EFFECT OF SULPHUR, CALCIUM, MAGNESIUM AND *BRADYRHIZOBIUM* FERTILIZATION ON THE SEED QUALITY OF GROUNDNUT

A Dissertation

By

MOHAMMAD ATAUR RAHMAN

DOCTORATE OF PHILOSOPHY

Bangladesh Agricultural University
Mymensingh

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DECLARATION

I declare that, except otherwise stated, this thesis is entirely my own work and has not been submitted to any form in another university for any degree.

(Mohammad Ataur Rahman)
March 2005

DEDICATED TO THE MEMORY OF MY PARENTS

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ABSTRACT

The study aimed at determining the effect of fertilizer elements sulphur, calcium, magnesium and *Brodyrhizobium* fertilization in improving the quality of groundnut seed, its storage performance by maintaining three level of initial moisture content of seed and storing in two type of storage container. The field experiment was conducted in 1997-98 and 1998-99 in the Oil Seed Division, BARI Joydebpur, Gazipur and the laboratory experiments also were conducted in the laboratory of the same division.

Results revealed that among the fertilizing elements sulphur and calcium affected significantly all the yield attributes and yield while magnesium affected the yield and some of the major yield attributes and *Bradyrhizobium* fertilization affected the yield significantly but the yield attributes fail to effect significantly. In storage optimum doses of sulphur, calcium, and magnesium checked the deterioration of both the germination percentage and vigour index of stored seed than untreated sample but the inoculation failed to check the deterioration of groundnut. Storage container especially the polythene bags helped to maintain the storage life of seed. Seeds with 60kg S/ha, 150kg Ca/ha and 10kg Mg/ha stored in polythene bags retained the germination percentage up to standard level of ISTA (ranging between 70 to 80 %) for 5 months efficiently. Least initial moisture content of seed (7.25%) with the above doses of fertilizer element also played a vital role in keeping the quality of stored seed for up to 5 months. Results in the respect of yield of pod, storage performance and percentage of germination and vigour index indicated that groundnut seed treated with fertilizer element during production and stored in polythene bags can retained better quality seeds, provided seeds were dried to a safe moisture level of 7.25% to 8.46%.

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CHAPTER I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important warm-season oil seed crop and food grain legume. Groundnut is one of the most important oil producing crops in Bangladesh and ranking the second position in area and production. Groundnut is grown on an area of 31283.40 hectares with a production of 39955 metric ton in the year 1999-2000. Bangladesh produces only about 19 % of the total requirement of edible oil though it has the optimum agro-climatic condition for successful cultivation of crop. (BARI, 1974). Groundnuts are grown on an estimated 19 million ha in 82 countries for use as food, oil and high protein meal. (Wyene and Gregory, 1981). Groundnut seed contains 45-50% oil, 25-30% protein and 20% carbohydrate besides vitamin B and E (Raddy and Kaul, 1986). The most important use of groundnut is cooking oil and it is also used as food by roasting. Ample scope exists for expanding groundnut cultivation without affecting the major crops in the vast char and haor lands where no important economic crop can be grown except sweet potato and watermelon, groundnut cultivation can be highly profitable. Also per hectare productivity of groundnut can be increased manifold through using better varieties and improved management practices. Groundnut seeds collected in the previous *rabi* seasons are commonly used in *kharif* season for producing seed in the next *rabi* season as the seeds loses its viability with in 2-3 months under farm level storage condition. *Kharif* cultivation of groundnut is generally done on a limited scale for seed production for *rabi* season.

The horizontal expansion of groundnut in *rabi* season is largely hindered due to unavailability of sufficient quantity of seeds. The problem is in fact, associated with the rapid deterioration of seed viability (DAE, 1987). Therefore, efforts should be made in finding out ways and means for maintaining the viability of seeds from *rabi* season harvested groundnut.

Sulphur has long been recognised as an essential nutrient elements for plants and it ranks in importance with nitrogen and phosphorous. The legume oil seed crops are more susceptible for sulphur deficiency due to their higher requirement. Since groundnut is a legume crop it is quite likely that it may respond to sulphur. Sulphur also plays a vital role in the longevity of seed in storage and better performance of seedling in the field. Sulphur is a component element of proteins, sulpholipids, enzymes.etc.

Calcium is the soil nutrient most likely to be deficient for groundnut production. A calcium deficiency results in lower yield and reduces percentage of sound mature kernels. A shortage of calcium has also been shown to decrease seed quality by inhibiting plumule development. A number of measures could be undertaken in maintaining the seed viability of groundnut. Among them fertilizer elements calcium can be used to improve the stiffness of shell and other qualities of seed. The percentage of oil of well-developed groundnut seed is thought to vary little with calcium treatment.

Magnesium is another nutrient element that plays an important role in the viability of the seed and vigour of the seedling. Magnesium increased nodulation, number of filled pods/plant and the pod yields. Seed quality of groundnut seed is affected by magnesium. Magnesium, like nitrogen is the component of chlorophyll and is essential for amino acids and fat synthesis. It also affects the viability of seed.

Rhizobium inoculation is a cheaper and usually more effective agronomic practice for ensuring adequate nitrogen supply. It is generally believed that legumes can meet their nitrogen requirement by symbiotic fixation of atmospheric nitrogen. The yield of groundnut can be increased by inoculation with the strains of *Rhizobium*.

Seed moisture content is regarded as the most important factor that impairs seed quality at storage. The metabolic activities of resting seed are dependent on the absolute seed moisture content. Moreover, it helps establish relative humidity surrounding seeds, which in turn influences microbial growth in the seed lot. This does not apply only to the absolute moisture content of the seeds, but also to the fluctuation of moisture depending on the relative humidity from the immediate atmosphere and type of storage container. Therefore, to achieve good survival at storage, reduction of seed moisture content to a suitable level through drying is of paramount importance.

Storage condition plays a significant role in seed preservation. Storage containers of semi-permeable to non-permeable status may be of noteworthy for short-term as well as long-term seed preservation. Seed growers at farm level use various containers most of them are not conducive to seed health because of their permeability to moisture. Under high humid condition, permeable containers allow moisture penetration, which in turn increases humidity surrounding the seeds. Seeds with the presence of excess moisture, and with the rise of ambient temperature during summer months tend to germinate at storage even with the absence of other conditions require for seed germination. In this process, seeds gradually lose vigour and eventuate complete destruction of viability. Once there grows a tendency of germination of seed at storage, these seed deceive germination in the field.

The storage potential of groundnut seeds depend on the genetic make up of each groundnut line, initial seed germinability and vigour. Viability of stored groundnut seeds in both traditional and improved containers was found to decrease with passage of time. Seed quality especially germination and vigour is essential to establish adequate plant stand for crop production. Seed quality can be adversely affected by the environmental factors. The most effective and economic method of storing seed by maintaining their viability is in the moisture resistant container after drying to a safe moisture level. Storing of groundnut seeds from *rabi* season to next *rabi* season in polythene bag or tin container is suggested by some workers (Bhuiya and Quashem, 1983). To ensure the amount of seed required means and ways should be found out to use the seed of *rabi* seeds in the next *rabi* season. Seed storage throughout the hot-humid season mainly for carry-over seeds, becomes a chronic problem. Subsistent seed growers cannot afford costly storage containers. Therefore, it is imperatively essential to identify cheap and handy containers that would be used safely for long-term seed preservation. Information in these aspects is almost lacking in Bangladesh. This basic information is very much essential for improvement of overall management practices of groundnut seed crop. Therefore, the present study was designed with the following general objectives:

i To evaluate the effect of sulphur, calcium, magnesium and *Bradyrhizobium* fertilization on the growth, yield and quality of groundnut.

ii. To find out the performance of sulphur, calcium, magnesium, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage and vigour index of stored seed.

iii. To see the effect of different storage containers on retention of seed quality in storage.

iv. To see the effect of initial moisture content of seed and their interaction with type of storage container on the retention of seed quality over storage period.

CHAPTER II

REVIEW OF LITERATURE

Groundnut has been studied for various aspects including the performance of fertilizer elements sulphur, calcium, magnesium, inoculum on the yield and yield attributes of the crop. Research results revealed that all these elements have a significant effect on the viability and vigour of the crop seed. A number of measures could be under taken in maintaining the viability and vigour of groundnut seed. Sulphur, calcium and magnesium can play a notable role in increasing the viability of groundnut seed and maintaining good seed vigour in storage. Initial seed moisture content and type of storage container also play a dominant role in maintaining seed viability and vigour of groundnut seed. The available literature on the effect of all these fertilizer elements on the yield, yield attributes and seed quality pertinent to this study has been reviewed below

2.1. Effect of sulphur

Sulphur is one of the very important components of protein and oil and it plays an important role in the formation of protein and involved in the metabolic and enzymatic process of all living cells. Sulphur also plays a vital role in the longevity of seed in storage and better performance of seedling in the field. Fox *et al.* (1977) observed that sulphur content of the seeds of cowpea is increased with increasing sulphur fertilization of soil. The levels of sulphur adequate for seed yield were also sufficient for near maximum sulphur content in the seed. Sridhara *et al.* (1997) stated that the interaction effect of Ca × Mg × S was clearly evident in terms of maximum yield obtained compared with the application of Ca, Mg or S alone and it was concluded that application of 840 kg Ca + 168 kg Mg and 14 kg S/ha was optimum for the soil of the experimental field.

2.1.1 Effect of sulphur on the growth and growth characteristics

Singh *et al.* (1995) observed that on a calcareous soil plants grown with sulphur compared to those without sulphur had increased plant height, number of flowers, nodule numbers and weight, higher DM, seed, haulm (leaves and stems), and oil yields. Pyrite and elemental sulphur were most effective when applied to the soil only, half as a basal soil dressing, and the remainder in 2 equal splits at 25 and 50 DAE. On a sandy loam soil gypsum application increased sulphur uptake at early flowering, 100 d after sowing and at harvesting. Gypsum application increased the DW of aboveground parts and roots and increased seed yield and CP and lipid contents. Yields were maximum (1.95 t/ha) with 250 kg gypsum/ha (Choi and Ryu, 1991).

Sulphur uptake was positively correlated with root DW, number of branches/hill, seed yield and CP and lipid contents. Application of 22 kg/ha of dust sulphur or the same amount of sulphur from gypsum, potassium sulphate or magnesium sulphate or ammonium sulphate in groundnut increased the dry matter production, shelling percentage, 100 seed weight, carbohydrate, protein and oil contents in seed. However, dust sulphur was found to be most effective (Thirumalaisamy *et al.*, 1986). Tajeldin and Salama (1987) stated that sulphur applied at sowing and at flowering stage of groundnut significantly increased the shoot dry weight and pod yield. Hago and Salama (1987) observed that application of 50 kg S/ha in groundnut produced significantly higher flower number per plant over control but beyond this rate no further response was observed.

Kale (1993) found that on clay soil during the rainy season, groundnuts given 0,15,30,45 or 60kg S/ha gave pod DM yields of 0.69,0.90,1.24,1.07 and1.12t/ha, respectively. Groundnuts were given 0 or 20 kg S/ha applied before sowing. Application of elemental sulphur reduced the chlorosis of groundnut leaves and increased the dry matter, nodule biomass, pod, shoot, and oil yields, and concentration of nutrients in leaf tissue and their uptake by groundnut. On average, application of 20 kg S/ha as elemental sulphur increased pod yield by 8.6-9.8% and oil yield by 8.8-15%(Singh and Chaudhari, 1997). Laurence *et al.* (1976) observed that sulphur applied either as a foliar dust or soil treatment increased yields of groundnut, although the effects of complementary treatments were not fully additive. Besides improving yield, sulphur application also produced kernels of better size and quality than untreated samples. Sulphur application generally increased nutrient content and uptake of seeds and haulms. Sulphur uptake increased with increasing sulphur rate, while sulphur use efficiency decreased. N: S, Ca: S and Mg: S ratios decreased with increasing sulphur rate(Devi *et al.,* 1999).

2.1.2 Effect of sulphur on the yield and yield attributes

Groundnuts were given 0, 30 or 60 kg S/ha. In general, yield and yield component values were higher with sulphur than without sulphur and there were no difference between rates (Vasisht and Pandey, 1999). Dimreej *et al.* (1993) stated that sulphur 0, 15, 30, 45 and 60 Kg/ha was applied one week before sowing and reported improved yield and yield attributes of groundnut. The use of sulphur was found to increase the number of peg and pods/plant, weight of 100 pods, kernel and shell ratio and pod yield of groundnut up to a level of 27 ppm. The use of sulphur found to increase the number of pegs and pods per plant, weight of 100 pods, kernel and shell ratio and pod yield of groundnut up to a level of 27 ppm (Bhardwaj and Pathak, 1987). Sahu *et al.* (1991) observed that sulphur is deficient in 60% of the alluvial soils and 16% of the red and lateritic soils of Orissa, India, where groundnuts are grown and sulphur supplied from treatments of single super phosphate, rock phosphate and gypsum, indicated that maximum pod yield (2.35 t/ha) and net profit (Rs 141/kg S applied) were obtained when 30 kg S/ha was applied as single super phosphate, 75% at time of sowing and 25% at the peg-initiation stage. Shivaraj and Gowda (1993) stated that groundnuts growing on a red sandy loam soil were given 10, 20 or 30 kg S/ha as the element or gypsum or 12.5, 25 or 37.5 kg Ca/ha as calcium oxide alone or in combination with sulphur. Pod, haulm and oil yield, oil and shelling percentages and 100-seed weight were highest with application of 30 kg sulphur as gypsum. Bandopadhyay *et al.* (1998) in an investigation using different sources of sulphur stated that sulphur application significantly improved yields and yields attributes. Among the S sources, gypsum was superior to SSP, the latter being superior to pyrites in case of pod and kernel yield. Gypsum and SSP performed at par for shelling percentage, 100-kernel weight and oil content in groundnut.

The effect of 0,15 or 30kg S/ha applied at sowing with or with out earthing up (at 30 days after sowing) the number of effective pegs, pod number and weight, shelling percentage and 100 seed weight increased with increase sulphur rate up to 30kg/ha (Nitsure and Ramteke, 1987). Mishra (1996) observed that application of 30 kg S/ha significantly increased pod and haulm yields, number of pods/plant, 100-kernel weight, shelling percentage and oil content compared with the control and 15 kg S/ha treatments. Verma *et al.* (1973) reported significant increase in shelling percentage and pod yield with 25 kg S/ha in kharif. Fornasieri *et al.* (1987) stated that increased number of pods and seeds produced in the treatments with sulphur applied in the form of gypsum resulted in the higher yield of groundnut.

Sulphur application through gypsum increased pod yield of groundnut in sandy-loam soil of pH 7.8. From pot trials on sandy soils (pH 7.9) they observed increased protein content of kernel and oil percentage in groundnut with the application of 44.8-kg S/ha (Singh *et al.,* 1970). Singh and Karla (1983) stated that application of sulphur was found to increase the yield of pod /ha significantly as compared to control. The highest yield of pod was produced with the highest level of 40 kg/ha of sulphur in both the year of study. Aulakh *et al.* (1980) found that the fertilization of groundnut by sulphur increased yield. Choudhury *et al.* (1991) reported that an increasing trend in oil content of groundnut with increase in the level of sulphur from 0-60 kg/ ha but there was no effect of sulphur on pod yield of groundnut. Das and Misra (1991) found that the yield of pod increased progressively from 0 to 40 Kg/ha of sulphur and then declined. De *et al.* (1982) reported that sulphur applied in the form of gypsum at the earthing up stage of groundnut at 1000 kg/ha increased the pod yield of groundnut significantly over a dose of 500 kg/ha of gypsum. Wali *et al.* (1994) observed that on a sandy loam soil (containing 8.5 ppm available S) pod yield was highest with 50kg S (2.06t/ha). Seed oil content increased with increasing sulphur. Groundnuts were sown in flat beds, broad bed furrow or ridge furrows and sulphur with 0, 20, 40 or 60 kg/ha. Pod yield was not affected by sulphur application but seed oil content increased with sulphur application rate (Hadvani *et al.*, 1993).

47.3 to 49.3% with 0-45 kg S/ha and was highest with sulphur application at pod initiation. Sakal *et al.* (1993) stated that on sandy loam soil groundnuts were given 0, 20, 30 or 40 kg S/ha as ammonium sulphate, gypsum or single super phosphate produced mean seed yields of 1.29, 1.57, 1.62 and 1.71 t/ha, respectively. Groundnut yields were not affected by sulphur source, but total sulphur uptake was highest with ammonium sulphate and lowest with gypsum.

2.1.3 Effect of sulphur on oil and protein content

Sulphur is an essential constituent of certain amino acids, which affected the nitrogen metabolism, and quality of groundnut (Ahlawat and Chohal, 1986). Yadav and Singh (1970) reported an Increase in oil content of groundnut due to application of sulphur. Bhuiya and Chowdhury (1974) observed that S @112 kg/ha on groundnut increased the percentage of protein and oil content in the kernels. Singh *et al.* (1995) observed that on calcareous soil groundnuts S @ 0 or 20 kg S/ha applied before sowing reduced the chlorosis of groundnut leaves and increased the dry matter, nodule biomass, pod, shoot, and oil yields, and concentration of nutrients in leaf tissue and their uptake by groundnut. On average, application of 20 kg S/ha as elemental sulphur increased pod yield by 8.6-9.8% and oil yield by 8.8-15%.

Application of 200 lb S/acre increased groundnut seed yields by 50% increased the contents of oil and S-containing amino acids and depressed cp. contents (Chopra and Kanwar, 1966). Dimree and Dwivedi (1994) observed that 0-60kg/ha each of sulphur as elemental sulphur when available sulphur in the soil was 8-mg/kg soils; seed yield increased with up to 45 kg sulphur. Sulphur application increased seed oil and protein contents. Pod yield and net profit were highest with 40 kg S/ha as gypsum. Seed oil content was highest with 40 kg S/ha as gypsum or pyrite Patra *et al.* (1995). Naphade and Wankhade (1988) reported that on a soil containing 17 kg available S/ha, application of 60kgS/ha as calcium sulphate increased pod yields from .75t to 1.00t/ha, seed protein content from 22.31 o28.96% and oil content from 48.82 to 51.97%. S at 90kg/ha gave no further increase in yield.

Application of 0 or 30 kg S/ha as phosphogypsum, elemental sulphur or single super phosphate, were tested. Pod yield was increased by sulphur application and was higher with single super phosphate (2.52 t/ha) than with phosphogypsum (2.47 t) or elemental sulphur (2.39 t). The oil content in pod, sulphur content in seed, shell and haulm were significantly higher with the bed and furrow method. S application increased seed oil content. The seed oil content was highest with phosphogypsum (50.56%) (Panda *et al.*, 1997). Reddy and Murthy (1989) reported that application of 120 kg S/ha as calcium sulphate increased oil contents. Application of sulphur increased contents of different amino acids, but the defatted protein content was lower with applied sulphur than without sulphur. Contents of unsaturated fatty acids in oil were lower in the *kharif* [monsoon] season than in the summer season. Treatments significantly affected arachidic and lingnoceric acid contents, but not those of other unsaturated fatty acids.

In sandy loam soil with 8 ppm available sulphur and were given an equivalent of 0, 30 or 60 kg S/ha as calcium sulphate. In groundnuts, seed sulphur content increased from 0.15% with no sulphur application to 0.18 and 0.20% with 30 and 60 kg S/ha, respectively. Sulphur application increased seed yield, total sulphur content and cysteine content of seeds in both species, but did not affect seed oil content (Lakkineni and Abrol, 1992). Evans *et al.* (1977) reported that it is possible to increase the sulphur amino acid content of groundnut and at the same time achieved greater yields of grains by increasing sulphur supply. Tisdale *et al.* (1985) stated that sulphur is essential to plant nutrition. sulphur ranks in importance with N as constituent of amino acids. Cysteine, cystine and methionine in protein that account for 90% of sulphur in plants. It is also involved in the promotion of oil in crops such as peanut. Pasricha *et al.* (1970) observed increased sulphur containing amino acids in response to sulphur fertilization of groundnut.

