 0.684 dSm^{-1}) at initial and eight months after storage period. This might be due to more seed damage (%) in green gram compared to soybean as observed the present study. As per Loeffler *et al.* (1988) the physical injury to seed coat and seed size adversely affect the electrical conductivity. This may also be due to the anatomical structure, membrane permeability and composition of the seed coat (Patil, 2016). Similar observations were made by Kumar *et al.* (2013) in paddy and Hosamani *et al.* (2013) in soybean.

In the present study, significantly lower electrical conductivity (0.414 and 0.655 dSm^{-1}) was recorded by treatment combination of malathion and thiram each @ 2 g per kg of seed (T_9) compared to all other treatments and control (0.480 and 0.706 dSm^{-1}) at initial and eight months after storage, respectively. Further, exposing the seeds to gamma irradiation (T_2 –T_6) showed an increase in electrical conductivity with increase in gamma irradiation dosage (Fig. 9). This increase in electrical conductivity due to gamma irradiation is attributed to increased membrane permeability which enhanced leakage of leachates (Krishnaswamy and Seshu., 1989). Similar findings were made by Muhammad Amjad and Muhammad Akbar (2002) who reported higher electrical conductivity of onion seeds exposed to gamma irradiation (10, 20, 40, 80 and 100 Krad) than that of unirradiated seeds.

In our present investigation, irrespective of the gamma irradiation dosage and seed treatment chemicals, the seed quality parameters declined progressively with an increase in the storage period. However, seed treatment with malathion + thiram each at the rate of 2 g per kg of seed was found superior in maintaining the longevity of seeds.

5.2 Physiological and biochemical changes in soybean and green gram seeds as influenced by mid storage exposure to gamma irradiation and fumigation

An attempt was made in the present investigation to expose the seeds of both crops under study to different dosage of gamma irradiation and fumigation during mid storage at an interval of three months. Irrespective of the treatments, the germination potential of seeds of both the crops decreased with the advancement of storage period. Among the crops, soybean maintained higher seed germination (82.9 and 65.3%) compared to green gram (82.5 and 62.6%) at one and two times mid storage exposure to gamma irradiation and fumigation but at three and four times mid storage exposure green

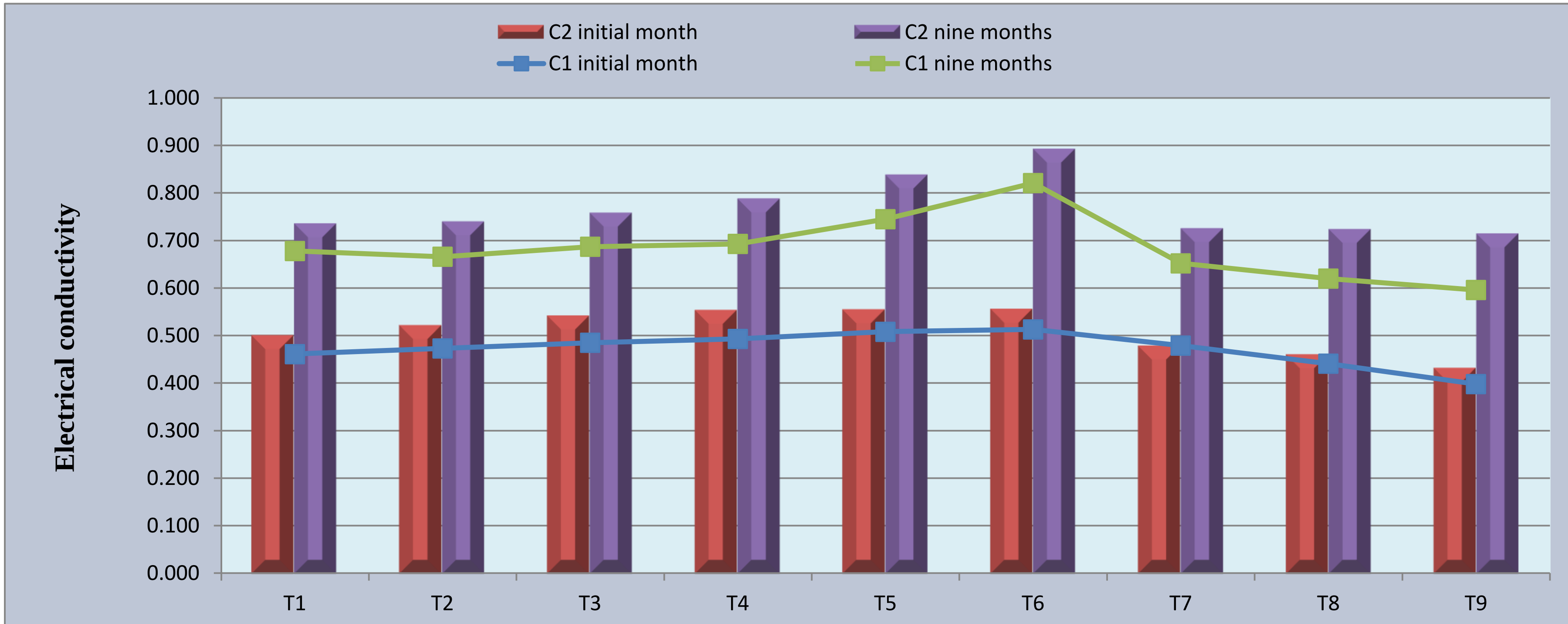


Fig. 9. Influence of gamma irradiation and seed treatment chemicals on electrical conductivity (dS/m) of soybean and green gram

C_1- Soybean
C_2- Green gram

T_1- Control
T_2- 200 Gy
T_3- 400 Gy
T_4- 600 Gy
T_5- 800 Gy
T_6- 1000 Gy
T_7- Malathion (2g/ kg of seed)
T_8- Thiram (2g / kg of seed)
T_9- Malathion+Thiram (each 2g / kg of seed)

gram recorded highest seed germination (59.9 and 51.7%) compared to soybean (56.7 and 50.8%) respectively. This variation in storability between the crops was obviously due to the genetic control to resist the impact of the imposed treatments and deterioration during storage. Yogalakshmi *et al.* (1996) noticed genotypic variation between the crops for their storability in rice. Decrease in germination potential during storage was mainly due to age induced phenomenon in most kind of seeds which is inevitable, irreversible and increase in membrane leakage (Abdul- Baki and Anderson, 1973). Deterioration in seed quality is associated with decrease in seedling length, dry matter production and vigour index with the advancement of storage period (Singh *et al*., 2004).

The results of the present study revealed that, among the different treatments significantly higher seed germination (89.8 and 71.4%) was recorded by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (88.8 and 71.1%) at one and four times exposure to fumigation (Plate 7 and 8). However, the seed germination (%) decreased significantly with an increase in both the number of repeated gamma irradiation and fumigation and also with the dosage of gamma irradiation. This reduction in germination (%) due to repeated fumigation might be due to higher residual effect of fumigants as well as phosphorelation activity leading to the blocking of glycolysis cycle (Shadi *et al*., 1978). The results are in line with the findings of Ramazan and Chahal (1989) who reported reduction in germination of wheat seeds fumigated with aluminium phopsphide (@ 1.2 g per tonne) up to five times. Similarly, Singh *et al*. (2002) reported that the seeds of green gram and chickpea fumigated with phosphine showed a reduction in germination after 21 months. On the contrary Gupta *et al*. (2000) reported that fumigation with aluminium phosphide at 3, 6 and 9 g per cubic meter significantly protected the seeds against infestation of *Rhyzopertha dominica* and there by registered no adverse effect on germination of wheat seeds due to repeated fumigation, even at three fold higher dose compared to un fumigated seeds. Similarly, Cogburn and Tilton (1963) reported that germination of rice seeds was not affected due to fumigation with phosphine (73-121 tablets/1000 cubic feet). Likewise, Gupta and Kashyap (1995) reported higher germination of green gram seeds fumigated with phosphine (0.125 mg/ litre) tablets. Similarly, Strong and Lindgren (1958) did not notice any adverse effect on seed germination (%) of wheat seeds due to fumigation with hydrogen cyanide, while, it was

control fumigation control fumigation

200 Gy 1000 Gy 200 Gy 1000 Gy

One time exposure Four time exposure

Plate 7. Influence of mid storage gamma irradiation and fumigation on seed germination (%) of soybean during storage

control fumigation control fumigation

200 Gy 1000 Gy 200 Gy 1000 Gy

One time exposure Four time exposure

Plate 8. Influence of mid storage gamma irradiation and fumigation on seed germination (%) of green gram during storage

affected due to methyl bromide. However, progressive reduction in germination (%) was noticed with thrice fumigation of both the fumigants. Further, the per cent reduction in germination was zero to three per cent during first fumigation. While, during second fumigation it ranged from zero to ten per cent.

The per cent reduction in seed germination (Fig.10) due to four time exposures to gamma irradiation at higher dose (1000 Gy- T_6) was 40.0 per cent, while it was only 18.3 per cent due to the fumigation (T_7) over one time exposure. This might be due to repeated irradiation of seeds with high dose of gamma rays disturb the synthesis of proteins (Xiuzher, 1994), hormone balance (Rabie *et al.*, 1996), leaf gas-exchange (Stoeva and Bineva, 2001), water exchange and enzyme activity (Stoeva *et al.*, 2001). Leaching of electrolyte was more in seeds exposed to higher dose than that of lower dose and thereby reduced the germinability of irradiated seeds accompanied by reduction in the activities of dehydrogenase and alpha amylase enzyme activity. This could also be due to accumulation of non-volatile growth inhibitors in irradiated seeds (Rajarajeshwari, 2011). Similarly, Meckelvie, (1977) reported that high dose of gamma irradiation progressively reduced the vigour of seedlings, root growth being more affected by irradiation than the shoot growth. Irradiation restricts the root growth possibly due to inhibition of cell division. These results are in line with the findings of Ariramana *et al.* (2014) in pigeon pea, Monica and Seetharaman (2014) in *Lablab purpureus* and Dhulgande *et al.* (2015) in pea who noticed inhibition of seed germination and seedling growth at higher dose or concentration of mutagens. Similarly, Chaudhuri (2002) reported significant reduction in seed germination at higher dosage (2 KGy), while at lower dose (0.1 KGy) the germination percentage was not significantly affected from that of control.

Irrespective of the crops, the abnormal seedlings (%) and dead seeds (%) increased with the number of mid storage exposure to gamma irradiation and fumigation. The per cent increase in abnormal seedlings (%) and dead seeds (%) due to four time exposures to gamma irradiation (Fig. 11) at higher dose (1000Gy- T_6) was 17.9 and 24.3 per cent, while it was only 10.3 and 6.4 per cent, respectively due to fumigation (T_7) over one time exposure. Among the crops, soybean seeds exposed to gamma irradiation and fumigation several times recorded significantly higher abnormal seedlings (6.5 and 23.4%) compared to green gram (5.8 and 19.6%) respectively. However, green gram recorded significantly higher dead seeds (8.4 and 27.0%) compared to soybean (6.3 and 22.9%) respectively, during one and four times exposure to gamma irradiation and

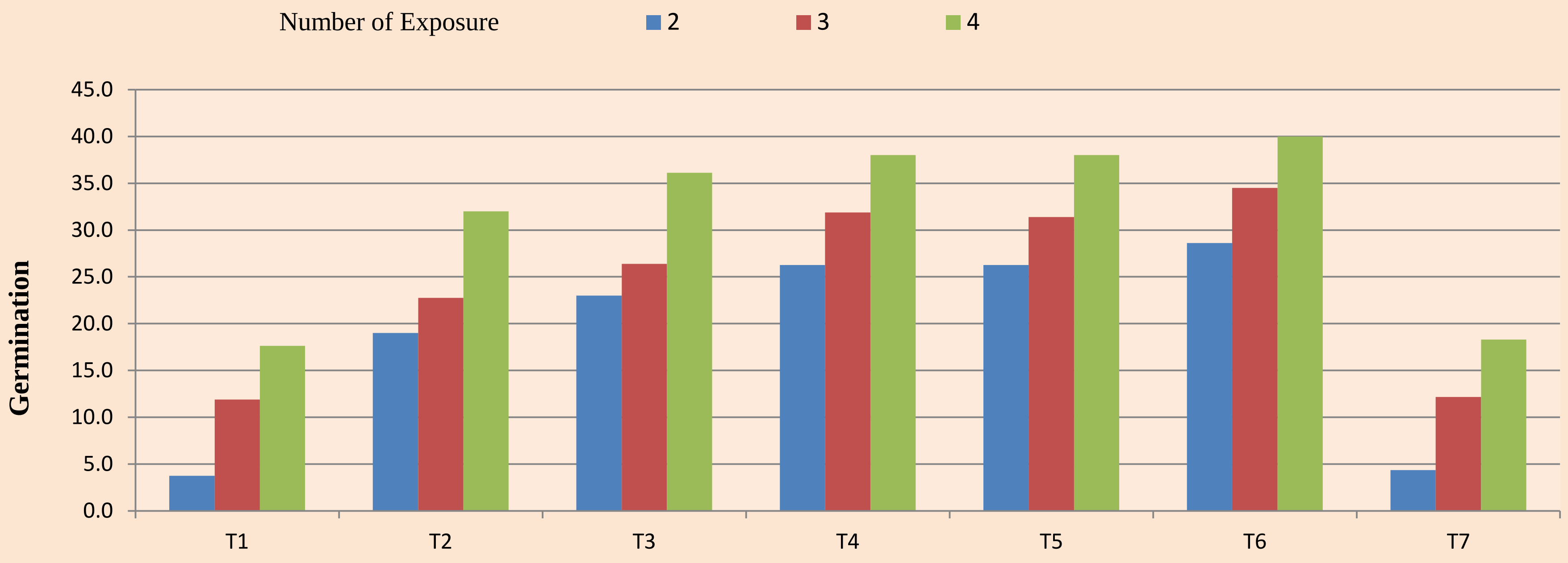


Fig. 10. Per cent decrease in seed germination due to number of mid storage exposure to gamma irradiation and fumigation over one time exposure

Crops: **C$_1$**- Soybean **C$_2$**- Green gram

T$_1$ - Control **T$_3$** - 400 Gy **T$_5$** -- 800 Gy T$_7$- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T$_2$ - 200 Gy **T$_4$** - 600 Gy **T$_6$** - 1000 Gy

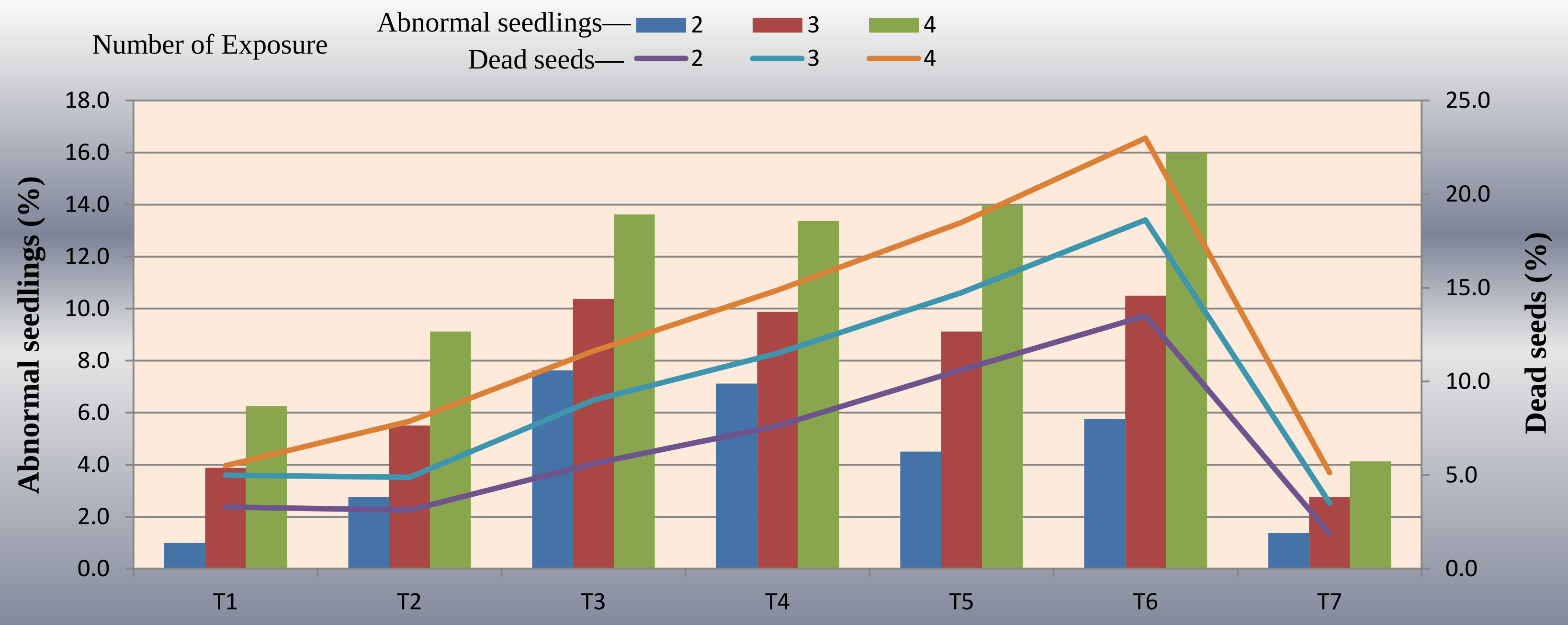


Fig. 11. Per cent increase in abnormal seedlings (%) and dead seeds (%) due to number of mid storage exposure to gamma irradiation and fumigation over one time exposure

Crops: **C_1**- Soybean C_2- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)
T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

fumigation. This variation in response as a result of exposure to gamma irradiation may be due to the difference in inherent genetic composition to withstand the impact of imposed treatment and also ageing. The present results are in conformity with the findings of Cheema and Atta (2003) who also reported varietal differences in radio sensitivity to gamma irradiation in three different basmati rice cultivars.