2.1.4 Effect of sulphur on seed quality, viability and vigour

Application of 2 t lime or 30-50-30 kg NPK/ha or with a combination of these was tested after harvest for 100 seed weight, germination and vigour. And then stored and tested again at 3-month intervals over 15 months. Although seeds from limed plots were smaller, they were superior throughout for germination and vigour (Maeda *et al.*, 1986). Rossetto *et al.* (1996) stated that lime applied @ 0 or 1.75 t/ha to dark red Latosol 1 month before sowing groundnuts in late September seeds were harvested at 7-d intervals from 87 to 143 days after sowing and was subjected immediately or after 6 months storage to tests of germination and vigour (electrical conductivity) number of normal seedling and speed and percentage of emergence under field conditions. Maturity occurred earlier, seed quality was higher and was sustained longer on limed plots.

2.2. Effect of calcium

Calcium is one of the most important components of shell and it plays an important role in increasing the stiffness of the shell. It is very often showed that stiffer shell has longer viability than others do. Viability duration and germination percentage of seed and seedling vigour is also increased by calcium application. Calcium also enhances the microbial activity when applied with *Rhizobium* inoculation. Cao and Zhang (1987) observed that calcium concentration in capsules of groundnut ranked cutis (82.5%) >shell (7.6%)> embryo (3.4%). Distribution of calcium was 36.6% in shell, 31.6% in cotyledon, 29.5% in cutis and 2.3% in embryo.

2.2.1 Effect of calcium growth and growth characteristics

Foliar applications of 30 mm $CaCl_2$ in water stressed plants, calcium application increased growth parameters and chlorophyll and protein contents (Mohan and Rao, 1989). Gowda *et al.* (1991) stated that calcium deficiency symptoms in the form of 'pops' (pods containing shriveled seeds with a darkened plumule) were studied in 10 groundnut cultivars grown on a Ca-deficient soil. The proportion of pops ranged from 0.1% in the early-maturing cv. Chico to 14.5-15.3% in the smooth podded cv. JL24, TGS2 and DH40. The average reduction in calcium concentration was 28% in shells and 41% in seeds. Pops (un filled pods) percentage was negatively correlated with shelling percentage and was positively correlated with pod surface area and shell thickness, indicating poor translocation of calcium to seeds in pods.

On red sandy loam or sandy clay loam in pot application of calcium oxide produced a higher pod yield than calcium sulphate (15.06 vs. 13.66 g/plant), a higher seed yield (11.27 vs. 10.03 g/plant) and shelling percentage (74.6 vs. 73.4). Pod yield increased from 13.22 (control) to 20.99 g in red sandy loam soil with increase in calcium saturation up to 75% but in the sandy clay loam, the yield response occurred up to 25% calcium saturation only. Similar trends were observed with respect to seed yield. Superior response to calcium saturation in the red sandy loam soil was related to it being more fertile than the sandy clay loam (Ramachandrappa and Kulkarni, 1992). Velasquez and Ramirez (1985) found that seed weight was greater when 80 ppm. Calcium was applied to the fruiting system area and yield was maximum when the soil soluble calcium content was 0.58-1.33 meq /litre. Above ground DM production from pots in which no calcium had been applied to the fruiting system was double that in which 80 ppm. Calcium had been applied, irrespective of the soil soluble calcium content in the root area.

2.2.2 Effect of calcium yield and yield attributes

Ashrif (1963) reported that pod weight per acre, leaf weight per acre and shelling percentage was unaffected by lime. He further confirmed it from another experiment that there was no significant effect of calcium on pod and straw yields of groundnut. Das and Garnayak (1995) stated that in the *kharif* season groundnut were given 15, 30, 45 or 60 kg Ca/ha as gypsum or $CaCO_3$ in paper mill sludge. Application of 60 kg Ca as gypsum gave the highest pod yield (1.79 t/ha), oil yield, number of pods per plant, shelling percentage and 100 seed weight. The better response to gypsum was attributed to the presence of sulphur, and to higher solubility than paper mill sludge. Ravikumar and Raghavulu (1995) were given 0 or 500 kg gypsum/ha as a basal application, at 35 DAS or 2 split applications (basal + 35 DAS). Pod yield increased significantly when gypsum was applied at 500 kg/ha and split application proved superior to basal application. Pod yield was positively correlated with the number of pods/plant and 100-seed weight. The advantage in pod yield due to split application of 500 kg of gypsum was 374, 354, 364 kg/ha over control in the first and second year and pooled data, respectively. Badiger *et* *al.* (1982) stated that calcium was very important for groundnut especially for gynophore development, pod setting and reducing 'pops' (unfilled pods). Peanut absorbs calcium through root system and also through peg and pod to meet the immediate requirement. Dubey and Patro (1993) found that in a trial on a loamy sand soil during *rabi* (winter) that liming enhanced crop germination, number of nodule/plant, and number of filled pods, seed weight and shelling percentage. In lateritic soil lime amendments individually and in combination increased pod yield in rainy and post rainy season by 5.0%, 18.5%, shelling percentage by 5.44%, 3.67% and oil content by 7.6%, 3.32%, respectively (Shahu *et al.*,1995). Blamey (1983) reported that on an acid medium sandy loam soil (typical Plinthustult) liming resulted in better growth of groundnut.

An application rate increasing yield by 39- 82.7 % (mean 29.3%) with soils with water soluble calcium content <90 mg /kg increased yield by 7- 13.7 % (mean 10.93%) in soils with 91-120 mg Ca/kg and by a mean of 4.8% with >120 mg Ca/kg soil (Zhang and Zhao, 1995). Loader *et al.* (1988) observed that 8 groundnut cultivars were given to 0, 136 or 318 kg Ca/ha as gypsum. Without calcium application seed yield ranged from 0.44t/ha in c.v. 10 to 1.31t/ha in cv Shulamit. Application of 136 kg calcium increased in all 8 cultivars with yield ranging from 1.38 t in cv. Early bunch to 2.78 t in cv Virginia bunch. Application of 318 kg calcium further increased seed yield in 6 cultivars.100-seed weight ranged from 67.1 to 78.7 g without calcium application and increased with application of 136kg. Average seed calcium concentration increased with calcium rate. Gajanan *et al.* (1991) reported that on an alfisol (pH-5.0) were given different lime and gypsum treatment. Pod yields were 0.99t/ha without soil amendments and highest (1.25t) on soil limed to 45% saturation.

Groundnut grown on sandy loam soil (pH-7.8), application of 0,30 or 60 kg calcium as calcium chloride dehydrate/ha at the flowering stage gave av. pod yield of 0.89,1.05 and 1.13t/ha, respectively (Giri and Saran, 1989). Patel and Golakiya (1986) stated that in black calcareous soil, application of calcium carbonate at 10% increased groundnut pod yield, but beyond this level it decreased the yield and uptake of nutrients except calcium. Cao (1986) reported that groundnuts were given 0,30,50 and 80 jin lime/mμ .The yield of the control was 573 jin pods and 404 jin seeds/mu while 50 jin lime gave 612 jin pods and 446 jin seeds/mμ. (1jin=0.5 kg; 1mμ=0.067 ha). Agasimani *et al.* (1992) observed groundnut were given 0, 250 or 500-kg gypsum/ha as a basal application or at pegging, or elemental sulphur or CaO equivalent to 250 or 500 kg gypsum/ha. Pod yield was highest with 500 kg gypsum at pegging (2.30 t/ha) followed by 500 kg gypsum as a basal application (2.15 t), CaO equivalent to 250 kg gypsum at pegging (2.12 t) and 250 kg gypsum at pegging (2.11 t). Application of lime increased groundnut yields. In another experiment groundnut were grown on plots given 0, 375 or 1000 kg lime either surface broadcast, shallow or deeply incorporated. The plots had received 375, 2350 or 6500 kg lime 29 months earlier. Lime application increased soil pH, exchangeable calcium, magnesium and potassium but reduced extractable Al, P and SO_4^{--}. In about a year, the effects of lime extended to deeper soil layers. Groundnut yields increased with lime and higher rainfall Amien (1992).

2.2.3 Effect of calcium on the protein and oil content

Groundnuts were given 0, 25, 50 or 100 kg S/ha and 0, 400, 500 or 600 kg Ca/ha. Pod yields and seed protein and oil contents generally increased with increasing rates of sulphur and calcium applied singly. Application of 25 kg S + 500 kg Ca gave the highest pod yield and oil content, while 50 kg S + 600 kg Ca gave the highest protein contents (Thakare *et al.,* 1998). Supplemental calcium applied at flowering improved yield and quality of large seeded peanuts. The role of calcium in reducing pod rot incidence in peanut is also well known (Alva *et al.,* 1989). The *kharif* groundnuts were given 0,120 or 240 kg/ha as gypsum or calcium carbonate at sowing, flowering or 50% at sowing + 50% at flowering. Pod yield, seed protein and oil content increased with rate of calcium application (Ursal *et al.,* 1994).

2.2.4 Effect of calcium on the seed quality, viability and vigour

A linear relationship between seed calcium content and seedling emergence of 'Florigiant' peanuts was demonstrated when seed calcium ranged from 0 to 420 ppm (Cox *et al.,* 1982) Seed vigour was positively correlated with degree of un-saturation of membrane fatty acids in the axis. Treatment with calcium, spermine or putrescine increased the unsaturation of membrane fatty acids, decreased membrane permeability and decreased leakage (Huang and Fu, 1991) Adams *et al.* (1993) observed that germination percentage and seedling survival were both highly correlated with seed calcium concentration. Minimum seed calcium needed for maximum germination ranged from 368 to 414 mg/kg. Comparable calcium values for seedling survival ranged between 361 and 445 mg/kg. The correlations between soils calcium and either germination or seedling vigour were less than those between seed calcium and germination or seedling vigour. It was suggested that groundnut seed crops required higher soil calcium levels than other groundnut crops. Zode *et al.* (1995) concluded that loss of seed viability in groundnuts couldn't be attributed to low soil calcium in paddy soils in Maharashtra. Liming increased seed protein content, but did not affect oil content or quality. Drying methods had no effect on protein and oil contents or oil quality (Fernandez and Rosolem, 1998). Germination of seed, harvested from the weight season crop was greater with than with out liming after 3 and 9-month storage at Marilia. Seed vigour was greater with than with out liming (i, e, conductivity was lower) for seed from wet and dry season crops (Nakagowa *et al.,* 1992). Germination disorders and seed calcium deficiency are frequently associated in Virginia peanuts (*Arachis hypogaea* L.) cultivars. Embryonic calcium concentration was compared with germination percentage after 3 days of cold treatment, calcium concentration was found to be positively correlated with germination percentage (Carrie *et al.,* 1978). Gypsum at 0.673Mg/ha reduced soil pH and the detrimental effect of potassium on fruit yield and quality, improved seed germination, seedling survival and vigour, and increased yield and improved seed quality (Sullivan *et al.*, 1974). Additions of calcium to fruiting zone during seed development improved the germination performance of seeds from Virginia cultivars (Harris and Brolmann, 1966). Calcium with concentrations ranging from 0.2 to 1.0% in plant tissue is also essential to plant life. Calcium deficiencies manifests in the failure of terminal buds and apical tips of root to develop. Also, lack of calcium results in general breakdown of membrane structures with resultant loss in retention of cellular diffuable compounds. Disorders in the storage of tissue of fruits and vegetable frequently indicate calcium deficiency (Tisdale *et al.* 1985).

2.3 Effect of magnesium

Magnesium is also another nutrient element that has an important role in the viability duration of seed in the storage and vigour seedling in the field. It also plays a potential role on growth, yield and quality of groundnut.

2.3.1 Effect of magnesium growth and growth characteristics

Application of >67kg Mg increased seed yield in 1978 and 1982. Application of Mg + K increased average pod yields by approximately 2.2t/ha (69.3%). Magnesium application had no consistent effects on percentage of sound mature seeds. Increasing magnesium application rate increased leaf and soil magnesium concentration. The minimum sufficiency levels in soil for maximum yield were established 20 kg Mg/ha (Walker *et al.*, 1988). 6, 12 or 18 t/ha of coarse (0-10 mm) coralline material containing 31.1% Ca and 1.67% Mg was banded or broadcast prior to sowing groundnuts. In the highest rainfall location, marketable yields of groundnuts were increased by 250% by liming at 6 t/ha, relative to the un amended control (Bekker *et al.*, 1993). Groundnut yield increases were associated with reduced manganese toxicity and/or with calcium and magnesium deficiency. Among the various cations essential for normal life of the plants, potassium, calcium and magnesium need a very special consideration because of their largest contribution to plant ash (Kamata ,1979).

2.3.2 Effect of magnesium on yield and yield attributes

On a red sandy clay loam soil (pH 5.5) application of 300 kg Mg/ha increased nodulation, number of filled pods/plant and the pod yields (Sudhir *et al.*, 1987). Lumpungu and Muteba (1983) reported significant increase in oil and pod yield when seeds were soaked in magnesium. An increase in the application rate of potassium, calcium and magnesium to 15% more than soil exchangeable potassium, calcium and magnesium contents significantly increased the seed yield and number of filled pods per plant of groundnuts but did not reduce the number of empty pods per plant (Taufiq and Sudaryono, 1997). Maliwal and Tank (1988) stated that to study the effect of phosphorous, with and without sulphur and magnesium found that magnesium did not influence pod yield compared with single super phosphate+ ammonium sulphate but gave significantly higher yields than the control and single super phosphate+ urea. Kale (1993) observed that groundnuts were given 0-40 kg $MgSO_4$/ha. Dry pod yield (1.22 t/ha) and seed oil content (45.97%) were the highest with 30-kg $MgSO_4$. Application of 10-kg borax; 15 kg copper sulphate, 20-kg magnesium sulphate or 2-kg ammonium molybdate/ha had no significant effect on yields (Kulkarni *et al.,* 1995). Balerao *et al.* (1994) revealed that in *kharif* (monsoon) seasons the effects of 12 different foliar fertilization and growth regulator treatments on groundnuts were compared. The highest yield was given by spray of 2% Magsulf at 20,40 and 55 days after sowing. Ground magnesia limestone significantly improved nodulation and gave the most frequent yield responses. Potassium and magnesium fertilizers tended to increase yield on the more fertile soils, but depressed yield on the poorer soils, because the application of one of these nutrients depressed uptake of the other (Foster, 1989).

2.3.3 Effect of magnesium on the protein and oil content

The direct and residual effect of 0-500 kg pyrites/ha containing 22% sulphur on groundnut was studied. Groundnut pod protein and oil contents increased with increasing pyrites application rate. Direct effects of 500 and 400 kg pyrites/ha gave the highest seed yields in groundnuts (Surendra *et al.,* 1991). Magnesium application had no effect on oil output, because it did not have favourable effect on kernel yield (Rajan *et al.,* 1992).

2.3.4 Effect of magnesium seed quality, viability and vigour

Dwivedi (1988) stated that magnesium, like nitrogen is the component of chlorophyll and is essential for amino acids and fat synthesis. It also affects the viability of seed.

2.4 Effect of *Bradyrhizobium* fertilization

It is generally believed that legumes can meet their nitrogen requirement by symbiotic fixation of atmospheric nitrogen. Groundnut being a leguminous crop, its yield can be increased by inoculation with the strains of *Rhizobium*.

3.4.1 Effect of *Bradyrhizobium* inoculation on growth and growth characteristics

Lombardi *et al.* (1993) found that on a dark red latosol and on apodzol, groundnut CV. Tatu were given 60kg N/ha or seeds were inoculated with one of the six *Bradyrhizobium* strains. Plant DM yields increased with inoculation by SMS-2 and SMS-561 on the latosol. Adu and Misari (1989) stated that the response of groundnuts to inoculation with *Rhizobium* strainNC-92 was investigated. Nodulation, pod yield and shelling percentage were not improved by inoculation. Inoculation decreased plant DW 51days after sowing in the 2nd year of the trial. Inoculation of groundnut with *Rhizobium* species encouraged branching and pod yield (Deshmukh and Dev, 1995). Joshi *et al.* (1990) revealed that pod yields were not significantly affected by strain and ranged from 0.40 t/ha in Punjab 1 to 2.47 t in JL 24 in 1985 and from 0.68 in GAUG 10 to 1.69 t in GG 2 in 1986. The number of nodules/plant in 1986 was greatest with strain NC 92 while nodule DW was greatest with IGR 68. Pod yields were greater in Spanish bunch than in Virginia cultivars. The same author (1987) observed that inoculated groundnut with *Rhizobium* strains increased the dry weight of plants even when treated with micronutrients.

3.4.2 Effect of *Bradyrhizobium* inoculation on yield and yield attributes

Rahman *et al.* (1994) stated that there were 6 treatments involving inoculums and fertilizer application of 50kg each of N, P and K/ha in combinations. The inoculums alone or phosphate or potash fertilizer significantly increased nodule number, nodule weight, dry shoot weight, straw weight and pod yields. Nguyen (1996) reported that groundnuts were un-inoculated and given no N fertilizer, inoculated with *Bradyrhizobium* sp. On the light alluvial soil, pod yields was1.63t/ha in the control and 1.90t after seed inoculation. Green matter yields increased from 25.0 t in the control to 32.5 t with inoculation. On the medium alluvial soil, pod yield was 2.13t/ha in the control and increased by 8.5% after seed inoculation 'FW yields were 29.67t/ha in the control, 33.33t with inoculation. Inoculation was equivalent to 11.5 13.9 kg N/ha on the light and medium soils, respectively. Anuar *et al.* (1993) stated that *Bradyrhizobium* (strain CB756)-groundnuts (cultivar's V13) combination produced maximum pod yield and N concentration in the haulm on both un-limed and limed soil. An equivalent of 77 kg Nha^{-1} without lime and 105 kg Nha^{-1} when limed was estimated to be returned to the soil as legume-N through the groundnut residue.

Locally isolated strain of *Rhizobia* BAU-700 produced the highest number of nodules, nodule weight and shoot weight/plant compared to uninoculated control (Haque, 1987). Pulatova *et al.* (1998) observed that *Bradyrhizobium* sp. (*Arachis hypogaea*) increased the dry mass of the plants, the seed yield, the mass of 1000 seeds, the total number of nodules, and the large ones to the greatest extent. Lee *et al.* (1990) observed higher concentration of chlorophyll, uptake and fixation of nitrogen, dry weight of plant, number of pods/plant and 100 seed weight in the groundnut crop treated with *Rhizobium* species. Kucey and Toomsan (1988) reported that the highest av. seed yields were with cv. KAC 431 and Tainan-9 in 1985 and 1986, respectively. In 1985 matured pod yields increased above non-inoculated yields in CV. Moket with all inoculants and in KAC 431 with

with a combination of *Rhizobium*+cobalt sulphate seed treatment. (47.1 and 25.5%, respectively) (Jana *et al.,* 1994) Wankhade *et al.* (1992) observed that seed inoculation with *Rhizobium* culture increased the chlorophyll and oil content in kernels significantly.

3.4.4 Effect of *Bradyrhizobium* inoculation on seed quality, viability and vigour

Jayaraj and Karivaratharaju (1988) observed that uninoculated seeds with 8% moisture content gave highest percentage of germination irrespective of storage containers. Inoculation decreased percentage germination and increased percentage of abnormal seedlings. Seed stored in cloth bags gave significantly higher percentage germination than those stored in aluminum foil pouches.

3.5 Effect of storage container and initial moisture content of the seed

Quality of peanut seed are greatly depending on post harvest practices offered by the producer are seed drying methods, initial moisture content of the seed, relative humidity and temperature of the storage and packaging materials. Research results show that moisture content and storage container play a very important role in maintaining good seed quality.