The results of the present study revealed that, among the different treatments significantly lower abnormal seedlings (1.1, 2.5, 8.4 and 11.4%) were recorded by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (1.5, 4.6, 8.8 and 12.0%) at one, two, three and four times exposure to gamma irradiation and fumigation. Similarly, the dead seeds (%) were also significantly lower in T_7 (5.5, 7.4, 8.5 and 11.9%) compared to all other treatments and control (5.8, 8.0, 9.5, 12.3%) respectively. Further, exposing the seeds to repeated gamma irradiation (T_2 –T_6), the per cent increase in abnormal seedlings (%) and dead seeds (%) increased with an increase in gamma irradiation dosage over one time exposure. This increase in abnormal and dead seeds (%) with repeated gamma irradiation might be due to gamma irradiation induced oxidative stress with over production of reactive oxygen species (ROS) such as super oxide radical, hydroxyl radical and hydrogen peroxide which reacts rapidly with almost all structural and functional organic molecules including proteins, lipids, nucleic acids causing disturbance in cellular metabolism (Salter and Hewitt, 1992). The results are in line with the findings of Muhammad Amjad and Muhammad Akbar (2002) who noticed higher number of abnormal seedlings with an increase in irradiation dose.

The mean germination time increased with the advancement of storage period in both the crops. Between the crops, soybean registered lower mean germination time (1.54 and 2.52) at one and two time exposure to irradiation and fumigation compared to green gram (1.90 and 2.54) but from three time exposure green gram recorded lowest mean germination time (2.70 and 2.90) compared to soybean (2.80 and 2.95) respectively. Among the gamma irradiation and fumigation treatments, significantly lower mean germination time (1.59, 1.69, 2.29 and 2.51) was recorded by T_7 (fumigation with aluminium phosphide with 3 tablets per tonne of seed) compared to all other treatments and control (1.68, 1.99, 2.30 and 2.60) at one, two, three and four time exposure. Lesser mean germination time represents early germination. Further, several time exposure of seeds to gamma irradiation (T_2 –T_6) showed an increase in mean germination time with an increase in gamma irradiation dosage wherein, T_6 (1000Gy) recorded higher mean germination time (1.88, 3.19, 3.35 and 3.54) respectively at one, two, three and four times exposure compared to control (1.68, 1.99, 2.30 and 2.60) respectively. This increase in mean germination time with repeated exposure to gamma irradiation might be due to inhibitory effect on seed quality (Majeed *et al*., 2010).

The peak value of germination and germination rate index declined with the progress of storage period in both the crops but the extent variation was not same. Between the crops, soybean maintained higher peak value of germination (20.5 and 15.5) and germination rate index (7237 and 6706) compared to green gram (20.3 and 14.4) and (7037 and 6131) respectively even at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation green gram recorded higher peak value of germination and germination rate index (12.6 and 9.7) and (4932 and 4158) compared to soybean (10.8 and 8.0) and (4612 and 3999) respectively. This high peak value of germination in soybean during initial month might be due to higher initial food reserves compared to green gram which always showed rapid and fast germination (Kavitha, 2002). The decrease in peak value of germination at later part of storage in soybean might be due to the sensitive nature of the seed which is structurally weak (Delouche *et al*., 1973).

Significantly higher peak value of germination (22.7, 19.6, 14.5 and 12.1) was recorded by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (22.0, 16.1, 13.9 and 11.7) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively. Similarly, the germination rate index was also significantly higher in T_7 (7706, 7393, 5441 and 4702) compared to all other treatments and control

(7492, 6355, 4578 and 4015) respectively. This might be due to the fact that seeds with reduced activity of enzymes and repair system make the seed to germinate slowly and ultimately reduce vigour of seeds (Manjesh, 2016). If the capacity for repair and enzymatic activity is below a critical level, damage would continue to accumulate resulting in death of seeds (Abdul-Baki and Anderson, 1973; Krishnaveni, 2003 and Kaewnareea *et al.,* 2008). Further, it was also noticed that, the peak value of germination and germination rate index decreased drastically with an increase in the number of exposure to gamma irradiation and fumigation. The results are in line with the findings of Polchaninova (1969) who reported slow germination rate when wheat and barley seeds were fumigated at 30 and 40 g per m^3 for two time fumigation at 72 hours of exposure period.

Exposing the seeds further to repeated gamma irradiation (T_2 –T_6) showed a significant decrease in peak value of germination with an increase in gamma irradiation dosage wherein, T_6 (1000 Gy) recorded the lower peak value of germination (16.5, 11.7, 9.3 and 5.3) respectively at one, two, three and four times exposure to gamma irradiation and fumigation compared to control (22.0, 16.1, 13.9 and 11.7) respectively. Similarly, the germination rate index was also lower in T_6 (6521, 5411, 4417 and 3603) compared to control (7492, 6355, 4578 and 4015) respectively. Similar reports of low peak value of germination with an increase in gamma dose were earlier reported by Din *et al*. (2003). Similarly, Aparna *et al*. (2013) reported that the speed of germination, mean daily germination, peak value and germination value decreased significantly with increase in radiation dose.

Irrespective of the crops, the root and shoot length decreased significantly with the number of exposures to gamma irradiation and fumigation. However, in the present study, green gram maintained higher root length (7.83 cm) and shoot length (7.80 cm) even after four times mid storage exposure to irradiation and fumigation. This variation in response by the crops as a result of exposure to gamma irradiation may be due to the difference in genotypic response, because of variation in inherent genetic composition to withstand the impact of imposed treatments. The present results are in conformity with the findings of

Cheema and Atta (2003) who also reported varietal differences in radio sensitivity to gamma irradiation in three different basmati rice cultivars.

Significantly higher shoot length (16.20, 14.73, 13.89 and 13.56 cm) was recorded by treatment fumigation with aluminium phosphide with 3 tablets/ tonne of seed (T_7) compared to all other treatments and control (16.08, 14.33, 13.79 and 13.34 cm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively. Similarly, the root length was also significantly higher in T_7 (20.23, 17.81, 16.59 and 15.05 cm) compared to all other treatments and control (19.39, 16.30, 15.54 and 14.01 cm) respectively. This might be due to the effect of phosphine which significantly protected the seeds from insect infestation (Gupta *et al.*, 2000). Further, it was noticed that the shoot and root length decreased with an increase in the number of exposure to gamma irradiation irrespective of the dosage and also with fumigation. The results are in line with earlier findings of Gupta and Kashyap (1995) who reported higher shoot (13.2 cm) and root length (8.2 cm) of green gram seeds due to one time fumigation compared to three times (12.5 and 7.7 cm).

Further, exposing the seeds to gamma irradiation (two to four times) showed a drastic decrease in shoot and root length with an increase in gamma irradiation dosage (T_2- T_6) wherein, T_6 (1000 Gy) recorded the least root length (14.88, 2.54, 1.30 and 0.74 cm) compared to control (19.39, 16.30, 15.54 and 14.01 cm) at one, two, three and four times exposure to gamma irradiation and fumigation. Similarly, the shoot length also decreased significantly in T_6 (10.95, 3.36, 1.86 and 1.03) compared to control (16.08, 14.33, 13.79 and 13.34 cm) at one, two, three and four times exposure to gamma irradiation and fumigation. This decrease in shoot and root length with several time exposure to gamma irradiation with high dosage might be due to increased plant sensitivity to gamma radiation which might have caused reduction in the amount of endogenous synthesis of growth regulators, especially cytokinins and thereby reduced the seed germination with a corresponding decline in growth of the plants (Kiong *et al.*, 2008). Reduction in seedling growth due to irradiation has been attributed to the changes in the level of auxin and ascorbic acid contents and physiological and biochemical disturbances (Gunekal and sparrow, 1954), changes in the enzyme activity (Alduous and Stewart 1952), chromosomal breakage and mitotic inhibition (Sparrow and Vans, 1961) and inhibition of DNA synthesis (Mikaelson, 1968). Similar results of decrease in seedling height (shoot length) and root length with increasing level of gamma irradiation dosage were earlier reported by Prabhakar (1985) and Shivaraj (1962) who noticed 50 per cent reduction in seedling height (injury) at 50KR irradiated sesame seedlings. Similarly, Amir and Khavar (2012) reported that gamma radiation decreased the shoot and root length of amaranth seedlings at higher dose.

In the present study, green gram maintained higher seedling dry weight (0.199 g) and seedling vigour index (968) at four times mid storage exposure to irradiation and fumigation treatments. This might be due to higher shoot and root length which had a direct correlation with seedling dry weight and seedling vigour index. However, the seedling dry weight and vigour index decreased with the advancement of storage period. Similar decrease in seedling dry weight and seedling vigour index in paddy with the advancement of storage period and variation among the varieties were reported by Pameri *et al.* (2016).

From the present study, among different treatments (exposing the seeds to different dose of gamma irradiation and fumigation several times) significantly higher seedling dry weight (0.409, 0.387, 0.362 and 0.323 g) was recorded by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (0.398, 0.366, 0.339 and 0.291 g) at one, two, three and four times exposure to gamma irradiation and fumigation. Similarly, the seedling vigour index was also significantly higher in T_7 (3258, 2772, 2663 and 2051) compared to all other treatments and control (3135, 2597, 2251 and 1952) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively. This might be due longer shoot and root length recorded in our study by the treatment T_7 which had a direct correlation with the seedling dry weight and seedling vigour index. Similarly, Gupta *et al.* (2000) reported significantly higher vigour index in the fumigated seeds over the untreated control. However, the seedling vigour index and seedling dry weight decreased drastically with an increase in the number of exposure to gamma irradiation and fumigation. These results are in contradictory to the earlier report of Gupta *et al*. (2000) did not observe adverse effect of repeated fumigation (aluminium phosphide @ 3, 6 and 9 g/ cubic meter) even at three fold higher dose, on the vigour of wheat seeds indicating non sensitivity of the crops to either repeated gamma irradiation or fumigation. Similarly, repeated fumigation (@ 3 g/m^3) with phosphine up to four times carried out at monthly intervals for a period of seven days had no adverse effect on vigour index of wheat seed (Singh *et al*., 1999). So also, Krishnaswamy and Seshu (1990) reported that at normal recommended dose of 3 g per m^3 of phosphine fumigation did not affect vigour, but at 6 g per m^3, vigour decreased significantly and the effect became more perceptible after 90 days of storage.

Exposing seeds to repeated gamma irradiation (T_2 –T_6) showed a drastic decrease in seedling dry weight and seedling vigour index with an increase in gamma irradiation dosage. The decrease in seedling vigour index due to four time exposures to gamma irradiation (Fig. 12) at higher dose (T_6 -1000 Gy) was 1869, while it was only 1207 even to one time exposure fumigation (T_7). This reduction in seedling dry weight and seedling vigour index due to several time exposures to gamma irradiation might be due to shorter root and shoot length registered in our study which had a direct correlation with dry

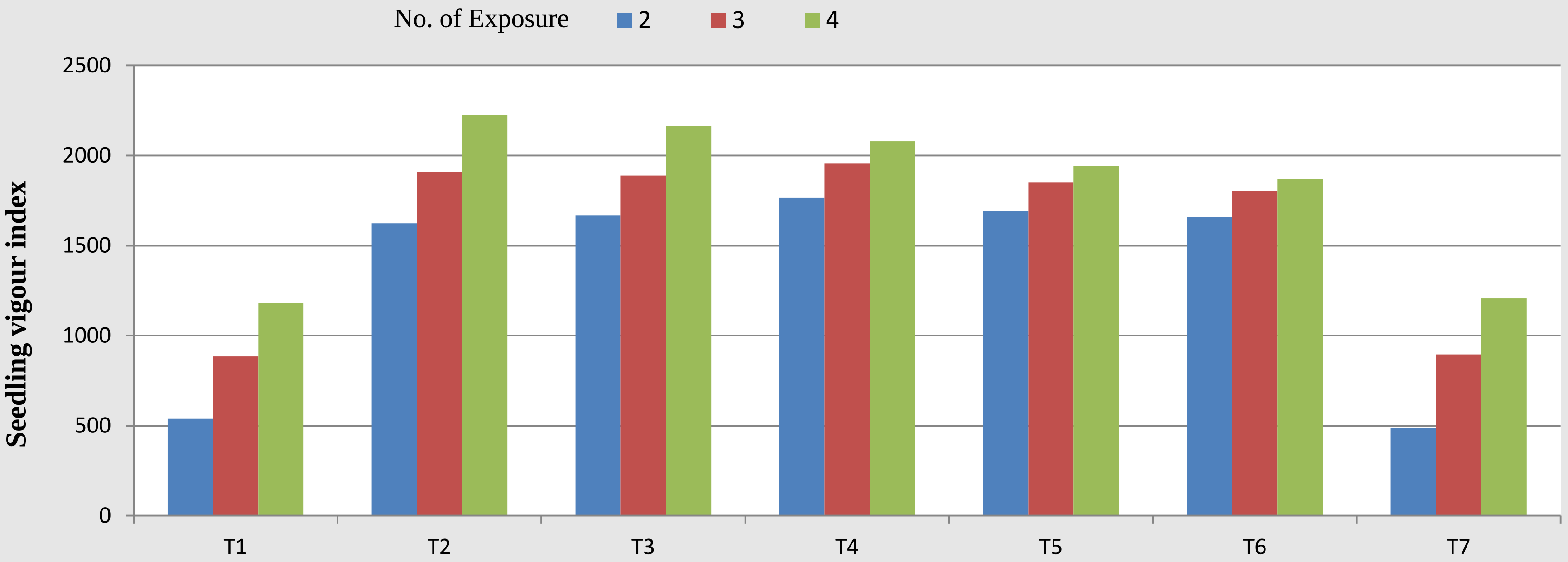


Fig. 12. Per cent decrease in seedling vigour index due to number of mid storage exposure to gamma irradiation and fumigation over one time exposure

Crops: **C_1**- Soybean **C_2**- Green gram

T_1 - Control **T_3** - 400 Gy **T_5** -- 800 Gy T_7- Fumigation (aluminium phosphide with 3 tablets / tonne of seed)

T_2 - 200 Gy **T_4** - 600 Gy **T_6** - 1000 Gy

weight and seedling vigour index. Several earlier studies on this aspect also indicated reduction in plant stature and reduced moisture contents in shoot due to radiation stress (Majeed *et al*., 2010), inhibition of mitosis and enzyme activities as it is more likely that the reserve food was utilized less efficiently at higher dose and repeated irradiation which might have resulted in reduction of seedling fresh and dry weight (Alduous and Stewert, 1952). The other causes for reduction in dry matter may be inhibition of cell elongation. Similarly, Kon *et al*. (2007) also reported a lesser shoot dry weight of long beans when exposed to higher gamma radiation dosage. Similarly, Aparna *et al*. (2013) in groundnut and Radha and Uma (2015) in finger millet reported a drastic reduction in seedling vigour index at higher dosage compared to control.

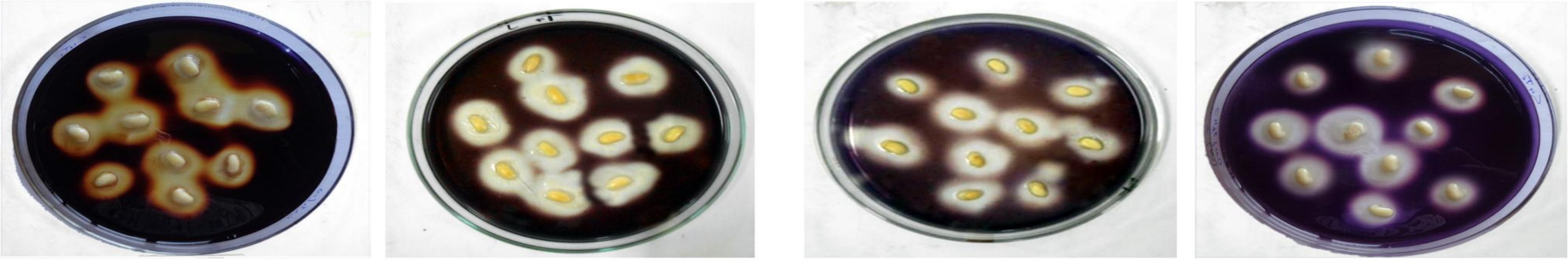
Irrespective of the crops, the seed infection (%) increased with the advancement of storage period and it decreased with mid storage exposure to irradiation and fumigation several times. Between the crops, green gram recorded significantly higher seed infection (23.8 and 21.5%) compared to soybean (18.9 and 15.6%) at one and four times exposure to gamma irradiation and fumigation, respectively.

Mid storage exposure to different dosage of gamma irradiation and fumigation revealed significantly lower seed infection (28.5, 22.8, 20.5 and 18.5%) in treatment fumigation with aluminium phosphide with 3 tablets/ tonne of seed (T_7) compared to control (30.0, 51.0, 64.0 and 77.0%) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively. This decrease in seed infection with repeated fumigation was probably due to the metabolic state of the spores, the thick wall of the fungal spores might have degraded. The permeability and metabolic activity associated with this change may increase the sensitivity of the fungal spores to fumigants (Stasz and Martin, 1988). On the contrary, Gupta *et al*. (2000) reported that phosphine fumigation (aluminium phosphide @ 3, 6 and 9 g /cubic meter) did not influence the seed microflora built up in wheat seeds during storage.