Application of calcium; magnesium and sulphur in the dry season planting did not affect either groundnut seed germination percentage or vigor of the four groundnut cultivars. However, in the rainy season, seed germination and seed vigour as determined by the accelerated aging technique at 42^{O} C, 100 % R.H. for 96 hours and field emergence counted at 14 and 21 days after planting was found to increase with the application of calcium, magnesium and sulphur (Juangjun and Sumran, 1991).

Begum and Akther (1988) observed that after 12 months, storage at room temperature, viability was 50% and moisture content 11% for both cultivars, and after 14 months, viability was nil for both cultivars at 11 and 13% moisture content for DG2 and Dhaka1, respectively. After 18 months at 10°C; viability of DG2 and Dhaka1 was 80 and 100% respectively, at moisture content 10 and 12.5%. Viability and moisture content of both cultivars were 20 and 15%, respectively after 37 months storage at 10°C. Ahmed *et al.* (1967) stated that data were given on the rates of drying and moisture content, free fatty acid values during storage of unshelled groundnut, for 210 days following sun drying and drying in a rotary dryer. The moisture content of pods dried in a rotary drier took 18 hour to fall to 7%, compared with about 15 days for sun dried nuts. With both drying methods the nut maintained their quality well during storage. Krishnappa *et al.* (1999) observed that Seeds when dried to about 7% moisture content germination did not differ among cultivars stored for up to 8 months, but at 16 months germination ranged from 3 to 37% (mean 21.4%). There was no significant difference in germination among cultivars given up to 3 days accelerated aging, but differences developed with longer accelerated aging periods. The same author (1998) also found that differences in storage potential between cultivars were small, with no significant effect on vigour, and a small but significant difference in germination only after 16 months. Among containers, the polyvinyl bags gave the greatest percentage germination and seed vigour after 16 months, but differences at earlier stages were not significant. All containers maintained the minimum certification standard of 70% germination for 12 months, and polyvinyl bags maintained this standard for 14 months. Duan *et al.* (1997) stated that dried seeds with different seed moisture content were stored in sealed containers at room temperature for 7-12 years. It is concluded that under the climatic conditions of Wuhan, dried seeds of groundnut (moisture content in the range of 3.2-3.3%) can be stored for 11 years or more without significant deterioration. Varietal differences were observed between genotypes in their sensitivity to seed moisture during storage.

Seeds at moisture content of 5.8-6.5% were stored in unlined gunny bags or polyethylene-lined gunny bags. Seeds were tested at 2-month intervals for germination and also for field emergence after 8 months. Germination percentage declined with storage in all treatments. It remained above 70% in seeds stored in the lined gunny bags with $CaCl_2$ although it fell to 4 and 11% in the other treatments. Field emergence was 69.75% in seeds stored in lined gunny bags with $CaCl_2$ (Nautiyal *et al.,* 1996). Groundnut seeds with moisture contents of 5.2, 7.8, 9.0 and 10.4% were stored for 0-60 d in polythene or cloth bags. Oil content, iodine values and protein content were not affected by storage moisture content (Ali *et al.,* 1995). Majhi and Bandopadhya (1995) stated that freshly harvested groundnut seeds dried to moisture content of 9% were stored in a glass bottle, polythene packets, and paper packets or cloth bags for between 1 and 9 months. Germination percentage and seedling root and shoot lengths were high where seeds were stored in glass bottles or polythene packets and comparatively low in paper packets or cloth bags.

Seeds of groundnuts were sun dried to 7.0,15.0,21.0 or28.0% moisture (±0.5) was hand or machine shelled and stored for 2,4 or 6 months in cloths bag in ambient condition. Mean germination percentage decreased with increased length of storage. Hand shelling gave higher mean seed yields than machine shelling (Subbaraman and Selvaraj, 1990).

Choudhury *et al.* (1991) reported that viability of stored groundnut seeds in both traditional and improved containers was found to decrease with passage of time. Viability of stored unshelled groundnut seed up to 9 (nine) months of storage in tin container and polythene line jute bag were 80% and 83.33%, respectively. Which lowered to 30% and 40%, respectively after 11 months storage. Juangiun and Chockchi (1989) determined the unshelled large-seeded groundnut storability under local ambient condition in five promising lines. Freshly hand harvested hand depoded groundnut pods were sun dried to 7% moisture content. Dried pods were put in nylon mesh bags and stored at ambient condition under open air-roofed farmhouse for 14 months. They indicate that storage potential of groundnut seeds depend on the genetic make up of each groundnut line, initial seed germinability and vigour.

Seeds stored under ambient conditions maintain satisfactorily germination for only five months. In contrast, seed stored under both controlled conditions still showed good germination, with no pronounced decrease, after ten months of storage. Seed vigour decreased under all storage conditions. The fastest reduction occurred in seed stored under ambient condition. The seed moisture content increased to an unsafe level for maintaining good seed quality in seed stored under ambient condition. Whereas moisture content in seed stored under the two controlled conditions remained at a safe level during the entire storage period (Prasat, 1990). Prasat and Chaumsri (1987) reported that seeds kept in sealed plastic bags maintained both germination and vigour higher than those in paper bags did. Germination and vigour of seeds stored under controlled condition declined slower than those stored under ambient condition. The fastest reduction of germination was found on seeds with high initial moisture content, kept in paper bags, and stored under ambient condition. Seeds with low initial moisture content, contained in sealed plastics bags, and stored under ambient condition showed no pronounced difference in germination from those with high and low initial moisture content, kept in paper bags and stored under controlled condition.

Storing of groundnut seeds at farm level is possible if the initial germination is high and seeds are dried to 4% moisture before storing under ambient condition (Paungthong and Lamduan, 1987). The same author (1990) found that plastic bag could retain good seed viability for a long period of time. They also reported that initial germination is an important factor and good quality seeds are an essential prerequisite for long period of storage. The same author (1990) observed that the unshelled pods stored in plastic bags were superior to others, which deteriorated rapidly after six months of storage. There was no significance differences percent germination of seeds stored in different packaging materials under cool room condition. Chakraborty *et al.* (1991) reported that storing the kharif crop seeds for 4 months did not decrease seed vigour. The loss of viability during 8 months storage of the summer crop was associated with high fluctuations in temperature and RH. During storage of both crops there were increases in seed moisture content, lipase activity, free fatty acids, malondialdehyde concentration and electrical conductivity, and a decrease in phospholipid concentration. Most changes were much more marked in the summer crop than in the kharif crop.

Viability of groundnut seeds from a *rabi* crop over a period of 7 months. The factors included were; two containers, biscuit tin and bags, and two seed condition- shelled and unshelled. Results showed that the storage containers did not but the seed condition and initial moisture level did produce significant variation s in germination and vigour index (Rahman *et al.,* 1994). Pods stored in polyethylene-lined bags containing anhydrous calcium chloride ($CaCl_2$) or silica gel gave seed viability above 50% after 12 months of storage. Seeds stored in airtight containers without any chemicals (closed tins or plastic silos) maintained above 50% viability in storage for up to 10 months, while those stored in gunny bags or earthen pots failed to germinate after this period. Retention of high seed viability in storage with $CaCl_2$ or silica gel could be attributed to low moisture percentage of seeds during storage. The seeds stored in polyethylene-lined gunny bag containing $CaCl_2$ had the highest field emergence and produced the highest pod yield (Tripathy *et al.,* 1996). Suchanya and Kritsanapong (1986) studied the storage of groundnut seeds with different initial moisture contents and in different storage containers under ambient condition. They reported that groundnut seeds stored in moisture vapour proof containers could maintain good viability providing that the seeds are fully matured and are low in initial moisture content. Suchanya *et al.* (1988) suggested that groundnut seed could be stored in well-ventilated manner for 6 month with high percentage of seed germination and seed vigour. Higher germination of seed can be maintained by reducing the moisture content of the seed to 4-5% by sun drying up to 10 - 11 days and subsequently stored in moisture proof materials such as plastic bags or kerosene cans.

Relative humidity between 50% offered the best conditions for storing peanut for period of 9 months (Tango *et al.,* 1977). Vichai *et al.* (1988) reported that the moisture and air-proof packaging enables peanuts to be kept for a year. Zade *et al.* (1987) said that harvesting of winter (*rabi*) summer groundnut at low initial pod moisture, followed by slow drying under shade retained the seed viability up to 80% in Virginia type of cultivars and up to 70% in a Spanish cultivars at 180 days of storage. Moisture content and temperature, perhaps, play the most dominant role in maintaining good seed viability during storage (Harrington and Minges, 1961). Savytilho *et al.* (1983) reported a 35% RH together with 15^0C temperature resulted in minimum loss in viability and ensured satisfactorily the storability up to 36 months.

High moisture content or storage humidity adversely affects seed vigour or storage duration. The most effective and economic method of storing seed for maintaining their viability is to store the seed in the moisture resistant container after drying to a safe moisture level. Storing groundnut seeds from *rabi* season to next *rabi* season in polythene bag have been reported by some workers (Bhuiyan and Quashem, 1983).

CHAPTER III

MATERIALS AND METHODS

The study involved 6 experiments, 3 were field experiments and 3 were laboratory. experiments. The 3 field experiments 3.3.1,3.3.2 and 3.3.3 were conducted to evaluate the effect of fertilizer elements sulphur, calcium, magnesium and *Bradyrhizobium* on the growth and yield of groundnut. And the 3 laboratory experiments 3.3.4,3.3.5 and 3.3.6 were carried out to evaluate the effect of sulphur, calcium, magnesium and *Bradyrhizobium* fertilization, initial moisture content of the seed and storage containers on the germination percentage and vigour index of the seed.

3.1 Experimental Sites

The field experiments were carried out in the *rabi* seasons of 1997-98 and 1998-99 in the Field laboratory of Oil Seed Division, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur. The laboratory experiments, germination and vigour tests were also conducted in the laboratory of above said division of the same institute. The physical and chemical properties of soil of the experimental units were determined utilizing the laboratory facilities of BARI. Soil samples were collected from different depths of the field to determine texture, pH, organic matter, and total nitrogen, available sulphur, calcium and magnesium and other relevant soil properties. The experimental field was a piece of well-drained high land with moderately even topography. This land was hardly inundated unless there was any devastating flood. The area under the experimental plot belongs to Madhupur Agro-ecological Region (AEZ. 28). The soil type was clay loam in texture; having low organic matter, moderately slow permeability and deficient in nitrogen, phosphorous, potassium and sulphur in comparison with the standard nutrition status. The soil was acidic in nature with pH range from 5.9 to 6.1. Experiments were conducted in this land after amendment of soil with cow dung and NPK fertilizers.

3.2 Meteorological information

The area was located at the latitude of 23.5°N and longitude of 90.2°E at an altitude of about 9 m above the sea level. The climatic condition of Joydebpur was unimodal rainfall pattern; most of the rainfall occurs during the months of May to September. The average rainfall was usually higher than 200 mm during May to September and lower than 100 mm during November to March. The hot months are April, May and June with mean maximum temperature of 31.34°C and the cold months are November, December and January when the temperature ranges from 10°C to 19°C. A decreasing trend in temperature was noticed after the cessation of monsoon in October when it sharply declines. The day length was 10-12 hours in the *rabi* season and 12-14 hours in *kharif* season, while sunshine was 5 to 8 hours in *kharif* season. Humidity range from 40% to 85% in *rabi* season and 70% to 100% in *kharif* season. Meteorological information in respect of monthly maximum and minimum temperature, total rainfall and relative humidity during the experimental period was collected from meteorology station at Joydebpur and presented in the Appendices in graph from A.1.1 to A.1.2

3.3 Experiment

In order to fulfill the objectives of the study the experiments 3.3.1; 3.3.2; 3.3.3; 3.3.4; 3.3.5 and 3.3.6 were carried out.

3.3.1. Effect of sulphur and *Bradyrhizobium* fertilization on the growth and yield of groundnut

3.3.1.1 Objectives:

i) To find out the effect doses of sulphur under different *Bradyrhizobium* fertilization treatment on the growth and yield of groundnut.

ii) To see the effect of sulphur and *Bradyrhizobium* fertilization on seed quality.

3.3.1.2 Treatment

Sulphur dose was 5 and *Bradyrhizobium* fertilization dose was 2. The experiment was set combining the treatment following the principles of Randomized complete block design. There were 10 combinations and the combinations were :

i. 0 kg S/ha +0 g I /kg of seed
ii. 20 kg S/ha +0 g I /kg of seed
iii. 40 kg S/ha +0 g I /kg of seed
iv. 60 kg S /ha +0 g I /kg of seed
v. 80 kg S /ha +0 g I /kg of seed
vi. 0 kg S /ha+50 g I /kg of seed
vii. 20 kg S/ha +50 g I /kg of seed
viii. 40 kg S/ha+50 g I /kg of seed
ix. 60 kg S /ha+50 g I /kg of seed
x. 80 kg S /ha+50 g I /kg of seed

The data was collected from each plot and analyzed through a statistical computer programme M-StatC. When the F value was significant, Least Significance Differences was used as a scale to distinguish between different treatments.

Replication – 3 Plot size- 4m × 2.5m

3.3.2. Effect of calcium and *Bradyrhizobium* fertilization on the growth and yield of groundnut

3.3.2.1 Objectives:

i) To find out the effect of doses of calcium under different *Bradyrhizobium* fertilization on the growth and yield of groundnut.

ii) To see the effect of calcium and *Bradyrhizobium* fertilization on seed quality.

3.3.2.2 Treatment

Calcium dose was 5 and *Bradyrhizobium* fertilization dose was 2. The experiment was set combining the treatment following the principles of Randomized complete block design. There were 10 combinations and the combinations were :

i. 0 kg Ca / ha +0 g I /kg of seed

ii. 50 kg Ca /ha +0 g I /kg of seed

iii. 100 kg Ca /ha +0 g I /kg of seed

iv. 150 kg Ca /ha +0 g I /kg of seed

v. 200 kg Ca /ha +0 g I /kg of seed

vi 0 kg Ca /ha +50 g I /kg of seed

vii 50 kg Ca / ha +50 g I /kg of seed

Viii. 100 kg Ca /ha +50 g I /kg of seed

ix. 150 kg Ca /ha +50 g I /kg of seed

x. 200 kg Ca /ha +50 g I /kg of seed

The method of data collection, analysis, replication and plot size was same as the experiment 3.3.1

3.3.3 Effect of magnesium and *Bradyrhizobium* fertilization on the growth and yield of groundnut

3.3.3.1 Objectives:

i) To find out the effect of doses of magnesium and under different *Bradyrhizobium* fertilization treatment on the yield contributing characters of groundnut.

ii) To see the effect of magnesium and *Bradyrhizobium* fertilization on seed quality.

3.3.3.2 Treatment

Magnesium dose was 5 and *Bradyrhizobium* fertilization dose was 2. The experiment was set by combining the treatment following the principles of Randomized complete block design. There were 10 combinations and the combinations were ;

i. 0 kg/ha mg +0 g I /kg of seed

ii. 5 kg mg / ha +0 g I /kg of seed

iii. 10 mg kg/ha +0 g I /kg of seed

iv. 15 kg mg /ha +0 g I /kg of seed

v. 20 kg mg /ha +0 g I /kg of seed

vi. 0 kg/ha mg +50 g I /kg of seed

vii. 5 kg mg / ha +50 g I /kg of seed

viii. 10 mg kg/ha +50 g I /kg of seed

ix. 15 kg mg /ha +50 g I /kg of seed

x. 20 kg mg /ha +50 g I /kg of seed

The method of data collection, analysis, replication and plot size was same as the experiment 3.3.1

3.3.4 Effect of sulphur , *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage and vigour index of stored seed.

3.3.4 .1 Objectives:

i. To determine safe seed initial moisture content for long-term seed preservation.

ii To identify cheap and handy storage containers suitable for long-term seed preservation at farm level.

iii. To evaluate the effect of sulphur and *Bradyrhizobium* fertilization on the longevity of seed.

3.3.4.2 Treatment

A.Sulphur : 5 dose of sulphur viz.

i. 0 kgS/ha ii. 20 kg S/ha iii. 40 kg S/ha iv. 60 kg S /ha v. 80 kg S /ha

B. *Bradyrhizobium* fertilization: 2 dose of inoculant viz.

i. 0 g I /kg of seed ii.50 g I /kg of seed

C. Initial moisture content of seed: 3 treatments were selected. The treatment was

i.7.25% initial moisture content of seed

ii. 8.46% initial moisture content of seed

iii .9.25% initial moisture content of seed

D. Storage container: 2 treatments were choosing as storage containers.

i. Biscuit tin with airtight lid.

ii. Polypropylene bag with 0.25mm thickness.

Sulphur dose was 5, *Bradyrhizobium* fertilization dose was 2, initial moisture content of seed level was 3 and storage container was 2. The experiment was set combining the treatment following the principles of Complete Randomized Design. There were 60 combinations and the combinations were :

The germination percentage and vigour index data was collected from each test and analyzed through a statistical computer programme M-StatC. When the F value was significant, Least Significance Differences was used as a scale to distinguish between different treatments. During analysis arc-sine transformation was made in case of germination percentage.

3.3.4.3 Germination test

The germination test was performed at an interval of one-month starting from August to December. A total no. 400 seeds was set for germination in 16 petridish each containing 25 seeds. Filter paper of 9cm. diameter was used as media of germination. The petridish was kept at normal room temperature. Germinated seedlings was counted when the seedling attained a height of 1 to 2 cm. Three counting was made at 3, 5 and 7 days after placing seeds for germination. % Germination was calculated by the following formula

$$\% \text{ Germination} = \frac{\text{No. of normal seedling}}{\text{Total no. of seed set for germination}} \times 100$$

3.3.4.4 Vigor test:

Vigour index was measured by using the following formula according to Maguire (1962)

Vigour = (number of normal seedling at first count ÷ days to first count) + ----------+(no. of normal seedling at final count ÷ days to final count)

3.3.5 Effect of calcium , *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage and vigour index of stored seed.

3.3.5.1 Objectives:

i. To determine safe seed initial moisture content for long-term seed preservation.

ii To identify cheap and handy storage containers suitable for long-term seed preservation at farm level.

iii. To evaluate the effect of calcium and *Bradyrhizobium* fertilization on the longevity of seed.

3.3.5.2 Treatment

Bradyrhizobium fertilization, Storage container, initial moisture content were similar to experiment 3.3.4 only the fertilizer element was calcium and the doses were i. 0 kg Ca/ha ii. 50 kg Ca /ha iii. 100 kg Ca/ha iv. 150 kg Ca /ha v. 200 kg Ca /ha

3.3.6 Effect of magnesium , *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage and vigour index of stored seed.

3.3.6.1 Objectives:

i. To determine safe seed initial moisture content for long-term seed preservation.

ii.To identify cheap and handy storage containers suitable for long-term seed preservation at farm level.

ii. To evaluate the effect of magnesium and *Bradyrhizobium* fertilization on the longevity of seed.

3.3.6.2 Treatment

Bradyrhizobium fertilization, storage container, initial moisture content were similar to experiment 3.3.4 only the fertilizer element was magnesium and the doses were i. 0 kg Mg/ha ii. 5 kg Mg /ha iii. 40 kg Mg/ha iv. 60 kg Mg /ha v. 80 kg Mg /ha

3.3.7 Experimental Material

3.3.7.1 Characteristics of the variety

The study was conducted with the groundnut cultivar 'Jhingabadam' known as ACC-12. It was an erect and early bunch type spreading variety released by the Oilseeds Research Centre of BARI. The life cycle of the crop was about 4 to 5 months and grown in char lands both in *rabi* and *kharif* seasons of Bangladesh. The pod usually contains three seeds and sometimes even more (SCA and BARC, 1992). The yield of the variety ranges from 1700 to 2250 kg/ha.