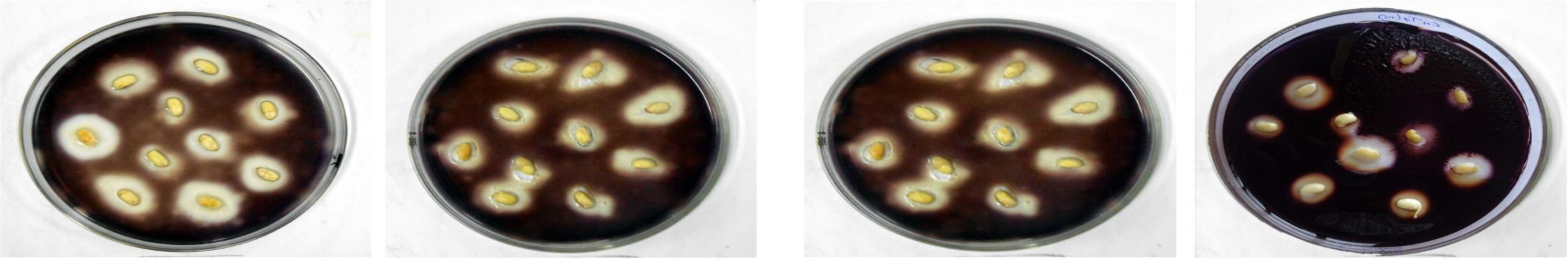
In the present study, exposing the seeds to gamma irradiation repeated times during storage showed a drastic reduction in seed infection with an increase in gamma irradiation dosage wherein, T_6 recorded lower seed infection (12.0, 8.5, 5.8 and 1.8%) respectively, at one, two, three and four times exposure to gamma irradiation and fumigation compared to control (30.0, 51.0, 64.0 and 77.0%) respectively. Irradiation at higher dosage, though was found more effective in decontaminating microbial infection, but negatively affected the seed germination in addition to impairment in metabolic status of the seeds (Maity *et al.,* 2004). The results are in line with the findings of Mahrous (2007) who reported that gamma irradiation (1 KGy) of *Aspergillus flavus* infected soybean seeds was sufficient to inhibit the fungal growth and production of afflatoxin. Similarly, Maity *et al.* (2009) concluded that the fungal growth and their population on gamma treated rice seeds were found to decrease significantly with an increase in irradiation dose and storage time.

In the present study, the dehydrogenase enzyme activity decreased with an increase in storage period. Between the crops, soybean recorded higher dehydrogenase enzyme activity (2.552 and 1.473 OD value) and alpha amylase enzyme activity (26.03 and 23.09 mm) compared to green gram (2.182 and 0.582 OD value) and (25.49 and 21.66 mm), respectively at one and two times exposure to gamma irradiation and fumigation. But from three and four times exposure to gamma irradiation and fumigation green gram recorded highest dehydrogenase enzyme activity (0.398 and 0.234 OD value) and alpha amylase enzyme activity (19.44 and 16.90 mm) compared to soybean (0.183 and 0.094 OD value) and (17.09 and 14.21mm) respectively. Decrease in these enzyme activities may be related to age induced deterioration which is a common phenomenon in any living entity and difference in genotypic response may be due to variation in inherent genotypic composition to withstand the impact of ageing. Present results are in conformity with the findings of Khidrapure (2015) and Nagrajaiah (2014) in paddy who also reported decrease in dehydrogenase and alpha amylase enzyme activities with the advancement of storage period.

The results of the present study also revealed higher dehydrogenase activity (2.632, 1.867, 0.375 and 0.319 OD value) by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (2.563, 0.993, 0.361 and 0.258 OD value) at one, two, three and four times exposure to gamma irradiation and fumigation. Similarly, alpha amylase enzyme activity was also significantly higher in T_7 (27.40, 25.85, 22.08 and 21.78 mm) compared to all other treatments and control (26.60, 23.90, 21.78 and 18.30 mm) respectively (Plate 9-10).



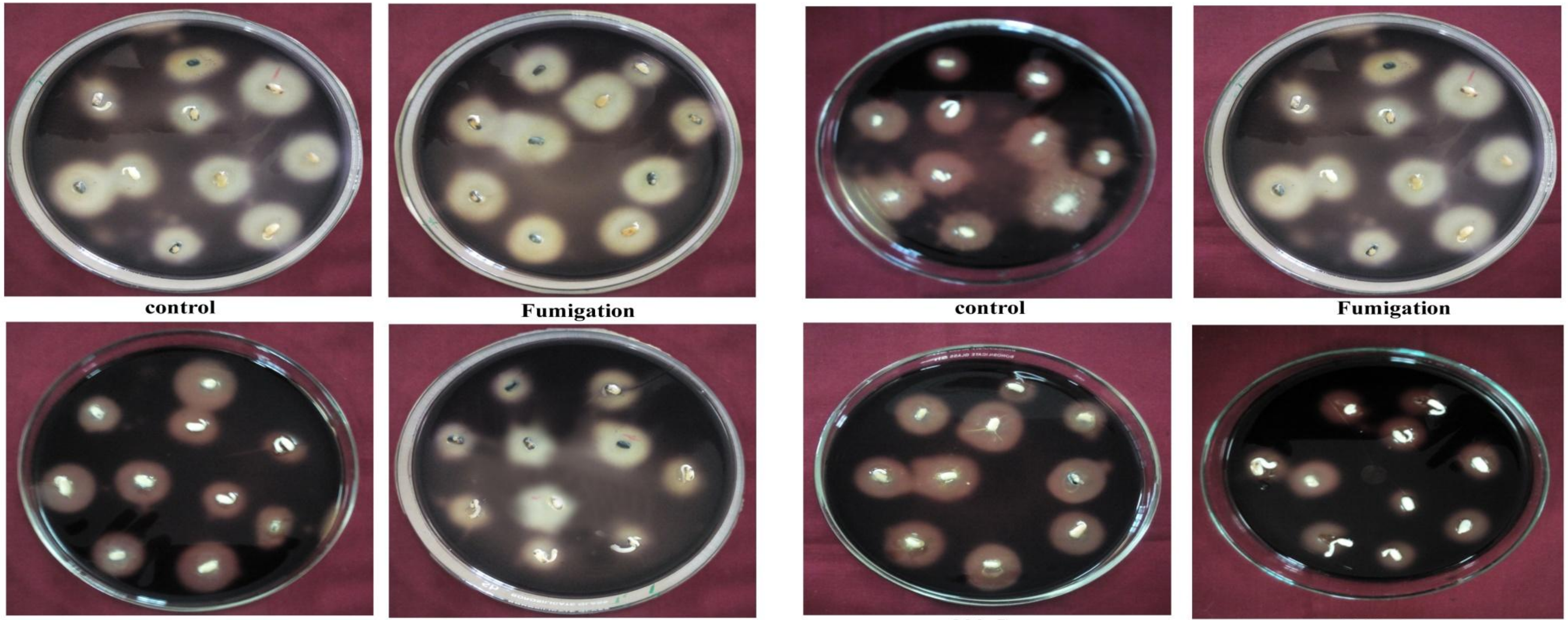
control Fumigation control Fumigation



200 Gy 1000 Gy 200 Gy 1000 Gy

One time exposure Four time exposure

Plate 9. Influence of mid storage gamma irradiation and fumigation on alpha amylase enzyme activity (mm) of soybean during storage



control
Fumigation
control
Fumigation
200 Gy
1000 Gy
200 Gy
1000 Gy
One time exposure
Four time exposure

Plate 10. Influence of mid storage gamma irradiation and fumigation on alpha amylase enzyme activity (mm) of green gram during storage

The results are in line with the findings of Kamble *et al*. (2013) who reported that groundnut seeds fumigated with ethylene dibromide at 30 and 90 days after harvest retained higher value for dehydrogenase activity up to six months. However, with an increase in the number of repeated fumigation the dehydrogenase enzyme activity decreased significantly. Repeated exposure of seeds to fumigation with phosphine might affect cell membranes as well as respiratory enzymes (Krishnaswamy and Seshu, 1990).

Exposing the seeds to gamma irradiation several times showed a drastic reduction in dehydrogenase and alpha amylase enzyme activity with an increase in gamma irradiation dosage. This decrease in dehydrogenase and alpha amylase activity with repeated gamma irradiation may be due to decline in the activity of amylases in seed which reduces the rate of starch hydrolysis and would thus be expected to slow down germination (Koksel *et al*., 1998). The results are in agreement with the findings of Ivan *et al*. (2012) who reported that irradiation of malt caused a significant reduction in alpha and beta amylase activity. Similarly, Delia *et al*. (2013) noticed biochemical differences based on photosynthetic pigment content which revealed an inverse relationship to the dosage of exposure.

Electrical conductivity of seed leachate, leaching of sugars and amino acids are negatively associated with membrane integrity and so with germination and vigour (Delouche and Baskin, 1973; Bhaskaran, 1995 and Sabirahamed, 2003). In the present study, the electrical conductivity of seed leachates increased with an increase in storage period. Among the crops, soybean recorded lower electrical conductivity (0.483 and 0.823dSm^{-1}) compared to green gram (0.528 and 1.057 dSm^{-1}) during one and four times exposure to gamma irradiation and fumigation. This significant variation in electrical conductivity may due to the anatomical structure, membrane permeability and composition of the seed coat (Patil, 2016).

In the present study, significantly lower electrical conductivity (0.465, 0.487, 0.628 and 0.678 dSm^{-1}) was recorded by treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to all other treatments and control (0.480, 0.600, 0.666 and 0.767 dSm^{-1}) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively. However, the electrical conductivity of seed leachates increased due to repeated exposure to gamma irradiation and fumigation. This might be due to the cumulative injury to seeds and some residue of fumigants retained after first fumigation which again gets accumulated in each subsequent fumigations that led to drastic reduction in seed quality parameters like germination, vigour and viability of seeds due to repeated fumigation (Kamble *et al.*, 2013).

Exposing the seeds several times to gamma irradiation (T_2–T_6) showed an increase in electrical conductivity with increasing gamma irradiation dosage wherein, T_6 (1000 Gy) recorded the higher electrical conductivity (0.533, 0.689, 0.882 and 1.141 dSm^{-1}) respectively at one, two, three and four times exposure to gamma irradiation and fumigation compared to control (0.480, 0.600, 0.666 and 0.767 dSm^{-1}) respectively. This increase in electrical conductivity with repeated exposure to gamma irradiation is attributed to increased membrane permeability which enhanced leakage of leachates (Krishnaswamy and Seshu, 1989). Similar findings were also made by Muhammad Amjad and Muhammad Akbar (2002) wherein the electrical conductivity of onion seeds exposed to gamma irradiation (10, 20, 40, 80 and 100 Krad) were higher than that of unirradiated seeds (control).

From the present investigation, all the seed quality parameters declined progressively due to both the number of exposure to gamma irradiation and also fumigation with advancement of storage period. Similar decrease in seed quality parameters by repeated fumigations with aluminium phosphide were also reported by Kirsur (1985) in maize, Rathod (2002) in wheat, Vijayanna (2006) and Kamble (2013) in ground nut.

Practical utility of the research

Based on results of the present study the following findings are of practical use

1. For better longevity of soybean and green gram seeds, seed treatment with the combination of malathion and thiram each at the rate of 2g per kg of seed can be used before storage.
2. For maintaining better seed quality during storage, fumigation of soybean and green gram seeds with alluminium phosphide at the rate of 3 tablets each of 3 grams per tonne of seed was found effective.
3. Gamma irradiation even at lower dosage of 200Gy cannot be used for stored pest management during seed storage of soybean and green gram as it is having inhibitory effect on all the seed quality parameters studied.

Future line of work

1. Optimum dosage of gamma irradiation needs to be standardized for different crops in order to assess the effect of gamma rays on seed quality.
2. Effects of other ionizing particles need to be studied thoroughly to know their influence on seed quality during storage.
3. The effect of different insecticides and fungicides and their combination under ambient conditions can be studied.
4. Influence of gamma irradiation dosage on crop mutation, growth and development need to be studied.

Summary and Conclusions

VI. SUMMARY AND CONCLUSIONS

The present investigation entitled “Effect of gamma irradiation and seed treatment chemicals on seed longevity of soybean [*Glycine max* (L.) Merill] and green gram (*Vigna radiata* L.)”. The experiment was carried out at the Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Raichur during 2016-17 in a Completely Randomized Design in factorial concept with four replications. The experiment was initiated with two objectives *viz*., 1) To study the Influence of gamma irradiation and seed treatment chemicals on seed longevity of soybean and green gram. 2) To know the effect of mid storage exposure to gamma irradiation and fumigation on seed quality of soybean and green gram. The summary of the results obtained and the conclusions drawn are summarised below.

6.1 Influence of gamma irradiation and seed treatment chemicals on seed longevity of soybean and green gram

Between the crops, C_1 (soybean) recorded significantly higher seed germination (85.5, 84.1, 80.8 and 79.2%) compared to C_2, green gram (83.0, 81.3, 79.9, 78.4%) respectively, from initial to three months after storage, but from fourth month onwards up to nine months green gram recorded higher seed germination (76.6, 74.7, 73.5, 72.6, 71.1 and 70.2%) compared to soybean (75.9, 73.8, 72.1, 69.9, 67.9, 64.5%), respectively.

Among the different dosage of gamma irradiation and seed treatment chemicals, combination of malathion + thiram each @ 2 g / kg of seeds (T_9) recorded significantly higher seed germination (90.5, 89.6, 88.0, 86.4, 83.6, 81.6, 79.6, 77.9, 76.0 and 73.8%) compared to control (88.8, 87.8, 86.4, 85.0, 81.0, 78.8, 76.9, 75.6, 72.9 and 71.1%) from initial to nine months after storage, respectively.

Between the crops, C_2 (green gram) recorded significantly lower abnormal seedlings (4.8, 6.0, 7.0, 7.4, 7.9, 8.7, 10.5, 11.3, 12.8 and 13.2%) compared to $C_{1,}$ soybean (5.4, 6.7 8.4, 8.7, 9.3, 9.8, 11.9, 13.2, 14.3 and 15.0%) from initial to nine months after storage, respectively.

The treatment, combination of malathion + thiram each @ 2g / kg of seeds (T_9) recorded significantly lower abnormal seedlings (1.3, 2.6, 3.6, 3.9, 4.6, 5.4, 8.0, 9.3, 10.5 and 11.1%) compared to control (1.5, 2.9, 4.0, 4.6, 5.3, 6.1, 8.8, 9.9, 11.4 and 12.0%) from initial to nine months after storage, respectively.

Between the crops, C_1 (soybean) recorded significantly lower dead seeds (5.5, 6.6, 7.6, 8.1, 8.8, 9.7, 10.2, 10.5, 11.1 and 13.1%) compared to C_2, green gram (8.2, 9.3, 10.4, 11.2, 11.5, 11.9, 12.2, 12.6, 13.4 and 14.0%) from initial to nine months after storage, respectively.

Significantly lower dead seed (5.0, 5.9, 7.0, 7.6, 8.1, 8.5, 8.9, 9.1, 10.1 and 11.5%) were observed in combination of malathion + thiram each @ 2 g / kg of seeds (T_9) compared to control (5.8, 6.6, 7.4, 8.0, 8.3, 9.3, 9.5, 9.8, 10.3 and 12.3%) from initial to nine months after storage, respectively.

Between the crops, C_1 (soybean) recorded significantly lower mean germination time (1.49, 1.69, 1.83 and 1.92) compared to $C_{2,}$ green gram (1.88, 1.90, 1.95 and 2.01) from initial to three months after storage, but from fourth month onwards up to nine months C_2 (green gram) recorded lower mean germination time (2.08, 2.15, 2.18, 2.25, 2.38 and 2.55) compared to $C_{1,}$ soybean (2.39, 2.42, 2.45, 2.54, 2.61 and 2.74) respectively.

Comparing gamma irradiation and of seed treatment chemicals, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) was significantly superior in maintaining lower mean germination time (1.55, 1.56, 1.71, 180, 1.93, 1.98, 2.01, 2.04, 2.21 and 2.31) than control (1.68, 1.78, 1.87, 1.99, 2.22, 2.25, 2.30, 2.34, 2.43 and 2.60) from initial to nine months of storage, respectively.

Between the crops C_1 (soybean) had significantly higher germination rate index (7417, 7089, 6789 and 6317) compared to $C_{2,}$ green gram (7242, 6681, 6469, 6062) from initial to three months after storage, but from fourth month onwards up to nine months C_2

(green gram) recorded higher germination rate index (5858, 5195, 4687, 4418, 4171 and 3896) compared to C_1, soybean (5314, 4869, 4515, 4329, 3977 and 3800) respectively.

Significantly higher germination rate index (8107, 7650, 7496, 6844, 6215, 5680, 5264, 5112, 4817 and 4579) was recorded by treatment combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) compared to control (7492, 7054, 6682, 6355, 5736, 5025, 4572, 4431, 4161 and 4015) from initial to nine months of storage, respectively.

Between the two crops, C_1 (soybean) recorded significantly higher peak value of germination (22.0, 19.8, 17.8 and 16.3) compared to C_2, green gram (21.1, 19.2, 17.5 and 16.0) from initial to four months after storage, but from fourth month onwards up to nine months, C_2 (green gram) recorded significantly higher peak value of germination (15.9, 15.2, 14.6, 14.4, 13.4 and 12.5) compared to C_1, soybean (14.8, 14.1, 13.6, 12.9, 12.3 and11.6), respectively.

Higher peak value of germination was noticed in combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) (26.9, 25.4, 24.3, 24.0, 23.0, 22.1, 20.8, 20.2, 19.5 and 18.3) compared to control (22.0, 20.3, 18.3, 16.1, 15.1, 14.4, 13.9, 13.1, 12.5 and 11.7) from one to nine months after storage, respectively.

Between the crops, C_2 (green gram) recorded significantly higher shoot length (16.34, 15.93, 14.44, 14.20, 14.07, 13.98, 13.69, 13.51, 13.27 and 12.68 cm) compared to C_1, soybean (12.63, 11.42, 10.77, 10.58, 10.49, 10.29, 10.07, 9.76, 9.62 and 9.43 cm) from initial to nine months after storage, respectively.