3.3.7.2 Fertilizer elements

Elemental sulphur contains 80% sulphur

Calcium oxide (CaO) contains 70% Calcium

and Magnesium chloride ($MgCl_2$)contains 25% magnesium

3.3.7.3 *Bradyrhizobium* inoculant

BAU-700 was used in the study. The Department of Soil Science of Bangladesh Agricultural University (BAU), Mymensingh, developed the inoculant.

3.3.7.4 A. Storage container: Only two storage container was chosen, as it has been established by many workers that polythene bags can retained the viability of seed for a reasonable period and traditionally most of the farmers keep their groundnut seed in commonly available biscuit tin. The storage containers were i) Biscuit tin with airtight lid ii) Propylene bag- with 0.25mm thickness.

3.3.7.5 Initial moisture level of the seed: Three initial moisture levels of the seed 7.25%, 8.46% and 9.25% were maintained by drying the seed in the sun and it was determined by oven dry basis. Four to five grams of groundnut kernels were placed in aluminum dish and dried in oven at $105^{\circ C}$ until constant weight was reached. Then the sample was cooled in desiccators and weighed.

3.3.8 Methods

3.3.8.1 Land preparation

The land was opened with tractor disc plough in the month of October for experiment3.3.1, 3.3.2 and 3.3.3. Subsequently, ploughing and cross ploughing was done with the help of tractor and laddering and leveling were done with the help of country plough. The field was left as such for a few days for conditioning. The land was again ploughed and laddered and the remaining stubble and weeds were cleaned.

3.3.8.2 Application of inoculant and fertilizers

In experiment 3.3.1,3.3.2 and 3.3.3 BAU-700 inoculant was used at the rate of 50 g /kg of seed just before sowing. The seed was mixed with the inoculum pouring little water in the inoculum. The inoculated seeds were placed in furrows and covered with the soil just after sowing. The fertilizers NPK at the rate of 20-60-50 kg/ha in the form of urea, triple super phosphate and muriate of potash was supplied in all the field experiments and spread uniformly all over the field as basal dressing and thoroughly incorporated with the soil through ploughing and laddering. The remaining 20kg N/ha was applied at 30 days after seed sowing. Sulphur, calcium and magnesium were applied in the form of elemental sulphur, calcium oxide and magnesium chloride, respectively.

3.3.8.3 Sowing of seeds

The seed was dibbled singly 15 cm. apart in furrows at a depth of 4 cm. in all the plots maintaining a distance of 30 cm. in between the rows. The seed was covered with fine soil to ensure uniform germination. Seeds were germinated within 10 days and gap filling was done using plants from the guard line to maintain desired plant population.

3.3.8.4 Inter-cultural operations

During growing period of the crop the field was kept weed free. Demarcation boundaries and drainage channel was also kept weed free. Facilities for drainage of rainwater were kept adequate. Earthing up was done at the start of pegging. When pegging was almost over, the crop was left undisturbed to facilitate the underground development of pods. Two irrigation was given to the experiments at an interval depending on soil moisture.

3.3.8.5 Control of insect and diseases

The incidence of pests in groundnut is generally less. To avoid the attack of Tikka disease, Dithane M-45 was sprayed three times at weekly intervals starting from 30 days after sowing. Calyxin was sprayed twice at an interval of 15 days starting from 40 days after sowing to control rust of groundnut.

3.3.9 Observations for field experiments 3.3.1, 3.3. 2 and 3.3.3

3.3.9.1 Plant height

Height of five plants was measured with meter scale of each plot from ground level to top of main shoot and mean height was expressed in cm.

3.3.9.2 Number of branches / plant

Number of branches of five plants was recorded from each plot and mean number was expressed as per unit basis.

3.3.9.3 Mature pods / plant

Mature pods of five plants of each unit plot were noted and mean was expressed as per plant basis.

3.3.9.4 Immature pods / plant

Immature pods of five plants of each unit plot was counted and mean was determined as per plant basis.

3.3.9.5 100 seed weight

Weight of 100 seed was taken at 12% moisture content from each plot and mean weight was expressed in gram (g).

3.3.9.6 Pod yield /ha

Crops were harvested from a10 square meter of each unit plot. The pods was separated from plants, was cleaned, dried and weighted separately. The pod weight was recorded in kg/ha and adjusted at 12 % moisture content.

3.3.9.7 % Shelling

Randomly selected 50 pods of each plot were shelled to obtain seeds. Seed and shell weights were recorded separately and shelling percentage was calculated as per following formula:

$$\% \text{ Shelling} = \frac{\text{Seed weight}}{\text{Pod weight}} \times 100$$

3.3.9.8 Harvest index

Harvest index was calculated as per following formula

$$\text{Harvest index} = \frac{\text{Pod yield}}{\text{Total yield}} \times 100$$

3.3.9.9 % protein content in seed

In order to determine crude protein in seeds a representative oven dried powdered seed sample was taken from each treatment to determine total nitrogen in seeds following Kjeldahl's digestion and distillation procedure (AOAC, 1960). Then the percentage of protein in seeds was calculated by multiplying the nitrogen percentage with 6.25.

3.3.9.10 % oil content in seed

To determine the oil content in the seeds 3 g of well-dried representative seed sample from each unit plot was used. The oil content of the sample was then determined following solvent extraction method by using petroleum ether by Soxhlet apparatus (AOAC, 1960)

3.3.10 Observations for laboratory experiments 3.3.4, 3.3.5 and 3.3.6

3.3.10.1 Storage container

2 containers were used, biscuit tin and polythene bag of 0.25 mμ. thickness. Tin containers were made of M.S. sheet and were painted to prevent rusting. It was provided with an ordinary circular lid.

3.3.10.2 Initial moisture content of the seed

There were 3 level of initial moisture content, 7.25%, 8.46% and9.25% of initial moisture in seed. The moisture content of the seed was determined by low constant temperature oven method (AOSA, 1978). Four to five grams of groundnut kernels were placed in aluminum dish and dried in oven at 105°C until constant weight was reached. Then the sample was cooled in dessicator and weighed. The percentage of moisture content was estimated by the following formula:

$$\%\ \text{Moisture} = \frac{(M1 - M_2)}{M_1 - M} \times 100$$

Where M_1 = Mass in gram of the dish with the material before drying

M_2 = Mass in gram of the dish with the material after drying

M = Mass in gram of dish

3.3.10.3 Storing of seeds

Seeds produced from 30 plots of each experiment were collected separately in different bags. Seeds from each plot were apportioned into 3 parts and sun dried in net bags. When they attained the required percentage of moisture then it was apportioned into two parts, one part was kept in biscuit tins and other part was kept in polyethylene bags. In this way the seeds were dried in three levels of moisture and stored in two types of container. The seeds were stored for 5 months. 20 biscuit tins were used to keep the seeds in 5 fractions by apportioning and 20 gunny bags were also used to keep the seeds in 5 fractions by apportioning so that moisture from atmosphere could not interfere when seeds were opened to set in the germination test.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the field experiment 3.3.1and laboratory experiment 3.3.4 have been presented and discussed in chapters 4.1.1, 4.1.2 and 4.1.3; the results of the field experiment 3.3.2 and laboratory experiment 3.3.5 have been present in chapter 4.2.1,4.2.2 and4.2.3 and the results of the field experiment 3.3.3 and laboratory experiment 3.3.6 have been presented in chapter 4.3.1,4.3.2 and 4.3.3. Summary of analysis of variances of different crop characters, percentage of germination and vigour index obtained from three field and laboratory experiments are presented in the appendices from 3.1 to 3.9.

4.1.1 Effect of sulphur and *Bradyrhizobium* fertilization on the growth and yield of groundnut

4.1.1.1 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on plant height

The effect of sulphur on plant height was not significant in 1997-98 and 1998-99 (Table 4.1.1.1). In 1997-98 the highest plant height was produced in the treatment 60 kg S /ha. The shortest plant was produced by the plant having 0 kg S /ha. In 1998-99 the tallest plant was produced in the treatment 40kg S /ha. The lowest height shown by the plant having 60kg S /ha. The result revealed that sulphur had an insignificant increase in plant height to different sulphur doses from 0-60 kg/ha but in the 1st year because of heavy rainfall the increase of plant height was much higher than the 2nd year. The results are in partial agreement with Singh *et al.* (1995) and Hadvani *et al.* (1993).

Bradyrhizobium fertilization was found to increase the plant height from 48.63 cm to 48.72 cm in 1997-98, and in 1998-99, from 46.50 to 47.99 though the difference was not significant. This result might be due to better growth of plant from inculated groundnut. Poi and Kabi (1983) reported similar result.

Plant height was not influenced significantly by sulphur and inoculum application in 1997-98 and 1998-99. In 1997-98, the tallest plant was produced with the treatment of 40 kg S/ha without inoculum and the shortest plant was produced by 0 kg S/ha without inoculum. In 1998-99, the tallest plant was produced in the treatment of 0 kg S/ha with inoculum and the shortest plant was produced by 20 kg S/ha with inoculum (Table-4.11.1, Appendix-3.1). This result might be due to the fact that sulphur had very little effect on plant height but inoculation had a positive effect on plant height and climatic differences made the variation among the years.

4.1.1.2 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on the number of branches/plant

The various levels of sulphur had significant effect on the number of branches/plant in 1997-98 and 1998-99 (Table 4.1.1.1). In 1997-98, the maximum number branches were obtained with the treatment of 60 kg S/ha, which was followed by 40 and 80 kg S/ha. Other treatments of sulphur produced lower number of branches. In 1998-99 the trend was similar but average number of branches was lower for poorer rainfall. The result indicated that application of sulphur doses increased the number of branches. Mirsha (1996) obtained similar result.

The effect of *Bradyrhizobium* fertilization on the number of branches/plant was not distinct. It was higher by 0.30 branches than uninoculated plant in 1997-98 and 0.31 branch in 1998-99. The above results indicated that inoculation could increase the number of branches/plant and was in partial agreement with Deshmukh and Dev (1995).

There was a significant effect of sulphur and *Bradyrhizobium* fertilization on number of branches/per plant in 1997-98 and 1998-99. In 1997-98, the highest number of branches/plant was produced by 20 kg S/ha with inoculation and the lowest number of branch/plant was produced by control. Other treatments produced intermediary results. In 1998-99, the trend was similar. In both the years, the highest number of branches/plant was obtained in inoculated plot with higher level of sulphur and the lowest number of branches was obtained in control. The result indicated that both sulphur and inoculation affected positively the number of branches/plant. The results are in agreement with Deshmukh and Dev (1995).

Table 4.1.1.1. Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on plant height and number of branches/plant

Treatment/Interaction	Plant height (cm)		Number of branches/plant	
	1997-98	1998-99	1997-98	1998-99
S dose (kg/ha)				
S_0	47.67	48.68	4.17	3.98
S_{20}	48.57	46.43	4.45	4.25
S_{40}	48.30	49.17	5.05	4.53
S_{60}	49.93	45.43	5.22	4.75
S_{80}	48.90	46.50	4.90	4.45
LSD (0.05)	NS	NS	0.3817	0.3186
Inoculation (g/kg seed)				
I_0	48.63	46.50	4.61	4.24
I_{50}	48.72	47.99	4.91	4.55
LSD (0.05)	NS	NS	NS	NS
Sulphur × Inoculation				
$S_0 \times I_0$	47.40	49.70	4.17	3.83
$S_{20} \times I_0$	47.93	47.67	4.17	4.13
$S_{40} \times I_0$	48.87	46.13	4.33	4.20
$S_{60} \times I_0$	48.27	46.73	4.57	4.30
$S_{80} \times I_0$	46.73	48.47	4.60	4.33
$S_0 \times I_{50}$	49.87	49.87	5.50	4.73
$S_{20} \times I_{50}$	51.27	43.87	5.87	4.57
$S_{40} \times I_{50}$	48.60	47.00	5.57	4.93
$S_{60} \times I_{50}$	48.87	44.33	5.07	4.27
$S_{80} \times I_{50}$	48.93	48.67	4.73	4.63
LSD (0.05)	NS	NS	0.5397	0.4560

4.1.1.3 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on the number of mature pods/plant.

Sulphur showed a significant effect on the number of mature pods/plant in 1997-98 and 1998-99 (Table 4.1.1.2). In 1997-98, the highest number of mature pods/plant was produced by 60 kg S/ha, and it was followed 40 and 80 kg S/ha. 0 S kg/ha produced the lowest number of mature pods/plant, which was identical to 20 kg S/ha. Similar result was also shown in 1998-99. The results indicated that higher doses of sulphur could affect the number of mature pods/plant but the poorer doses failed to do so. Dimreej *et al.* (1993) reported similar results.

The number of mature pods/plant showed an insignificant increase (0.52/plant) with the inoculated seeds over uninoculated one in 1997-98. In 198-99, the increase in number of mature seeds over uninoculated ones was 0.83/plant. The result indicated that the number of pods/plant was found to increase insignificantly with inoculum. *Rhizobium* as inoculum could not effect properly in this type of soil. (Lee *et al.*, 1990)

Table4.1.1.2 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on number of mature pods/plant and number of immature pods/plant

Treatment/Interaction	Number of mature pods/plant		Number of immature pods/plant	
	1997-98	1998-99	1997-98	1998-99
S dose (kg/ha)				
S_0	11.07	13.40	5.87	4.40
S_{20}	11.23	14.23	6.77	3.37
S_{40}	12.80	15.97	6.30	2.90
S_{60}	13.83	16.25	7.30	3.22
S_{80}	13.03	14.57	7.60	3.97
LSD (0.05)	0.9134	1.203	1.632	0.4306
Inoculation (g/kgseed)				
I_0	12.13	14.47	7.56	3.80
I_{50}	12.65	15.30	5.97	3.34
LSD (0.05)	NS	NS	NS	NS
Sulphur × Inoculation				
$S_0 \times I_0$	10.87	13.00	6.00	4.67
$S_{20} \times I_0$	11.27	13.80	5.73	4.13
$S_{40} \times I_0$	10.93	13.20	8.20	4.07
$S_{60} \times I_0$	11.53	15.27	5.33	2.67
$S_{80} \times I_0$	12.27	15.80	6.27	3.13
$S_0 \times I_{50}$	13.33	16.13	6.33	2.67
$S_{20} \times I_{50}$	13.67	15.73	8.33	3.07
$S_{40} \times I_{50}$	14.00	16.77	6.27	3.37
$S_{60} \times I_{50}$	12.93	14.60	9.00	4.07
$S_{80} \times I_{50}$	13.13	14.53	6.20	3.87
LSD (0.05)	1.292	1.702	2.308	0.6089

The number of mature pods/plant showed a significant effect due to interaction of inoculum and sulphur in 1997-98 and 1998-99. In 1997-98, the uninoculated treatments produced poorer number of pods/plant. The largest number of mature pods/plant

(14.0/plant) was obtained in the treatment of 40 kg S/ha with inoculation, which produced identical number with 20 kg S/ha with inoculation and inoculated plot with no sulphur. Other treatments produced lower number of mature pod/plant. The lowest number was obtained in control, which was identical to 20, 40 and 60 kg S/ha without inoculation. In 1998-99, similar results were also obtained. It is evident from the results that sulphur with or without inoculum exhibited better positive effect on the number of mature pods/plant.

4.1.1.4 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on the number of immature pods/plant

The number of immature pods/plant was observed quite high from produced under different levels of sulphur in 1997-98. This might be due to unfavorable environmental condition. In 1998-99, the number of immature pods/plant was reduced with the increase of sulphur significantly and the lowest number of immature pods/plant was obtained in 40 kg S/ha (Table 4.1.1.2) Hadvani *et al.* (1993), and Desai and Kenjale (1992) also reported similar results.

The number of immature pods/plant did not show any appreciable difference between the inoculated and uninoculated one, though uninoculted plants produced the higher number of immature pods/plant.

The differences in the treatment means of inoculum and different dose of sulphur was not statistically significant. Sulphur with or without inoculum reduced the number of immature pods/plant.

4.1.1.5 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on harvest index

The effect of sulphur on the harvest index was significant in 1997-98 and 1998-99 (Table 4.1.1.3). In 1997-98, there was an increasing trend of harvest index with the increase of sulphur dose from 0-60 kg S/ha and then it declined. In 1998-99, the trend was similar but the highest harvest index was obtained in the treatment 40 kg S/ha and produced at par harvest index with 60 kg S/ha. The result revealed that with the increase in sulphur doses yield of total pod increased in higher rate in comparison to other growth parameters of groundnut crop. Shivraj and Gowda (1993) obtained similar results.

Bradyrhizobium fertilization did not affect the harvest index of the crop significantly in 1997-98 and 1998-99 but there was a general increasing trend of harvest index with inoculation. The results are in partial agreement with Bhuiyan *et al.* (1996).

The interaction of sulphur and *Bradyrhizobium* fertilization was significant in 1997-98 and 1998-99. In both the years, inoculation exhibited better performance with sulphur. In the first year sulphur interacted poorly without inoculation but with inoculation the performance was distinctly better and in the 2nd year the performance of sulphur was better with or without inoculation and higher doses of sulphur produced identical harvest index with or without inoculation. This might be due to the fact that heavy rainfall and other climatic conditions were not in favour for better pod yield in the 1st year.

4.1.1.6 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on the shelling percentage of groundnut

Sulphur affected the shelling percentage of the crop significantly in 1997-98 and 1998-99 (Table- 4.1.1.3). In 1997-98, the highest shelling percentage was obtained in 60 kg S /ha. Other treatments produced significantly lower percentage. The lowest shelling percentage was obtained in control. In 1998-99, the highest shelling percentage was obtained in the treatment 40kg S /ha that produced at par percentage to 60 S kg/ha while other treatments produced significantly lower shelling percentage. It is evident from the result that under favourable climatic conditions lower doses of sulphur did better and significant increase in the shelling percentage of groundnut was found with different doses of sulphur. Bhardwaj and Pathak (1987) and Thirumalaisamy *et al.* (1986) observed similar results.

The effect of *Bradyrhizobium* fertilization on shelling percentage was found significant in 1997-98 trials and in 1998-99; a substantial increase in shelling percentage was observed but not significant. Bhuiyan *et al.* (1996) observed higher shelling percentage in groundnut due to *Bradyrhizobium* application. But, Adu and Misari (1989) however did not find improvement in the shelling percentage of groundnut inoculated with *Rhizobium*.

Table 4.1.1.3 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on % shelling and harvest index of groundnut

Treatment/ Interaction	% Shelling		Harvest index	
	1997-98	1998-99	1997-98	1998-99
S dose (kg/ha)				
S_0	62.34	59.15	33.38	32.20
S_{20}	64.07	60.78	33.41	33.58
S_{40}	65.88	64.01	37.50	35.25
S_{60}	68.62	63.15	38.57	35.16
S_{80}	66.85	61.27	37.95	34.60
LSD (0.05)	1.165	1.032	1.779	1.018
Inoculation (g/kg seed)				
I_0	64.65	61.00	35.57	33.91
I_{50}	66.45	62.34	37.82	34.40
LSD (0.05)	NS	NS	NS	NS
Sulphur × Inoculation				
$S_0 \times I_0$	61.20	58.52	33.64	32.14
$S_{20} \times I_0$	63.49	59.78	33.12	32.26
$S_{40} \times I_0$	63.36	60.01	33.49	33.96
$S_{60} \times I_0$	64.79	61.54	33.32	33.20
$S_{80} \times I_0$	64.44	63.28	34.67	34.73
$S_0 \times I_{50}$	67.31	64.74	40.32	35.77
$S_{20} \times I_{50}$	67.65	62.41	37.79	34.56
$S_{40} \times I_{50}$	69.60	63.90	39.35	35.76
$S_{60} \times I_{50}$	66.61	60.80	36.60	34.17
$S_{80} \times I_{50}$	67.09	61.74	39.31	35.03
LSD (0.05)	1.647	1.460	2.515	1.439

The interaction of sulphur and inoculum on shelling percentage was significant in 1997-98 and 1998-99. In 1997-98, the highest shelling percentage was obtained in 40 kg S/ha with inoculation and other treatments produced significantly lower percentage of shelling. The lowest was obtained in control. In 1998-99, the highest shelling percentage was obtained in control and produced at par shelling percentage with 40 kg S/ha and other produced lower shelling percentage. The results indicated that shelling percentage was found to be slightly higher due to the effect of inoculum with sulphur.. This might be due to the fact that interaction of sulphur and inoculum increased the weight of seed.