Significantly higher shoot length (16.56, 15.88, 14.95, 14.71, 14.51, 14.40, 14.26, 14.13, 13.93 and 13.73 cm) was recorded in combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) compared to control (16.08, 15.26, 14.54, 14.34, 14.20, 13.96, 13.79, 13.71, 13.38 and 13.34 cm) from initial to nine months of storage, respectively.

Between the crops studied, C_2 (green gram) was significantly superior in maintaining higher root length (20.42, 19.81, 18.00, 16.98, 16.58, 16.23, 16.0, 15.71, 15.48 and 15.20 cm) compared to $C_{1,}$ soybean (16.16, 14.79, 14.29, 14.06, 13.81, 13.66, 13.49, 13.16, 12.58 and 12.16 cm) from initial to nine months after storage, respectively.

Among the gamma irradiation treatment and seed dressing chemicals, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) recorded significantly higher root length (20.56, 19.75, 18.66, 18.05, 17.54, 17.45, 17.11, 16.79, 16.51 and 16.24 cm) compared to control (19.39, 18.16, 17.13, 16.30, 15.99, 15.74, 15.51, 14.99, 14.71 and 14.00 cm) from initial to nine months of storage, respectively.

Between two pulse crops, C_2 (green gram) recorded significantly higher seedling dry weight (0.384, 0.374, 0.367, 0.355, 0.347, 0.337, 0.328, 0.318, 0.306, 0.293 g) compared to $C_{1,}$ soybean (0.379, 0.367, 0.362, 0.352, 0.343, 0.334, 0.323, 0.314, 0.303, 0.290 g) from initial to nine months after storage, respectively.

Significantly higher seedling dry weight (0.418, 0.406, 0.400, 0.386, 0.380, 0.368, 0.363, 0.354, 0.343 and 0.333 g) was noticed in combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) compared to control (0.398, 0.387, 0.380, 0.366, 0.360, 0.351, 0.339, 0.319, 0.307 and 0.291 g) from initial to nine months after storage, respectively.

Upon comparing the crops, C_2 (green gram) recorded significantly higher seedling vigour index (3065, 2923, 2620, 2472, 2374, 2283, 2212, 2147, 2067 and 1979) compared to $C_{1,}$ soybean (2490, 2238, 2061, 1987, 1873, 1795, 1721, 1624, 1527 and 1410) from initial to nine months after storage, respectively.

Among the different dosage of gamma irradiation and seed treatment chemicals, the treatment, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) maintained higher seedling vigour index (3343, 3174, 2946, 2818, 2675, 2595, 2498, 2410, 2320, 2222) compared to all other treatments including control (3135, 2917, 2725, 2597, 2441, 2336, 2251, 2174, 2051 and 1952) from initial to nine months after storage, respectively.

Upon comparing the crops, C_1 (soybean) recorded significantly lower seed infection (13.6, 16.7, 20.9, 23.3, 26.0, 28.9, 31.6, 39.1, 43.6 and 48.4%) compared to $C_{2,}$

green gram (17.6, 26.0, 32.7, 47.1, 59.8, 64.0, 66.7, 72.0, 74.7 and 78.2%) from initial to nine months after storage, respectively.

Significantly lower seed infection (4.0, 7.0, 11.0, 20.0, 26.0, 29.0, 31.0, 39.0, 46.0 and 50.0%) was observed in combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) compared to control (30.0, 33.0, 37.0, 51.0, 57.0, 63.0, 64.0, 71.0, 73.0 and 77.0%) from one to nine months after storage, respectively.

Between the two pulse crops, in C_1 (soybean) the insect eggs were not at all noticed whereas $C_{2,}$ green gram (0.69, 1.13 and 1.58%) insect eggs were noticed at seven, eight and nine months after storage, respectively. Among the gamma irradiation dosage and seed treatment chemicals, the lower percentage of insect eggs were noticed in the treatments, T_7 (0.48, 0.70 and 0.88%), T_8 (0.70, 0.80 and 1.0%) and T_9 (0.58, 0.63 and 0.85%) at seven, eight and nine months of storage. However, T_1 (control) recorded significantly higher insect egg (1.34, 1.66 and 1.78%) during seven, eight and nine months after storage, respectively. Among the gamma irradiation dosage, T_6 recorded the lowest insect egg (0.00, 0.10 and 0.30%) compared to control (1.34, 1.66 and 1.78%) during seven, eight and nine months after seed storage only in green gram.

Between the crops, the seed damage was not at all noticed in C_1 (soybean) while, in $C_{2,}$ green gram (0.76, 1.41 and 2.17%) it was observed from seven, eight and nine months after storage, respectively. Among the different dosage of gamma irradiation and seed dressing chemicals, the lowest of seed damage were noticed in the treatment T_7 (0.55, 0.70 and 1.24%) followed by T_8 (0.81, 0.93 and 1.35) and T_9 (0.38, 0.79, 1.28%) at seven, eight and nine months of storage. However, T_1 (control) recorded significantly higher seed damage (1.66, 1.83 and 2.08%) during seven, eight and nine months after storage respectively. Among the gamma irradiation dosage, T_6 recorded the lowest seed damage (0.00, 0.24 and 0.36%) compared to control (1.66, 1.83 and 2.08%) during seven, eight and nine months after seed storage that to in only green gram.

Between the crops, per cent weight loss was not at all noticed in C_1 (soybean) but it was 3.12 per cent in $C_{2,}$ green gram at nine months after storage. Among the gamma irradiation and seed treatment chemicals, the lower per cent weight loss was noticed in the treatments T_7, T_8 and T_9 (1.73, 1.93 and 1.63) at the end of storage period. However, T_1 (control) recorded significantly higher seed weight loss (2.65%) at the end of storage period. Among the gamma irradiation dosage, T_6 recorded the lowest seed weight loss (0.70%) compared to control (2.65%) at the end of storage period only in green gram (3.12%).

Between the crops, C_1 (soybean) registered significantly higher dehydrogenase enzyme activity (2.690 and 1.836 OD value) compared to C_2, green gram (2.384 and 1.476 OD value) at initial and two months after storage, but from fourth month onwards C_2 (green gram) recorded higher dehydrogenase enzyme activity (0.785, 0.438, 0.204 OD value) compared to C_1, soybean (0.402, 0.251 and 0.181 OD value) respectively at four, six and eight months of storage.

The treatment, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) maintained higher dehydrogenase enzyme activity (3.447, 1.894, 1.052, 0.450 and 0.252 OD value) compared to control (2.563, 1.670, 0.531, 0.361 and 0.203 OD value) at initial, two, four, six and eight months after storage, respectively.

Between the Crops, C_1 (soybean) recorded significantly higher alpha amylase activity (26.34 and 25.64 mm) compared to C_2, green gram (26.05 and 24.96 mm) respectively, at initial and two months of storage but from fourth month onwards C_2 (green gram) registered higher alpha amylase activity (24.31, 23.09 and 22.13 mm) compared to C_1, soybean (22.14, 21.41 and 20.46 mm) at four, six and eight months of storage, respectively.

Among the different dosage of gamma irradiation and seed dressing chemicals, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) recorded higher alpha amylase enzyme activity (28.50, 27.23, 26.75, 25.63, 24.95 mm) compared to control (26.60, 25.55, 24.10, 22.20, 21.18 mm) at initial, two, four, six and eight months of storage, respectively.

Comparing the two crops, C_1 (soybean) recorded significantly lower electrical conductivity (0.472, 0.483, 0.496, 0.639 and 0.684 dSm^{-1}) then C_2, green gram (0.509, 0.522, 0.533, 0.725 and 0.766 dSm^{-1}) at initial, two, four, six and eight months after storage, respectively.

Comparing the treatments, combination of malathion + thiram each @ 2 g/ kg of seeds (T_9) registered significantly lower electrical conductivity (0.414, 0.425, 0.438, 0.615 and 0.655 dSm^{-1}) then control (0.480, 0.497, 0.530, 0.666 and 0.706 dSm^{-1}) at initial, two, four, six and eight months after storage, respectively.

6.2 Influence of mid storage gamma irradiation and fumigation on seed quality of soybean and green gram during storage

Between the crops, C_1 (soybean) recorded significantly higher seed germination (82.9 and 65.3%) compared to C_2, green gram (82.5 and 62.6%) at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation C_2, (green gram) recorded highest seed germination (59.9 and 51.7%) compared to C_1, soybean (56.7 and 50.8%) at three and four times exposure to gamma irradiation and fumigation, respectively.

Among the mid storage gamma irradiation (at different dosage) and fumigation, the treatment, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) recorded significantly higher seed germination (89.8, 85.4, 77.6 and 71.4%) compared to control (88.8, 85.0, 76.9 and 71.1%) at one, two, three and four time exposure to gamma irradiation and fumigation, respectively.

Between the crops, C_2 (green gram) recorded significantly lower abnormal seedlings (5.8, 11.4, 16.0 and 19.6%) compared to C_1, soybean (6.5, 15.1, 19.3 and 23.4%) respectively, at one, two, three and four times exposure to gamma irradiation and fumigation.

The treatment, fumigation with aluminium phosphide with 3 tablets/ tonne of seed (T_7) recorded significantly lower abnormal seedlings (1.1, 2.5, 8.4 and 11.4%) compared to control (1.5, 4.6, 8.8 and 12.0%) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between the crops, C_1 (soybean) recorded significantly lower dead seeds (6.3, 14.4, 17.7 and 22.9%) compared to $C_{2,}$ green gram (8.4, 18.4, 22.1 and 27.0%) respectively at one, two, three and four times exposure to gamma irradiation and fumigation.

Significantly lower dead seeds (5.5, 7.4, 8.5 and 11.9%) was observed in fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to control (5.8, 8.0, 9.5 and 12.3%) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between the crops, C_1 (soybean) recorded significantly lower mean germination time (1.54 and 2.52) compared to $C_{2,}$ green gram (1.90 and 2.54) at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation $C_{2,}$ green gram (2.70 and 2.90) registered lower mean germination time compared to $C_{1,}$ soybean (2.80 and 2.95) exposure to gamma irradiation and fumigation, respectively.

Compared to all the mid storage gamma irradiation (at different dosage) and fumigation and control, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) maintained significantly lower mean germination time (1.59, 1.69, 2.29 and 2.51) compared to control (1.68, 1.99, 2.30 and 2.60) at one, two, three and four time exposure to gamma irradiation and fumigation, respectively.

Between the crops C_1 (soybean) had significantly higher germination rate index (7237 and 6706) compared to $C_{2,}$ green gram (7037 and 6131) at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation C_2 (green gram) recorded higher germination rate index (4932 and 4158) compared to $C_{1,}$ soybean (4612 and 3999) at three and four times exposure to gamma irradiation and fumigation, respectively.

Significantly higher germination rate index (7706, 7393, 5441 and 4702) was recorded by fumigation with aluminium phosphide with 3 tablets/ tonne of seed (T_7) compared to control (7492, 6355, 4578 and 4015) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between two crops, C_1 (soybean) recorded significantly higher peak value of germination (20.5 and 15.5) compared to $C_{2,}$ green gram (20.3 and 14.4) at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation $C_{2,}$ green gram (12.6 and 9.7) registered higher peak value of germination compared to C_1, soybean (10.8 and 8.0) at three and four times exposure to gamma irradiation and fumigation.

Higher peak value of germination was noticed in treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) (22.7, 19.6, 14.5, 12.1) compared to control (22.0, 16.1, 13.9 and 11.7) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between two pulse crops, C_2 (green gram) recorded significantly higher shoot length (15.82, 10.29, 9.28 and 7.80 cm) compared to C_1, soybean (12.10, 8.09, 6.30 and 5.71 cm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Significantly higher shoot length (16.20, 14.73, 13.89 and 13.56 cm) was registered in treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) compared to control (16.08, 14.33, 13.79 and 13.34 cm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between the crops studied, C_2 (green gram) was significantly superior in maintaining higher root length (19.78, 9.68, 8.94 and 7.83 cm) compared to $C_{1,}$ soybean (15.66, 8.02, 6.66 and 5.68 cm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

The treatment, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) recorded higher root length (20.23, 17.81, 16.59 and 15.05 cm) compared to control (19.39, 16.30, 15.54 and 14.01 cm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

With respect to the crops, C_2 (green gram) recorded significantly higher seedling dry weight (0.375, 0.268, 0.240 and 0.199 g) compared to $C_{1,}$ soybean (0.368, 0.262, 0.214 and 0.186 g) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Among the treatments, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) maintained significantly higher seedling dry weight (0.409, 0.387, 0.362 and 0.323 g) compared to control (0.398, 0.366, 0.339 and 0.291 g) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Upon comparing the crops, C_2 (green gram) recorded significantly higher seedling vigour index (2953, 1398, 1185 and 968) compared to $C_{1,}$ (soybean) (2327, 1188, 898 and 692) at one, two, three and four times repeated gamma irradiation and fumigation.

Among the various mid storage gamma irradiation (at different dosage) and fumigation, treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) maintained higher seedling vigour index (3258, 2772, 2363 and 2051) compared to all other treatments including control (3135, 2597, 2251 and 1952) at one, two, three and four times repeated gamma irradiation and fumigation, respectively.

Upon comparing the crops, C_1 (soybean) recorded significantly lower seed infection (18.9, 18.4, 15.9 and 15.6%) than $C_{2,}$ green gram (23.8, 23.4, 22.9 and 21.5%) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Significantly lower seed infection (12.0, 8.5, 5.8 and 1.8%) was registered in 1000 Gy (T_6) compared to control (30.0, 51.0, 64.0 and 77.0%) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Between the two crops under study, C_1 (soybean) registered significantly higher dehydrogenase enzyme activity (2.552 and 1.473 OD value) compared to $C_{2,}$ green gram (2.184 and 0.582 OD value) at one and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation C_2 (green gram) recorded higher dehydrogenase enzyme activity (0.398 and 0.234 OD value) compared to $C_{1,}$ soybean (0.183 and 0.094 OD value) at three and four times exposure to gamma irradiation and fumigation, respectively.

Among mid storage gamma irradiation (at different dosage) and fumigation, treatment fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) maintained higher dehydrogenase enzyme activity (2.632, 1.867, 0.375 and 0.319 OD value) compared to control (2.563, 0.992, 0.361 and 0.258 OD value) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Soybean (C_1) recorded significantly higher alpha amylase enzyme activity (26.03 and 23.09 mm) compared to $C_{2,}$ green gram (25.49 and 21.66 mm) at one, and two times exposure to gamma irradiation and fumigation but from three times exposure to gamma irradiation and fumigation C_2 recorded higher alpha amylase enzyme activity (19.44 and 16.90 mm) compared to C_1 (17.09 and 14.21 mm) at three and four times exposure to gamma irradiation and fumigation, respectively.

Among the treatments, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) recorded higher alpha amylase enzyme activity (27.40, 25.85, 22.08 and 21.78 mm) compared to control (26.60, 23.90, 21.78 and 18.30 mm) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Comparing the two crops, C_1 (soybean) recorded significantly lower electrical conductivity (0.483, 0.621, 0.756 and 0.823 dSm^{-1}) than $C_{2,}$ green gram (0.528, 0.642, 0.791 and 1.057 dSm^{-1}) respectively, at one, two, three and four times exposure to gamma irradiation and fumigation.

Among the treatments, fumigation with aluminium phosphide with 3 tablets per tonne of seed (T_7) registered significantly lower electrical conductivity (0.465, 0.487, 0.628 and 0.678 dSm^{-1}) compared to control (0.480, 0.600, 0.666 and 0.767 dSm^{-1}) at one, two, three and four times exposure to gamma irradiation and fumigation, respectively.

Conclusions

1. Seed treatment with the combination of malathion and thiram each at 2g per kg of seed was found superior in maintaining the longevity of soybean up to seven months and up to nine months in green gram under ambient storage conditions of storage.
2. Negative effect of gamma irradiation on all the seed quality parameters were noticed both at lower and higher dosage in soybean but in green gram, the low dosage (200 Gy) did not have any significant negative effect.
3. Fumigation of soybean and green gram seeds with aluminium phosphide at the rate of three tablets of three grams each per tonne of seed was superior in maintaining better seed quality during storage.

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VII. REFERENCES

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Appendix

APPENDIX – I

Monthly meteorological data for the experimental year 2016-17 and last 84 years recorded at meteorological observatory, Main Agricultural Research Station, University of Agricultural Sciences, Raichur

Month	**Rainfall (mm)**		**Temperature (°C)**				**Relative Humidity (%)**	
			Maximum		**Minimum**			
	1932-2015	**2016-17**	**1932-2015**	**2016-17**	**1932-2015**	**2016-17**	**1932-2015**	**2016-17**
January	3.90	1.4	30.9	31.2	19.8	17.7	62.3	53.1
February	0.80	0.0	33.6	35.5	21.7	21.6	59.7	43.6
March	27.30	0.0	36.6	38.4	22.6	24.6	65.2	37.5
April	50.30	0.0	38.8	41.8	23.9	28.3	61.7	32.7
May	49.7	87.2	39.6	39.6	24.7	26.6	64.6	47.8
June	61.1	194.1	36.5	33.8	24.0	24.2	70.5	68.6
July	92.1	143.2	34.5	31.8	22.7	23.5	74.7	73.2
August	172.6	78.0	33.4	32.4	22.0	23.1	76.7	70.1
September	193.2	292.5	34.1	29.2	20.7	22.6	79.8	81.6
October	72.1	39.2	32.3	31.2	20.4	19.7	74.5	66.7
November	11.9	0.0	31.4	31.1	19.0	16.1	67.9	59.2
December	4.00	0.3	30.6	30.2	18.7	15.2	67.8	58.1
Total	**739.1**	**835.9**						