4.1.1.7 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on 100 seed weight

Application of sulphur affected the 100 seed weight of groundnut significantly in 1997-98 and 1998-99 (Table 4.1.1.4). Hundred seed weight varied significantly due to the effect of various levels of sulphur. In 1997-98, the heaviest seed was produced in of 60 kg/ha and the lightest seed was produced in the control plot. The second highest weight was obtained in 20 kg S/ha that was followed in succession by 40 and 80 kg S/ha. In 1998-99, the heaviest seeds were produced by the same treatment. The application of 40 and 80 kg S/ha was also produced at par weight of seed with 60 kg S/ha. The lowest weight of 100 seed was obtained in 0 kg S/ha. The results indicate that increasing rate of sulphur increased the size and weight of groundnut seed. Bhardwaj and Pathak (1987) and Mishra (1996) obtained similar results.

This weight of *Bradyrhizobium* fertilization groundnut seed was higher than that of uninoculated one in 1997-98 and 1998-99. In 1997-98, the variation in weight among treatments was not significant but in 1998-99, the effect of inoculum was significant and it produced significantly heavier seed. Increased weight of either 1000 seeds (Lee *et al.*, 1990) or 100 seeds (Joshi *et al.*, 1989) was reported.

The interaction of inoculum and sulphur was significant in 1997-98 and 1998-99. Inoculated seed with sulphur produced heavier seed over uninoculated one. In 1997-98, the heaviest seeds were produced with the treatment of 40 kg S/ha with inoculation and the lightest seed was produced in control. In 1998-99, similar trend was also followed.

The heaviest 100 seed weight was obtained in inoculated plot with 40 kg S/ha and the lowest was obtained in control. The results revealed that inoculation of seed with increasing rate of sulphur increased the weight of groundnut seed.

4.1.1.8 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on pod yield

The effect of sulphur on pod yield was significant in 1997-98 and 1998-99 (Table 4.1.1.4). In 1997-98 the variation due to various levels of sulphur varied from 1.51 to 1.84 t/ha. The highest yield was obtained in 60 kg S/ha and the control produced the lowest yield. The treatment 40 and 80 kg S/ha produced identical yield with the highest one. In 1998-99 the variation due to levels of sulphur ranged from 1.56 to 1.76 t/ha. The highest yield was obtained from 40 kg S/ha that produced identical yield with 60 and 80 kg S/ha. The control produced the lowest yield. The result indicated that for the soil of the experimental areas 40 kg S/ha was enough for higher yield though the yield increased in one year up to 60 kg S/ha and the levels of sulphur adequate for seed yield were also sufficient for near the maximum sulphur content in seed. The variation of yield in the different years might be due to climatic condition. The findings were in conformity with those of Fox *et al.* (1977), Agasimani *et al.* (1992), Das and Misra (1991) and Giri and Saran (1989).

The effect of *Bradyrhizobium* fertilization on pod yield was not significant in 1997-98 and 1998-99.In 1997-98, the yield of pod from the inoculated groundnut with *Bradyrhizobium* and uninoculated were 1.73 and 1.67 t/ha, respectively. The variation in the yield due to inoculated (0.06 t/ha) In 1998-99, the yield variation due to inoculation varied from 1.66 to 1.70 t/ha and the differences in yield due to inoculation was (0.04 t/ha). The result indicated that *Rhizobium* inoculum did not improve the pod yield of groundnut. Results were in full agreement with Adu and Misari (1989).

Table 4.1.1.4 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on 100 seed weight and pod yield

Treatment/Interaction	100 seed weight (g)		Pod yield (t/ha)	
	1997-98	1998-99	1997-98	1998-99
S dose (kg/ha)				
S_0	24.42	24.45	1.51	1.56
S_{20}	25.12	25.08	1.59	1.64
S_{40}	25.50	27.95	1.80	1.76
S_{60}	26.75	28.23	1.84	1.73
S_{80}	25.63	26.97	1.77	1.69
LSD (0.05)	0.7378	0.6149	0.0542	0.0383
Inoculation (g/kg seed)				
I_0	25.06	26.07	1.67	1.66
I_{50}	25.91	27.00	1.73	1.70
LSD (0.05)	1.04	0.87	0.08	0.05
Sulphur ×Inoculation				
$S_0 \times I_0$	24.10	23.86	1.49	1.53
$S_{20} \times I_0$	24.73	25.05	1.54	1.59
$S_{40} \times I_0$	24.50	24.63	1.55	1.63
$S_{60} \times I_0$	25.73	25.53	1.63	1.65
$S_{80} \times I_0$	25.00	27.81	1.77	1.73
$S_0 \times I_{50}$	26.00	28.09	1.83	1.79
$S_{20} \times I_{50}$	25.70	27.58	1.80	1.71
$S_{40} \times I_{50}$	27.80	28.87	1.87	1.75
$S_{60} \times I_{50}$	26.00	26.47	1.75	1.69
$S_{80} \times I_{50}$	25.27	27.48	1.80	1.70
LSD (0.05)	1.04	0.87	0.08	0.05

The interaction of inoculum and sulphur were significant in 1997-98 and 1998-99 and followed a definite trend. The highest yield was produced in inoculum and 40 kg S/ha and the lowest from control in 1997-98. Other treatments of inoculation with or without sulphur produced similar mean yield. In 1998-99, the highest yield was produced in 0 kg S/ha with inoculum and the lowest yield was obtained in control. The result indicated that inoculation played a very important role to boost up production with higher dose of sulphur. Hadvani *et al.* (1993), Desai and Kenjale (1992), Shivraj and Gowdal (1993) also reported similar results.

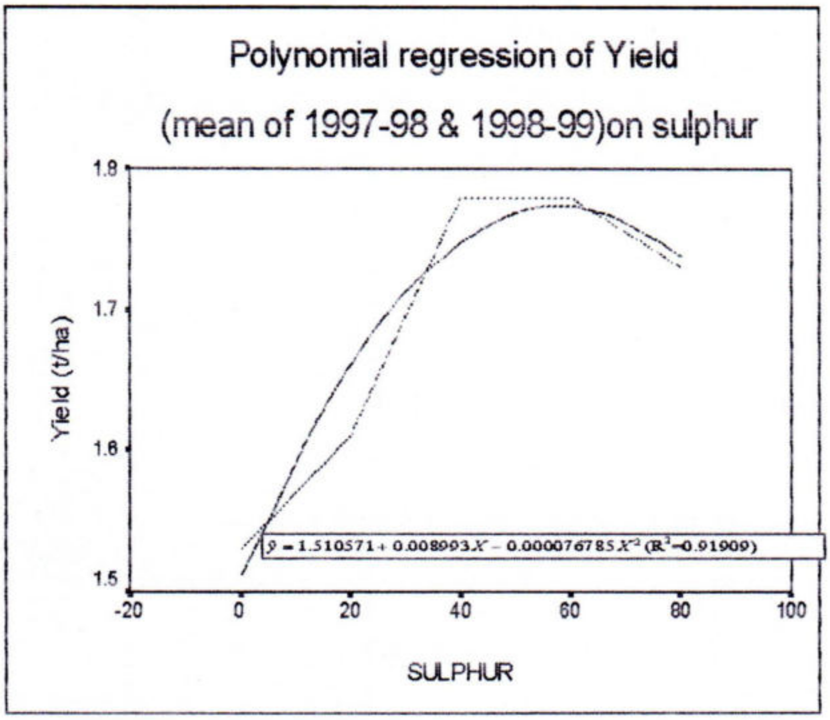


Fig 4.1.1 Polynomial regression of yield (mean of 1997-98 and 1998-99) on yield

4.1.1.9 Effect of sulphur and *Bradyrhizobium* and their interaction on the oil content of the seed

Oil content of the seed was affected significantly in 1997-98 and 1998-99 (Table 4.1.1.5). In 1997-98, the highest percentage of oil was produced in 60 kg S /ha and the lowest percentage was obtained in control. In 1998-99, similar trend was also observed and the highest percentage of oil was obtained in 40 kg S /ha and the lowest percentage was obtained in control. The result indicated that the oil content of groundnut seed increase with the increase of doses of sulphur as it is the component of certain fatty acids. The results were in full agreement with Wali *et.al* (1994); Singh *et al.* (1997).

The application of inoculation failed to affect the oil content of seed significantly in1997-98 and 1998-99(Table 4.1.5) but there was a positive trend in oil content with the application of inoculation. The result was in partial agreement with Jana *et al.* (1994).

Table 4.1.1.5 Effect of sulphur and *Bradyrhizobium* fertilization and their interaction on %oil and % protein content of groundnut

Treatment/Interaction	% Oil		% Protein	
	1997-98	1998-99	1997-98	1998-99
S dose (kg/ha)				
S_0	48.88	50.09	21.52	22.55
S_{20}	50.02	51.07	22.37	23.31
S_{40}	50.27	51.84	24.04	26.31
S_{60}	51.09	51.52	24.58	25.78
S_{80}	50.23	50.67	23.63	25.19
LSD (0.05)	0.8128	0.6077	1.779	1.097
Inoculation (g/kg seed)				
I_0	49.74	50.79	22.69	24.05
I_{50}	50.46	51.29	23.76	25.21
LSD (0.05)	1.212	0.8594	0.7438	1.097
Sulphur × Inoculation				
$S_0 \times I_0$	48.49	49.86	21.12	22.14
$S_{20} \times I_0$	49.28	50.32	21.92	22.95
$S_{40} \times I_0$	49.55	51.15	21.89	22.83
$S_{60} \times I_0$	50.49	50.98	22.85	23.79
$S_{80} \times I_0$	49.58	51.42	23.32	25.77
$S_0 \times I_{50}$	50.96	51.27	24.76	26.84
$S_{20} \times I_{50}$	51.00	51.30	23.79	25.09
$S_{40} \times I_{50}$	51.18	51.74	25.36	26.48
$S_{60} \times I_{50}$	50.07	50.19	23.35	24.43
$S_{80} \times I_{50}$	50.39	51.15	23.91	25.96
LSD (0.05)	1.212	0.8594	0.7438	1.097

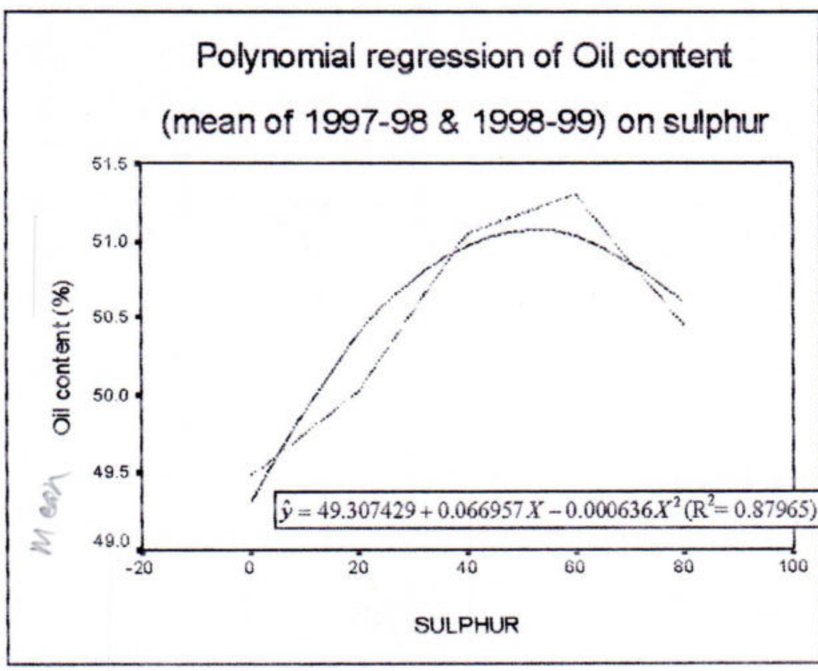


Fig 4.1.2 Polynomial regression of oil content (mean of 1997-98 and 1998-99) on sulphur

Interaction of sulphur and inoculation was significant in 1997-98 and 1998-99(Table 4.1.1.5). In the first year, the highest percentage of oil was produced in the treatment of 40kg S/ha with inoculation and the lowest in control. Inoculated plots with higher doses of sulphur produced higher percentage of oil. In 1998-99 the highest percentage of oil was produced in the inoculated plot with zero sulphur, which was at par with 40 kg S/ha with inoculation. The results revealed that sulphur as well as *Bradyrhizobium* fertilization equally affected the oil content of groundnut seed.

4.1.1.10 Effect of sulphur and *Bradyrhizobium* and their interaction on the protein content of the seed

Sulphur had significant effect on the protein content of groundnut seed in 1997-98 and 1998-99 (Table 4.1.1.5). The protein content increased with the increase of sulphur doses up to 60 kg S/ha and then it declined. In 1997-98, the highest percentage of protein was produced in 60 kg S/ha and was followed by the treatment 40 and 80 kg S/ha. The lowest percentage of protein was produced with 0 kg S/ha which was followed by 20 kg S/ha. In 1998-99, similar trend was also found with sulphur application in groundnut seed excepting that 80 kg S/ha produced lower percentage of protein than that of 20 kg S/ha. It was evident from the result that sulphur increased the protein content of seed by increasing the amino acid content of groundnut. Naphade and Wankhade (1989) reported that seed protein content increased from 22.3 to 29.0%.

Inoculation affected protein content of the seed significantly in 1997-98 and 1998-99(Table 4.1.1.5) and inoculated plot produced significantly higher percentage of protein over uninoculated one. The result revealed that inoculation increased the protein content of groundnut seed by greater synthesis amino acids. The results are in partial agreement with the results obtained by Jana *et al.* (1994).

Interaction of sulphur and inoculation was significant in 1997-98 and 1998-99(Table 4.1.1.5). In 1997-98, the highest percentage of protein was obtained with 40 kg S/ha with inoculation. The lowest percentage was obtained in control. In 1998-99, the highest percentage of protein was obtained with the inoculated plot without sulphur which was identical with that of 40 kg S/ha with inocuation and 80 kg S/ha without inoculation. The lowest percentage of protein was obtained in control. Other treatments produced intermediary results. The result indicated that sulphur and inoculation were equally important to increase the protein content of seed.

4.1.2.1 Effect of sulphur, *Bradyrhizobium* fertilization, storage container and initial moisture content of the seed on the germination percentage of stored seed

Sulphur did not affect the germination percentage of seed at 1-month interval in 1997-98 indicating that deterioration of stored seed had not yet been started (Table 4.1.2.1). At an interval of 2-month, the effect of sulphur on the germination percentage of seed was significant and the highest percentage of germination was obtained in seed with 60 kg S/ha and the lowest in control. At an interval of 3 and 4-month, the effect of sulphur on the germination percentage of stored seed was also significant and the trend was similar to that of 2- month interval. At an interval of 5-month, the effect of sulphur was significant and seed with 40 and 80 kg S/ha retained identical percentage of germination. The highest and the lowest percentage of germination were obtained by 60 and 0 kg S/ha, respectively. In 1998-99, at an interval of 1- month the effect of sulphur on the germination percentage of stored seed was significant. At an interval of 2-month, the seed with 60, 80 and 40 kg S/ha produced at par percentage of germination. At an interval of 3-month, seed with 60 kg S/ha retained significantly higher and seed with 0 kg S/ha lower percentage of germination. The seed with 80, 40 and 20 kg S/ha retained identical percentage of germination. From the above results it was clear that doses of sulphur increased the germination retention capacity of seed up to 60 kg S/ha and higher doses of sulphur than that had no impact on the germination percentage of store seed. Juangiun and Sumran (1991) obtained similar results.

The effect of inoculation of seed with *Bradyrhizobium* at an interval of 1-month of storage was not significant in 1997-98 (Table 4.1.2.1). From the interval of 2-month the inoculated seed retained significantly superior percentage of germination over uninoculated one and this results continued up to 5-month intervals in storage. In 1998-99 the inoculation treatment did not affect the germination percentage of stored seed significantly but there was an increasing trend of germination percentage due to inoculation. The results indicate that germination percentage of stored seed was improved with the application of inoculation.

The container affected the germination percentage of stored seed significantly in 1997-98 and 1998-99 except at an interval of 1-month in 1997-98 (Table 4.1.2.1). In all the intervals seed in polythene bags retained significantly higher percentage of germination over tin container indicating that there was little exchange of moisture in polythene bags than the tin container and the seed was more safe in polythene bags. Similar results were obtained by Paungthong and Lamduan (1990) and Vichai (1988).

The initial moisture content of the seed affected significantly the germination percentage of seed from 1-month interval of storage in 1997-98 (Table 4.1.2.1). The highest percentage of germination was retained by the treatment, 7.25% initial moisture while the lowest percentage of germination was obtained in 9.25% initial moisture content, and 8.25% initial moisture content retained intermediate level of germination. Similar results were also obtained in all the intervals. In 1998-99, the effect of initial moisture content was at par to that of previous years. The results indicated that the initial moisture content of the seed was very important for retaining germination percentage of seed and the groundnut seed could be stored safely at 7.25% initial moisture content of seed. Paungthong and Lamduan (1987) and Bajracharya (1997) obtained similar results.

Table4.1.2.1 Effect of sulphur and *Bradyrhizobium* fertilization, initial moisture content of the seed and storage container on the germination percentage of stored seed.

Treatment	1997-98					1998-99				
	1mon	2 mon	3 mon	4 mon	5 mon	1 mon	2 mon	3 mon	4 mon	5 mon
S level										
S_0	77.57	67.98	64.96	59.85	55.47	77.90	69.99	65.45	60.71	58.03
S_{20}	77.53	69.95	65.90	60.89	56.39	78.26	69.70	66.83	60.99	57.01
S_{40}	77.50	71.13	66.67	61.87	57.29	78.18	71.08	67.58	62.14	58.09
S_{60}	77.91	72.16	68.04	62.84	58.67	78.49	72.32	68.84	62.88	59.28
S_{80}	77.48	69.32	65.90	60.73	57.02	78.27	71.37	67.76	62.12	57.97
LSD (0.05)	NS	0.389	0.345	0.454	0.358	0.417	0.389	0.961	0.736	0.976
Inoculation										
I_0	77.62	69.79	66.11	61.08	56.84	78.19	70.86	67.05	61.58	58.04
I_{50}	77.58	70.43	66.48	61.40	57.09	78.24	70.93	67.53	61.96	58.36
LSD (0.05)	NS	1.347	1.94	1.574	1.238	NS	NS	NS	NS	NS
Storage condition										
Sc_1	77.21	69.32	64.76	58.87	54.00	78.18	68.96	65.39	59.95	55.77
Sc_2	77.99	70.90	67.82	63.60	59.94	78.25	72.83	69.20	63.59	60.62
LSD (0.05)	NS	1.347	1.494	1.574	1.238	NS	3.68	3.328	2.549	3.381
Moisture Level										
Ml_1	78.19	72.92	68.73	65.19	62.12	78.85	73.94	70.72	65.27	63.05
Ml_2	77.64	70.23	66.11	61.75	57.46	78.14	70.54	67.10	61.71	58.89
Ml_3	76.97	67.18	64.04	56.78	51.32	77.66	68.19	64.06	58.33	52.64
LSD (0.05)	0.297	0.824	0.267	0.352	0.277	0.323	0.301	0.744	0.570	0.567

4.1.2.2Interaction of sulphur and inoculation on the germination percentage of stored seed

The interaction of sulphur and inoculation was not significant in 1997-98 and 1998-99.

4.1.2.3Interaction of sulphur and storage container on the germination percentage of stored seed

The interaction of S and storage container was not significant on the percentage of germination in 1997-98 and 1998-99.

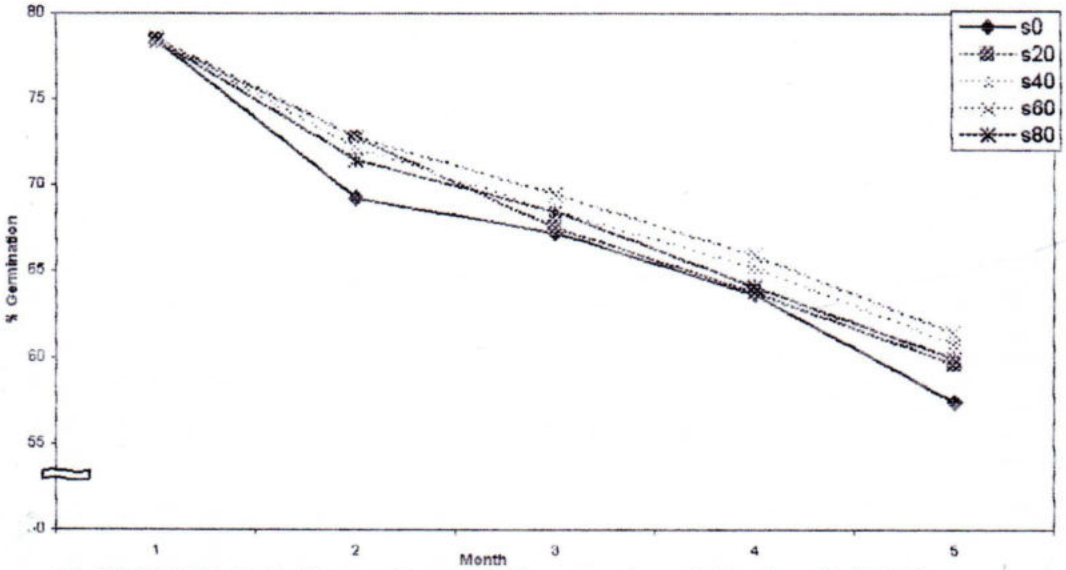


Fig 4.1.2.1.1 Effect of sulphur on the germination percentage of stored seedin 1997-98

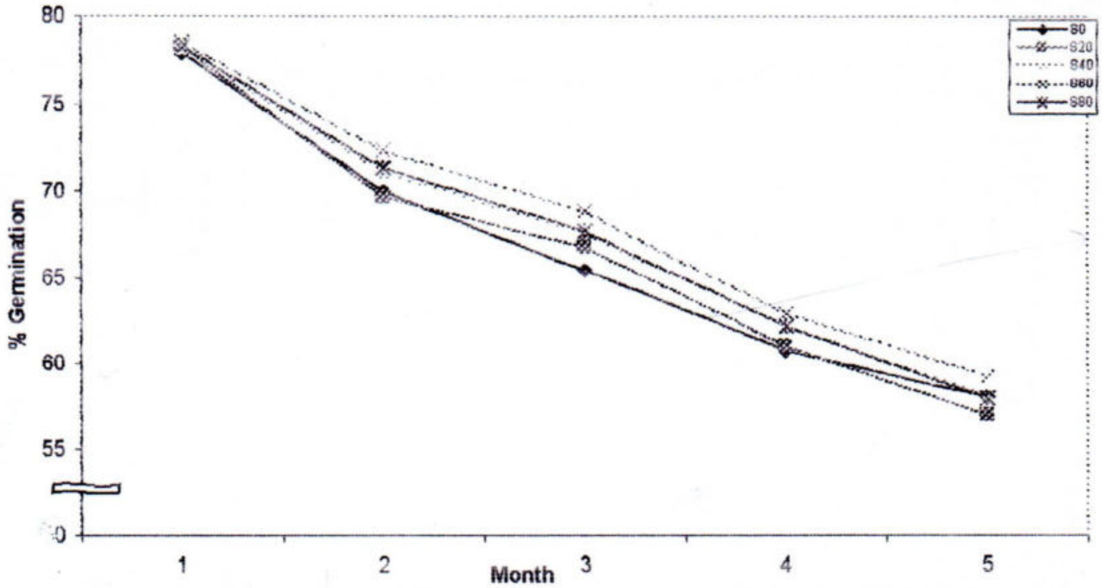


Fig.4.1.2.1.2 Effect of sulphur on the germination percentage of stored seed in 1998-99

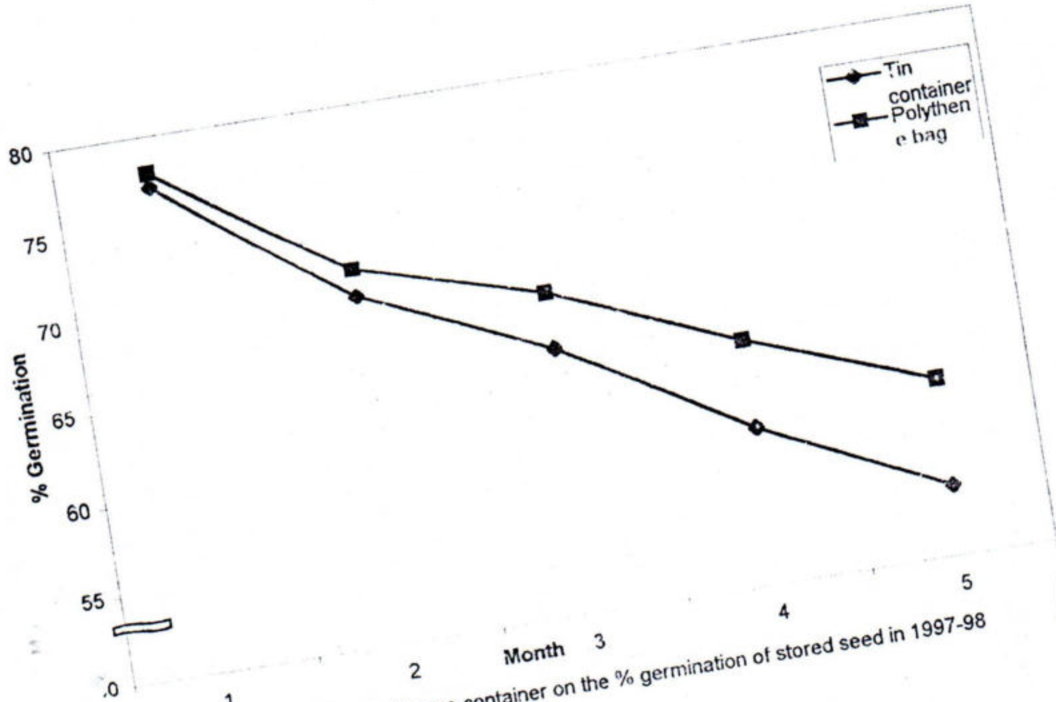


Fig 4.1.2.1.3 Effect of storage container on the % germination of stored seed in 1997-98

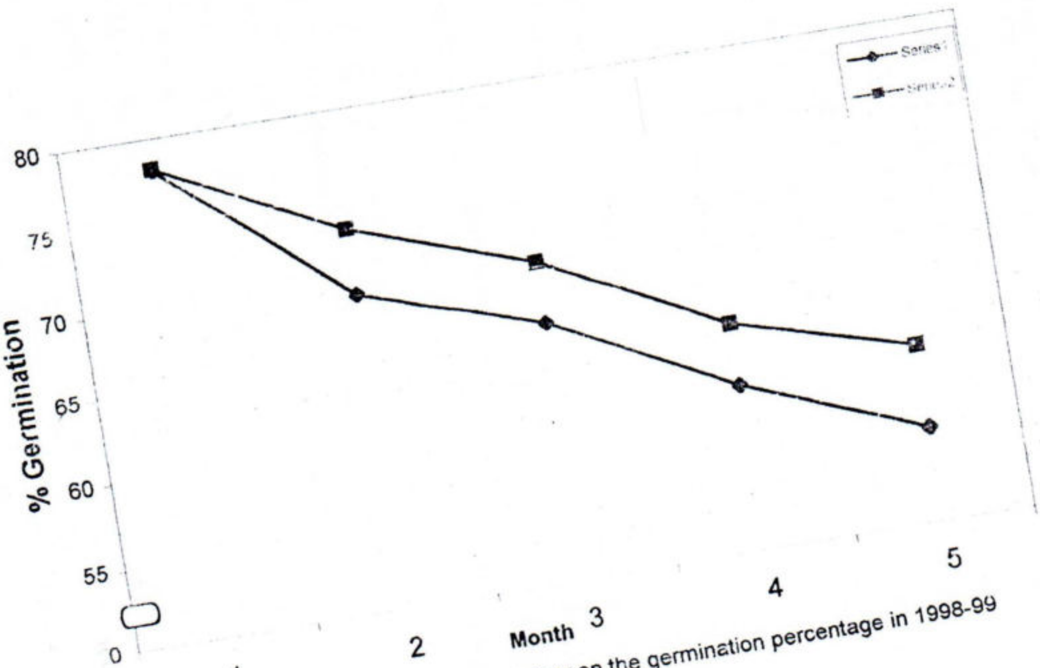


Fig 4.1.2.1.4 Effeect of storage container on the germination percentage in 1998-99

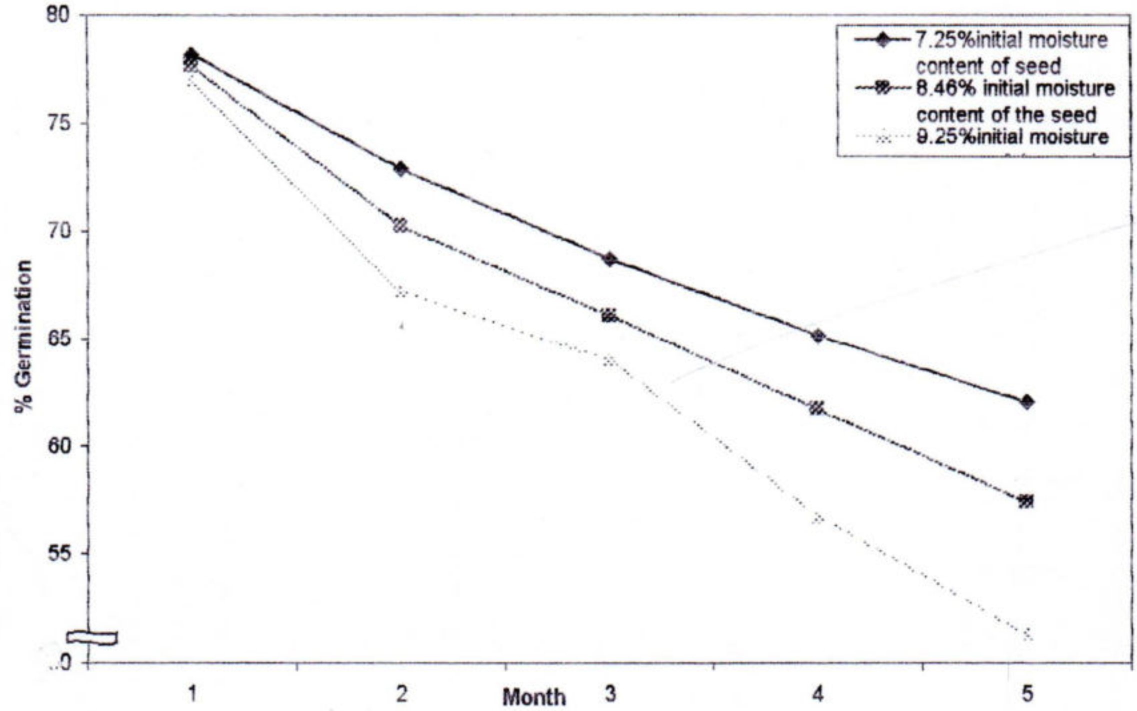


Fig 4.1.2.1.5 Effect of initial moisture content of seed on the germination percentage of stored seed in 1997-98

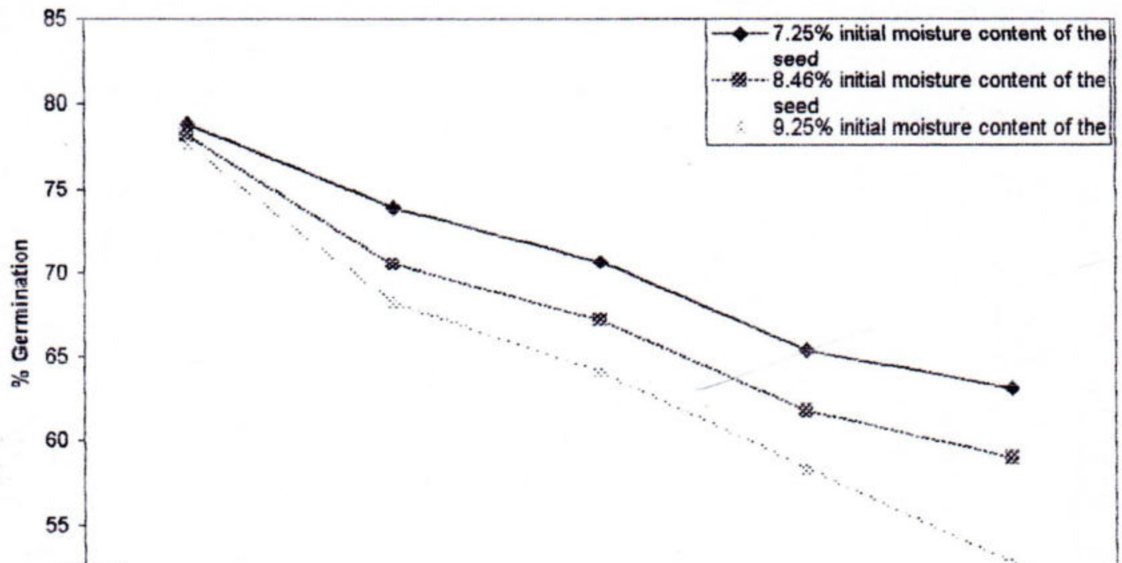


Fig 4.1.2.1.6Effect of initial moisture content of seed on the germination percentage of stored seed in'98-99

4.1.2.4 Interaction of inoculation and storage container on the germination percentage of stored seed

Interaction of inoculation and storage container was not significant in 1997-98 and 1998-99 but seeds with or without inoculation in polythene bag retained high percentage of germination over un-inoculated seed kept in tin container. It is evident from the results that polythene bags can retain the standard germination percentage of seed for longer period of storage. The results are in partial fulfillment with Jayraj and Karivaratharaju (1988).

4.1.2.5 Interaction of sulphur, inoculation and storage container on the germination percentage of stored seed

The interaction of sulphur, inoculation and storage container was not significant in 1997-98 and 1998-99. The germination percentage obtained in the treatment 60 kg S/ha with or without inoculation and kept in polythene bags was higher.

4.1.2.6 Interaction of sulphur and initial moisture content of seed on the germination percentage of seed stored

Seeds with higher dose of sulphur up to 60 kg S/ha and low initial mistune content retained higher percentage of germination in 1997-98 and 1998-99 (Table 4.1.2.2). At an interval of 2-month, seeds with 60 kg S/ha and with initial moisture content of 7.25% retained significantly higher percentage of germination over other treatments. The lowest percentage of germination was retained by 0 kg S/ha with initial moisture content of 9.25%. At an interval of 3-month results obtained were also similar to the previous month. Results of the experiment showed that seeds with higher level of sulphur content and lower initial moisture content played a vital role in maintaining the higher germination percentage of stored seed.

Table 4.1.2.2 Interaction of sulphur and initial moisture content of seed on the germination percentage of seed stored

Interaction	1997-98					1998-99				
S×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times MI_1$	78.09	70.46	67.27	63.85	60.49	78.43	72.54	69.34	64.59	62.31
$S_0 \times MI_2$	77.55	68.04	64.83	60.32	56.09	77.86	69.78	65.33	60.33	58.06
$S_0 \times MI_3$	77.08	65.45	62.78	55.38	49.83	77.40	67.67	61.98	57.21	50.67
$S_{20} \times MI_1$	78.10	72.56	68.51	64.87	61.38	78.82	72.73	69.95	64.46	63.02
$S_{20} \times MI_2$	77.64	70.01	65.59	61.39	56.93	78.09	69.12	66.66	61.11	58.72
$S_{20} \times MI_3$	76.85	67.28	63.60	56.42	50.84	77.87	67.24	63.87	57.41	52.52
$S_{40} \times MI_1$	78.10	74.13	69.38	65.38	62.42	78.69	74.25	71.00	65.57	63.81
$S_{40} \times MI_2$	77.62	71.32	66.30	62.61	57.69	77.99	70.79	67.63	62.21	59.15
$S_{40} \times MI_3$	76.78	67.95	64.33	57.65	51.78	77.86	68.21	64.11	58.63	52.95
$S_{60} \times MI_1$	78.58	75.40	70.89	67.24	64.18	79.38	76.23	72.75	66.19	64.04
$S_{60} \times MI_2$	77.57	72.37	67.70	63.25	58.86	78.46	71.86	68.47	63.00	59.97
$S_{60} \times MI_3$	77.41	68.72	65.52	58.02	52.98	77.64	68.85	65.30	59.45	53.83
$S_{80} \times MI_1$	78.08	72.05	67.63	64.59	62.12	78.95	73.95	70.83	65.52	62.10
$S_{80} \times MI_2$	77.62	69.44	66.11	61.17	57.75	78.33	71.18	67.43	61.90	58.56
$S_{80} \times MI_3$	76.74	66.47	63.97	56.41	51.18	77.52	68.99	65.02	58.93	53.24
LSD (0.05)	NS	0.674	0.597	NS	NS	NS	NS	NS	NS	NS

4.1.2.7 Interaction of inoculation and initial moisture content of the seed on the germination percentage of stored seed

The interaction of inoculation and initial moisture content was not significant at all the intervals in 1997-98 and 1998-99. The results are in partial agreement with Jayaraj and Karivaratharaju (1988).

4.1.2.8 Interaction of sulphur, inoculation and initial moisture content of the seed on the germination percentage of stored seed

The interaction of S, inoculation and initial moisture content of the seed was not significant in 1997-98 and 1998-99.

4.1.2.9 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of storage container and initial moisture content of the seed was significant (Table 4.1.2.3) but in 1997-98, germination percentage in the first two months interval was not significant. From the interval of 3-month, the interaction was significant and the seed with different initial moisture level stored in polythene bags retained higher percentage of germination over seeds at the same initial moisture content and stored in tin container. At an interval of 4-month, the seeds with 7.25% initial moisture content and kept in tin container retained identical percentage of germination with seeds with 8.46% initial moisture content and kept in polythene bags. A similar result was also obtained in 1998-99. At an interval of 5-month in 1998-99, the results were at par to that of 1997-98. The above results indicated that seeds with higher initial moisture content and kept in polythene bags can retained the germination percentage longer than seeds kept in tin containers with low initial moisture content. Prasat and Chaumsri (1987) obtained similar results.

Table 4.1.2.3 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
St.condition ×M. level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	77.74	72.11	66.51	63.17	59.68	78.75	71.08	67.81	62.51	59.90
$Sc_1 \times Ml_2$	77.35	69.54	64.81	60.66	54.54	78.31	68.73	65.50	60.41	57.17
$Sc_1 \times Ml_3$	76.56	66.32	62.97	52.80	47.78	77.48	67.07	62.85	56.92	50.26
$Sc_2 \times Ml_1$	78.64	73.73	70.96	67.21	64.55	78.96	76.80	73.62	68.03	66.21
$Sc_2 \times Ml_2$	77.93	70.93	67.40	62.84	60.39	77.98	72.37	68.71	63.02	60.61
$Sc_2 \times Ml_3$	77.39	68.04	65.11	60.76	54.86	77.84	69.32	65.26	59.73	55.03
LSD (0.05)	NS	NS	0.378	0.498	0.392	0.420	1.165	1.053	0.806	3.381

4.1.2.10 Interaction of sulphur, storage container and initial moisture content of seed on the germination percentage of stored seed

In 1997-98 at an interval of 2-month, the seeds with 60 kg S/ha and initial moisture content (7.25%) and kept in polythene bags retained significantly superior percentage of germination which retained at par germination percentage with 40 kg S/ha and 7.25% initial moisture content and kept in polythene bags (Table 4.1.2.4). In 1998-99, the seeds with initial moisture content of 7.25% and kept in polythene bags with different doses of sulphur in control retained significantly superior percentage of germination and other retained identical percentage of germination. The result indicated that higher level of sulphur with lower initial moisture content of seed in polythene bags could increase the germination percentage of stored seed. Paungthong and Lamduan (1990) found similar results.

Table 4.1.2.4 Interaction of sulphur, storage container and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98						1998-99		
Sulp.×St.con×Moist. level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times Sc_1 \times Ml_1$	77.74	70.45	65.26	61.66	58.03	78.43	67.60	65.38	64.50	58.67
$S_0 \times Sc_1 \times Ml_2$	77.09	66.80	63.65	59.32	53.41	78.43	66.18	65.30	60.44	53.01
$S_0 \times Sc_1 \times Ml_3$	76.65	64.50	61.55	51.43	45.75	78.43	61.21	57.50	57.44	46.89
$S_0 \times Sc_2 \times Ml_1$	78.43	70.46	69.27	66.03	62.94	78.43	73.74	72.39	64.68	65.39
$S_0 \times Sc_2 \times Ml_2$	78.00	69.28	66.01	61.32	58.78	78.43	72.95	71.26	60.22	61.57
$S_0 \times Sc_2 \times Ml_3$	77.51	66.40	64.01	59.34	53.91	78.43	72.20	61.90	56.99	53.44
$S_{20} \times Sc_1 \times Ml_1$	77.51	71.71	66.41	62.82	59.00	78.43	68.71	66.54	63.66	61.78
$S_{20} \times Sc_1 \times Ml_2$	77.09	69.57	64.51	60.42	54.12	78.43	68.51	67.52	60.66	57.94
$S_{20} \times Sc_1 \times Ml_3$	76.42	66.40	62.59	52.81	47.37	78.43	62.16	59.13	57.20	49.39
$S_{20} \times Sc_2 \times Ml_1$	78.69	73.41	70.61	66.92	63.77	78.43	75.19	74.87	65.26	67.20
$S_{20} \times Sc_2 \times Ml_2$	78.20	70.46	66.67	62.36	59.76	78.43	74.14	75.01	61.56	63.56
$S_{20} \times Sc_2 \times Ml_3$	77.28	68.15	64.62	60.02	54.31	78.43	73.45	62.85	57.62	55.44
$S_{40} \times Sc_1 \times Ml_1$	77.51	73.04	67.21	63.29	59.98	78.43	68.74	67.07	65.03	62.63
$S_{40} \times Sc_1 \times Ml_2$	77.51	70.61	65.01	61.43	54.62	78.43	68.09	70.91	61.80	58.57
$S_{40} \times Sc_1 \times Ml_3$	76.44	66.92	63.29	53.41	48.33	78.20	62.03	60.81	59.20	50.37
$S_{40} \times Sc_2 \times Ml_1$	78.69	75.22	71.54	67.46	64.87	78.43	77.11	76.08	66.12	66.80
$S_{40} \times Sc_2 \times Ml_2$	77.74	72.02	67.60	63.78	60.75	78.43	75.84	76.39	62.62	62.36
$S_{40} \times Sc_2 \times Ml_3$	77.11	68.99	65.37	61.90	55.22	78.20	75.94	64.76	58.07	56.39
$S_{60} \times Sc_1 \times Ml_1$	78.20	73.94	68.42	64.75	61.44	78.43	70.64	68.01	66.19	62.02
$S_{60} \times Sc_1 \times Ml_2$	77.53	71.88	66.40	62.01	55.95	78.43	69.41	70.85	63.02	59.45
$S_{60} \times Sc_1 \times Ml_3$	76.86	67.87	64.50	53.81	49.39	78.43	64.51	61.99	59.01	51.65
$S_{60} \times Sc_2 \times Ml_1$	78.95	76.86	73.37	69.74	66.93	78.47	72.40	77.07	66.20	66.70
$S_{60} \times Sc_2 \times Ml_2$	77.97	72.86	68.99	64.51	61.77	78.69	76.25	75.60	62.99	62.96
$S_{60} \times Sc_2 \times Ml_3$	77.97	69.58	66.53	62.24	56.56	78.43	75.47	65.38	59.89	58.28
$S_{80} \times Sc_1 \times Ml_1$	77.74	71.40	65.25	63.30	59.98	78.43	66.93	66.27	65.38	60.44
$S_{80} \times Sc_1 \times Ml_2$	77.51	68.86	64.50	60.09	54.62	78.43	70.03	65.73	61.60	58.04
$S_{80} \times Sc_1 \times Ml_3$	76.42	65.88	62.94	52.51	48.04	78.43	61.11	60.04	58.58	49.98
$S_{80} \times Sc_2 \times Ml_1$	78.43	72.69	70.00	65.88	64.26	78.43	76.44	77.09	65.66	66.03
$S_{80} \times Sc_2 \times Ml_2$	77.74	70.01	67.73	62.25	60.88	78.43	76.25	74.80	62.21	61.60
$S_{80} \times Sc_2 \times Ml_3$	77.07	67.07	65.00	60.31	54.31	78.43	75.86	63.78	59.28	57.03
LSD	NS	0.953	NS	NS	NS	NS	NS	NS	NS	2.391

4.1.2.11 Interaction of inoculation, storage container and initial moisture level on the germination percentage of stored seed

The interaction of inoculation, storage container and initial moisture content of the seed was not significant in 1997-98 and 1998-99. The results are in agreement with the results of Majhi and Bandopadhya (1993).

4.1.2.12 Interaction of sulphur, inoculation, storage container and initial moisture percentage of seed on the germination percentage of stored seed

At all the intervals the interaction of all the four treatments was not significant in 1997-98 and 1998-99. Bhuiyan and Quashem (1983) reported similar results.

4.1.3.1 Effect of sulphur, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the vigour index of stored seed

Doses of sulphur affected the seed vigour index expressed in terms of speed of germination. Doses of sulphur up to 60 kg S/ha showed increasing speed of germination and then it declines (Table 4.1.3.1). From the early stage of storage, seeds containing 60 kg S/ha showed the highest speed of germination and the lowest speed of germination was obtained with the seed produced in the control and other doses showed identical speed of germination. These results obtained might be due to the potentiality of the seed to germinate with uniform speed with higher content of sulphur. The results were in full agreement with Fox *et al.* (1977).

Seed from inoculated plots showed an increasing speed of germination from the early stage of storage in 1997-98 and 1998-99 (Table 4.1.3.1). The speed of germination was significant in 1998-99 but was not significant in 1997-98.The effect of inoculation was significant from the 3-month interval and it continued up to 4-month. The result revealed that inoculation could also modify the quality of seed.

The effect of storage container on the vigour index of stored seed was significant from 2-month of storage and continued up to 5-month (Table 4.1.3.1). Storage container affected the speed of germination significantly at different intervals of time. The seed stored in polythene bag retained significantly higher speed of germination over seed stored in tin container at all the intervals. The result revealed that polythene bag, as storage container

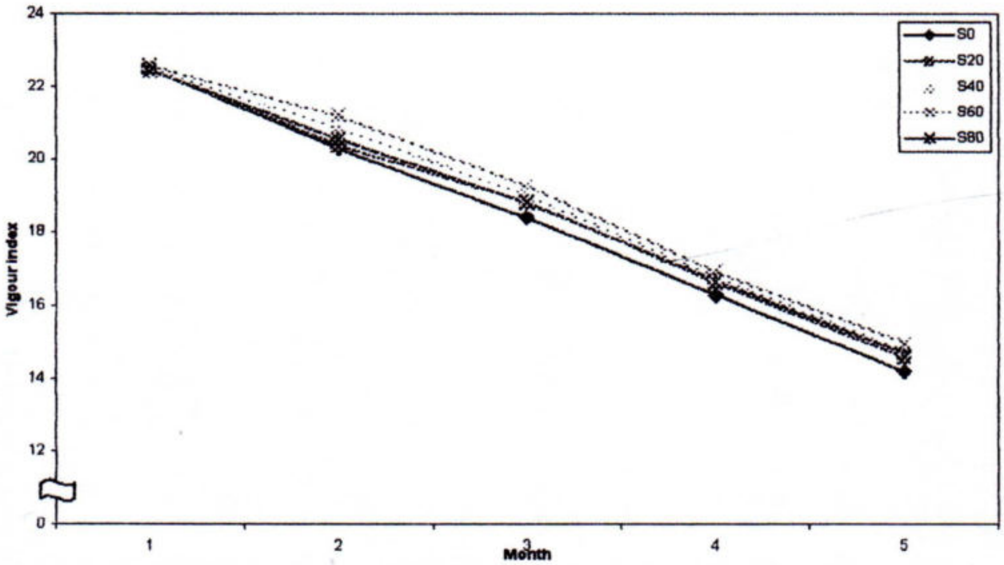


Fig 4.1.3.1.2 Effect of sulphur on the vigour index of stored seed in 1997-98

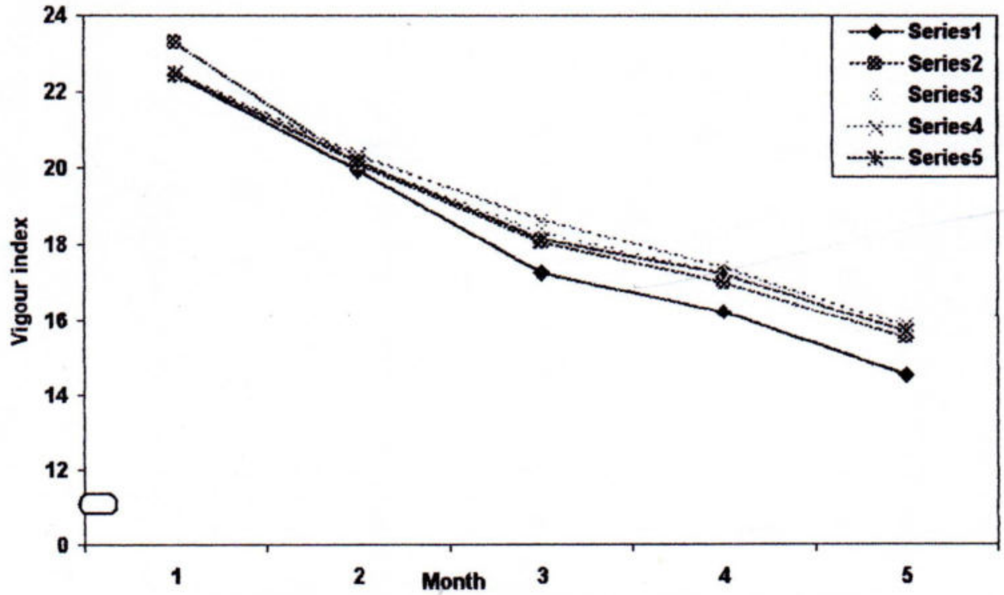


Fig 4.1.3.1.2 Effect of sulphur on the vigour index in 1998-99

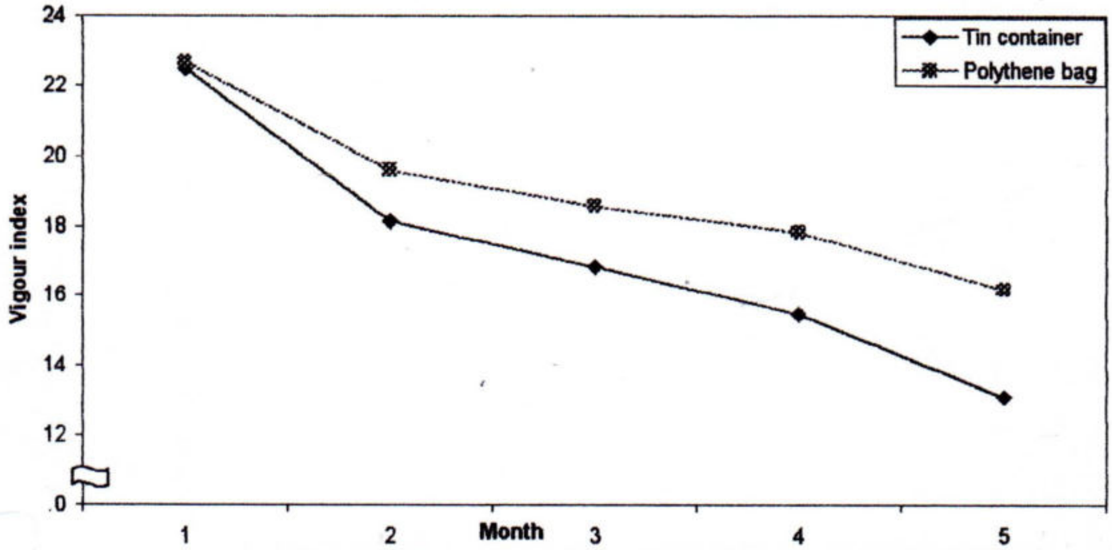


Fig 4.1.3.1.3 Effect of storage container on the vigour index of stored seedin 1997-98

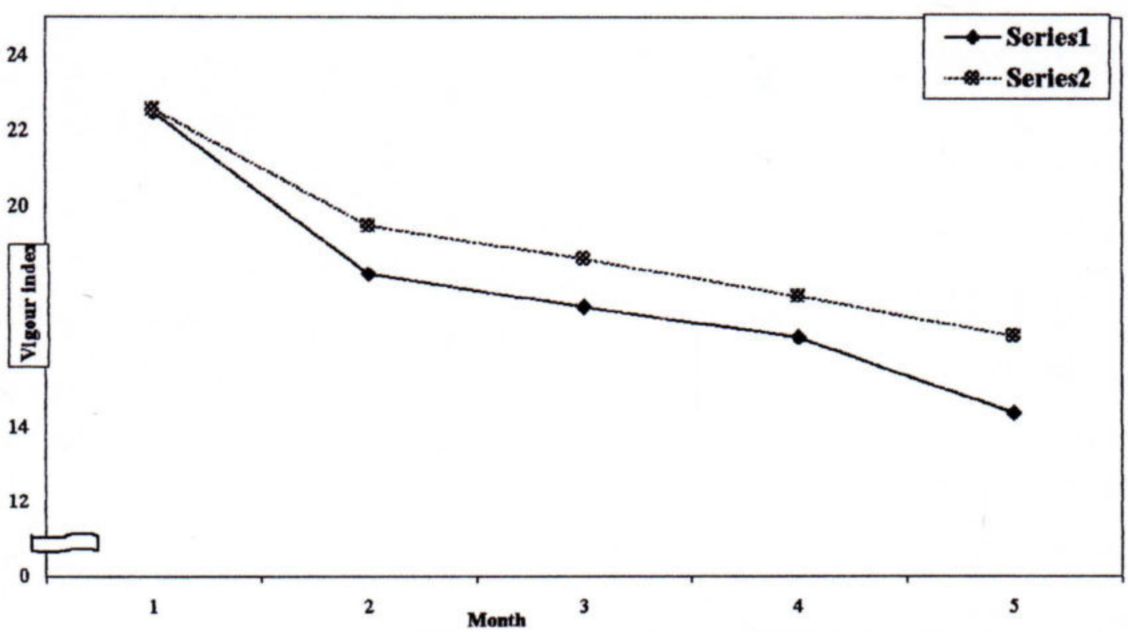
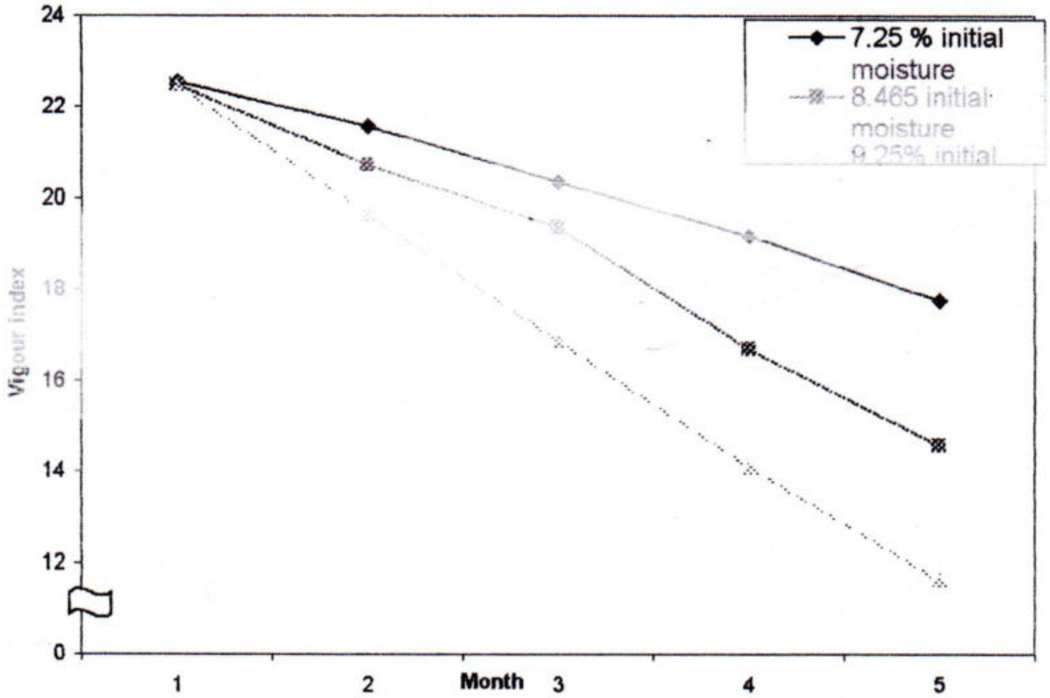


Fig 4.1.3.1.4 Effect of storage container on the vigour index in 1998-99



4.1.3.1.5 Effect of initial moisture content of the seed on the vigour index of stored seedin 1997-98

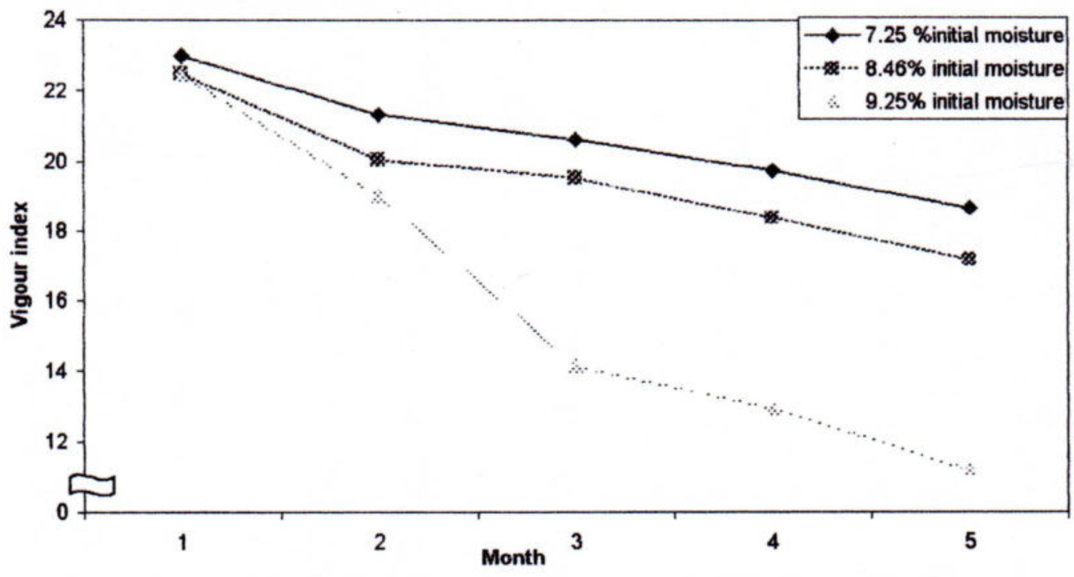


Fig 4.1.3.1.6 Effect of initial moisture content of seed on the VI of stored seed in 1998-99

4.1.3.2 Interaction of sulphur and *Bradyrhizobium* fertilization on the vigour index of the stored seed

The interaction of sulphur and inoculation speeded the speed of germination from the early stage of storage in 1997-98 and 1998-99 but the effect was not significant.

4.1.3.3 Interaction of sulphur and storage container on the vigour index of the stored seed

The interaction of sulphur and storage container on the speed of germination was not significant at the initial stage of storage. Seeds stored in polythene bags with different doses sulphur retained significantly superior speed of germination over seeds stored in tin container at an interval of 2-month in 1997-98 (Table 4.1.3.2). The highest speed of germination was obtained in the treatment of 60 kg S/ha and stored in polythene bags and the lowest speed of germination was obtained with the seed obtained from control and stored in tin container. In 1998-99 at an interval of 3 and 4-month the interaction was significant and showed a distinct positive effect on the speed of germination but it fails to continue up to 5 month. The results indicating that storage container had more potentially to affect the speed of germination whereas the effect of S was not stable enough to affect the speed of germination of the stored seed.

Table 4.1.3.2 Interaction of sulphur and storage container on the vigour index of the stored seed

Interaction	1997-98					1998-99				
SxSt.containe	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times Sc_1$	22.46	19.52	17.41	15.16	12.57	22.42	19.43	16.81	15.87	13.74
$S_0 \times Sc_2$	22.50	21.06	19.44	17.42	15.85	22.46	20.49	17.72	16.63	15.34
$S_{20} \times Sc_1$	22.49	19.49	17.88	15.45	13.03	22.47	19.47	17.27	16.34	14.36
$S_{20} \times Sc_2$	22.50	21.27	19.80	17.81	16.14	24.16	20.79	18.89	17.72	16.72
$S_{40} \times Sc_1$	22.49	20.49	18.11	15.60	13.22	22.49	19.60	17.47	16.66	14.54
$S_{40} \times Sc_2$	22.49	21.24	19.96	17.97	16.29	22.49	20.72	19.17	17.87	16.87
$S_{60} \times Sc_1$	22.48	20.68	18.31	15.74	13.46	22.50	19.78	17.66	16.90	14.77
$S_{60} \times Sc_2$	22.67	21.72	20.26	18.09	16.53	22.50	20.92	19.68	17.95	16.96
$S_{80} \times Sc_1$	22.43	20.18	18.05	15.50	13.20	22.50	19.58	17.47	16.66	14.61
$S_{80} \times Sc_2$	22.50	20.94	19.58	17.89	16.22	22.48	20.77	18.86	17.82	16.82
LSD	NS	0.353	NS	NS	NS	NS	NS	0.198	0.271	NS

4.1.3.4 Interaction of *Bradyrhizobium* fertilization and storage container on the vigour index of the stored seed

The interaction of inoculation and storage container on the speed of germination was not significant in 1997-98 and 1998-99.

4.1.3.5 Interaction of sulphur, *Bradyrhizobium* fertilization and storage container on the vigour index of stored seed

The interaction of sulphur, inoculation and storage container affected the speed of germination of stored seed at an interval of 2-month in 1997-98 though other treatments were not significant (Table 4.1.3.3). The seeds containing higher doses of sulphur up to 60 kg S/ha and were stored in polythene bags with or without inoculation retained higher speed of germination.

Table4.1.3.3 Interaction of sulphur, *Bradyrhizobium* fertilization and storage container on the vigour index of stored seed

Interaction	1997-98					1998-99				
Sulp.xInocul.x St. con.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times I_0 \times Sc_1$	22.43	19.66	17.36	15.16	12.58	22.41	19.47	16.74	15.77	13.70
$S_0 \times I_0 \times Sc_2$	22.51	21.06	19.40	17.39	15.86	22.46	20.47	17.73	16.54	15.29
$S_0 \times I_{50} \times Sc_1$	22.49	19.39	17.46	15.17	12.56	22.42	19.40	16.88	15.97	13.79
$S_0 \times I_{50} \times Sc_2$	22.49	21.06	19.48	17.46	15.84	22.47	20.51	17.71	16.71	15.40
$S_{20} \times I_0 \times Sc_1$	22.48	19.44	17.87	15.42	12.98	22.46	19.48	17.17	16.19	14.31
$S_{20} \times I_0 \times Sc_2$	22.49	21.14	19.83	17.76	16.13	22.49	20.76	18.86	17.71	16.68
$S_{20} \times I_{50} \times Sc_1$	22.50	19.54	17.89	15.48	13.09	22.48	19.47	17.38	16.49	14.41
$S_{20} \times I_{50} \times Sc_2$	22.51	21.39	19.77	17.86	16.14	25.82	20.82	18.92	17.73	16.76
$S_{40} \times I_0 \times Sc_1$	22.50	20.26	17.97	15.57	13.14	22.48	19.58	17.42	16.60	14.48
$S_{40} \times I_0 \times Sc_2$	22.50	21.14	20.02	17.94	16.24	22.48	20.70	18.98	17.83	16.84
$S_{40} \times I_{50} \times Sc_1$	22.48	20.72	18.24	15.63	13.30	22.50	19.62	17.51	16.72	14.60
$S_{40} \times I_{50} \times Sc_2$	22.49	21.34	19.89	17.99	16.33	22.50	20.74	19.37	17.90	16.89
$S_{60} \times I_0 \times Sc_1$	22.48	20.67	18.39	15.70	13.44	22.50	19.72	17.62	16.83	14.71
$S_{60} \times I_0 \times Sc_2$	22.83	21.62	20.14	18.09	16.56	22.50	20.81	19.56	17.90	16.92
$S_{60} \times I_{50} \times Sc_1$	22.49	20.70	18.23	15.78	13.47	22.50	19.84	17.69	16.97	14.82
$S_{60} \times I_{50} \times Sc_2$	22.51	21.81	20.37	18.10	16.50	22.50	21.03	19.81	18.00	17.00
$S_{80} \times I_0 \times Sc_1$	22.44	20.67	18.09	15.58	13.22	22.50	19.56	17.43	16.64	14.58
$S_{80} \times I_0 \times Sc_2$	22.50	20.81	19.38	17.87	16.19	22.48	20.73	18.83	17.79	16.81
$S_{80} \times I_{50} \times Sc_1$	22.42	19.70	18.01	15.42	13.18	22.50	19.61	17.50	16.68	14.64
$S_{80} \times I_{50} \times Sc_2$	22.50	21.08	19.79	17.91	16.24	22.48	20.80	18.88	17.86	16.82
LSD (0.05)	NS	0.499	NS	NS	NS	NS	NS	NS	NS	NS

The seeds with lower and higher doses than the optimum sulphur content and stored in tin container retained poorer speed of germination. From the above results it was concluded that to keep the speed of germination adequate sulphur should be applied to the crop in proper amount and inoculation would also be helpful for retaining the speed of germination and the seed should be stored in polythene bags.

4.1.3.6 Interaction of sulphur, and initial moisture content of seed on the vigour index of stored seed

The interaction of sulphur and initial moisture content of the seed affected greatly the speed of germination of the stored seed at later stage of storage (Table 4.1.3.4). The seed with high doses of sulphur content and stored with lower initial moisture content (7.25%) retained significant superiority over seeds with high initial moisture content (9.25%). In the early stage of storage, seeds with medium moisture content (8.46%) retained closer mean to the highest one.

Table4.1.3.4 Interaction of sulphur, and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
SxM.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times Ml_1$	22.49	21.18	20.10	18.94	17.26	22.45	20.97	19.70	18.64	16.92
$S_0 \times Ml_2$	22.48	20.42	19.17	16.26	14.21	22.44	19.89	18.72	17.43	16.10
$S_0 \times Ml_3$	22.47	19.27	15.99	13.68	11.16	22.42	19.02	13.38	12.67	10.61
$S_{20} \times Ml_1$	22.51	21.39	20.30	19.12	17.69	24.99	21.32	20.70	19.84	18.63
$S_{20} \times Ml_2$	22.50	20.27	19.41	16.73	14.49	22.48	20.02	19.67	18.42	17.01
$S_{20} \times Ml_3$	22.48	19.48	16.81	14.04	11.57	22.46	19.06	13.87	12.82	10.98
$S_{40} \times Ml_1$	22.50	21.92	20.45	19.25	17.88	22.49	21.48	20.88	20.08	18.77
$S_{40} \times Ml_2$	22.49	20.88	19.47	16.88	14.69	22.48	20.13	19.79	18.68	17.17
$S_{40} \times Ml_3$	22.48	19.79	17.17	14.22	11.69	22.49	18.88	14.29	13.02	11.17
$S_{60} \times Ml_1$	22.75	21.92	20.62	19.41	18.18	22.50	21.63	21.07	20.31	18.99
$S_{60} \times Ml_2$	22.51	21.27	19.51	16.99	14.81	22.50	20.28	19.93	18.83	17.32
$S_{60} \times Ml_3$	22.48	20.42	17.73	14.35	11.98	22.50	19.15	15.01	13.13	11.28
$S_{80} \times Ml_1$	22.49	21.56	20.42	19.22	17.90	22.50	21.34	20.91	20.04	18.86
$S_{80} \times Ml_2$	22.44	20.77	19.40	16.69	14.63	22.49	20.08	19.62	18.63	17.18
$S_{80} \times Ml_3$	22.47	19.37	16.63	14.18	11.60	22.48	19.11	13.96	13.06	11.10
LSD (0.05)	NS	NS	0.405	NS	NS	NS	NS	0.243	0.331	0.273

With the progress of time of the seed in store, the seeds with medium initial moisture content (8.46%) lost its superiority and the mean differed significantly from the mean obtained in the treatment of lowest initial moisture content (7.25%). This result revealed that seed with higher content of sulphur could be stored for substantial time maintaining its speed of germination with little higher initial moisture content.

4.1.3.7 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed

The interaction of inoculation and initial moisture content of the seed was not significant in 1997-98 and 1998-99. At the later stage of storage the level of initial moisture content of seed responded differently though the interaction was not significant. The effect of initial moisture content of the seed on the mean value was not distinct in the early stage of storage but with the advance of time of seed in storage, these effects became distinct.

4.1.3.8 Interaction of sulphur, *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed

The interaction of sulphur, inoculation and initial moisture content of seed on the speed of germination was not significant.

4.1.3.9 Interaction of storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of storage container and initial moisture content of the seed showed a significant effect on the speed of germination of stored seed (Table 4.1.3.5). The seeds, which were stored in polythene bags and with lowest initial moisture content of the seed, had the highest speed of germination starting from 2 to 5-month of storage. The lowest speed of germination was obtained with the seed stored in tin container and highest initial moisture content of the seed. The result indicated that seeds with low level of initial moisture content but stored in tin container did better than the seed with high initial moisture content and stored in polythene bags and initial moisture content of seed and storage container was equally important to maintain the speed of germination of seed. The results are in agreement with Duan *et al.* (1997).

Table 4.1.3.5 Interaction of storage container and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
St.contxM.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	22.49	20.93	19.08	17.03	15.45	22.48	20.73	19.99	19.06	17.11
$Sc_1 \times Ml_2$	22.47	20.04	18.34	15.87	13.51	22.47	19.53	18.93	17.90	16.30
$Sc_1 \times Ml_3$	22.46	19.26	16.43	13.57	10.33	21.47	18.47	13.08	12.50	9.803
$Sc_2 \times Ml_1$	22.60	22.26	21.67	21.34	20.12	22.49	21.96	21.32	20.51	19.76
$Sc_2 \times Ml_2$	22.50	21.41	20.45	17.55	15.62	22.49	20.63	20.16	18.90	17.61
$Sc_2 \times Ml_3$	22.49	20.07	17.30	14.61	12.87	21.47	19.62	15.12	13.39	12.25
LSD (0.05)	NS	0.273	0.256	0.140	0.120	NS	NS	0.485	0.210	0.173

4.1.3.10 Interaction of sulphur, storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of sulphur, storage container and initial moisture content of the seed affected the speed of germination of the seed from 2-month intervals in 1998-99 (Table 4.1.3.6). The effect of sulphur was very dominant in the treatment combination. At an interval of 3-month sulphur showed a very significant effect in the treatment combination and the seeds containing higher doses of sulphur showed higher vigour index than the seeds with poorer or zero content of sulphur. Other two treatments had profound effect and dictated the speed of germination of stored seed. Seeds stored in polythene bags showed significant superiority over the seeds that were stored in tin container. The three level of initial moisture content have fallen the whole interaction into three groups. The highest speed of germination was retained in the treatment of 60kg S /ha with 7.25 % initial moisture content of seed and stored in polythene bags. The poorest speed of germination was obtained by the treatment of 0 kg S /ha with initial moisture content of 9.25% and stored in tin container. In 1997-98 the trend of vigour index was similar but only the treatment at an interval of 5-month was significant. The result showed that storage container did not but the initial moisture level produced significant variations in vigour index. Rahman *et al.* (1994) showed similar result.

Table 4.1.3.6 Interaction of sulphur, storage container and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
Sulp.xSt.conxM oist. level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$S_0 \times Sc_1 \times Ml_1$	22.47	20.23	18.77	16.73	14.63	22.35	20.50	19.42	18.40	16.32
$S_0 \times Sc_1 \times Ml_2$	22.43	19.03	17.18	15.55	13.23	22.33	19.35	18.18	17.12	15.58
$S_0 \times Sc_1 \times Ml_3$	22.32	14.12	13.43	13.20	9.83	22.32	13.95	12.75	12.08	9.33
$S_0 \times$ I $Sc_2 \times Ml_1$	22.57	22.17	21.43	21.15	19.88	22.32	21.43	19.98	18.88	17.53
$S_0 \times Sc_2 \times Ml_2$	22.52	19.95	18.33	16.97	15.18	22.32	20.43	18.67	17.75	16.62
$S_0 \times Sc_2 \times Ml_3$	22.47	15.42	14.38	14.15	12.48	22.32	15.60	14.02	13.25	11.88
$S_{20} \times Sc_1 \times Ml_1$	22.53	20.45	18.93	16.93	15.37	22.48	20.62	19.88	18.88	17.07
$S_{20} \times Sc_1 \times Ml_2$	22.52	19.27	17.58	15.90	13.37	22.37	19.48	18.80	17.77	16.25
$S_{20} \times Sc_1 \times Ml_3$	22.38	14.43	13.75	13.52	10.37	22.45	14.15	12.97	12.37	9.77
$S_{20} \times Sc_2 \times Ml_1$	22.68	22.33	21.67	21.30	20.02	22.53	22.02	21.52	20.80	20.18
$S_{20} \times Sc_2 \times Ml_2$	22.63	20.28	18.70	17.55	15.62	22.52	20.55	20.08	19.08	17.77
$S_{20} \times Sc_2 \times Ml_3$	22.58	16.07	15.20	14.57	12.78	22.45	15.80	14.77	13.28	12.20
$S_{40} \times Sc_1 \times Ml_1$	22.63	20.75	19.17	17.08	15.58	22.58	20.80	20.12	19.25	17.25
$S_{40} \times Sc_1 \times Ml_2$	22.52	19.60	17.62	16.02	133.6	22.58	19.55	18.95	18.15	16.45
$S_{40} \times Sc_1 \times Ml_3$	22.45	14.62	14.03	13.70	10.48	22.62	14.45	13.15	12.58	9.92
$S_{40} \times Sc_2 \times Ml_1$	22.82	22.50	21.73	21.42	20.18	22.70	22.15	21.67	20.92	20.30
$S_{40} \times Sc_2 \times Ml_2$	22.77	20.50	18.88	17.75	15.78	22.68	20.72	20.28	19.22	17.88
$S_{40} \times Sc_2 \times Ml_3$	22.72	16.30	15.48	14.73	12.90	22.67	15.97	14.92	13.47	12.42
$S_{60} \times Sc_1 \times Ml_1$	22.80	21.02	19.33	17.32	15.93	22.80	20.97	20.35	19.53	17.52
$S_{60} \times Sc_1 \times Ml_2$	22.68	19.75	17.77	16.13	13.77	22.78	19.72	19.15	18.38	16.68
$S_{60} \times Sc_1 \times Ml_3$	22.55	14.87	14.12	13.77	10.67	22.75	14.67	13.38	12.78	10.10
$S_{60} \times Sc_2 \times Ml_1$	23.00	22.65	21.90	21.50	20.43	22.90	22.28	21.80	21.08	20.47
$S_{60} \times Sc_2 \times Ml_2$	22.92	20.70	19.12	17.85	15.85	22.85	20.85	20.32	19.28	17.95
$S_{60} \times Sc_2 \times Ml_3$	22.77	16.62	15.72	14.93	13.30	22.83	15.97	14.93	13.48	12.47
$S_{80} \times Sc_1 \times Ml_1$	22.53	20.50	19.22	17.08	15.72	22.32	20.75	20.20	19.23	17.42
$S_{80} \times Sc_1 \times Ml_2$	22.38	19.23	17.78	15.75	13.57	22.32	19.55	18.93	18.08	16.52
$S_{80} \times Sc_1 \times Ml_3$	22.33	14.27	13.93	13.67	10.32	22.30	14.45	13.13	12.67	9.90
$S_{80} \times Sc_2 \times Ml_1$	22.62	22.18	21.62	21.35	20.08	22.53	21.93	21.62	20.85	20.30
$S_{80} \times Sc_2 \times Ml_2$	22.53	20.42	18.92	17.63	15.68	22.43	20.60	19.35	19.17	17.85
$S_{80} \times Sc_2 \times Ml_3$	22.50	15.97	15.28	14.68	12.88	22.38	15.77	14.75	13.45	12.30
LD(0.05)	NS	NS	NS	NS	0.268	NS	0.258	0.343	0.469	0.368

4.1.3.11 Interaction of inoculation,storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of inoculation ,storage container and initial moisture content of seed was not significant in 1997-98 and 1998-99.

4.1.3.12 Interaction of sulphur, inoculation,storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of all the four treatment was not significant in 1997-98 and 1998-99.

4.2.1 Effect of calcium *Bradyrhizobium* fertilization on the growth and yield of groundnut

4.2.1.1 Effect of calcium *Bradyrhizobium* fertilization on the plant height and number branches/ plant

The fertilizer element calcium significantly influenced plant height in 1997-98 and 1998-99 (Table 4.2.1.1). In the first year the longest plant was obtained from the treatment 150kg Ca/ha while the shortest plant from the control plot and other treatment of calcium produced identical height with the highest one. In 1998-99 similar trend was also showed by calcium and produced significant effect on plant height. The result might be due to the fact that calcium enhances the growth of groundnut plants.

Bradyrhizobium fertilization had not affected the plant height (Table 4.2.1.1). In the first year, plants without inoculation produced longer plants but in the second year, inoculated plants produced longer plants, and the difference between inoculated and uninoculated one was not significant. The result indicated that inoculation had little effect on the growth of groundnut plants. The result was in partial agreement with Poi and Kabi (1983).

The interaction of calcium and *Bradyrhizobium* fertilization was significant in 1997-98 and was insignificant in 1998-99 (Table 4.2.1.1). In the first year, the longest plant was produced in the treatment 50 kg Ca/ha with inoculation and the shortest plant was produced in control. Inoculation with out calcium produced the second highest long plant, which produced comparable plant height to other treatments. In the second year, similar results also showed by the interaction of *Bradyrhizobium* fertilization and calcium fertilization. The result revealed that calcium as well as inoculation showed better positive effect on the growth of groundnut.

4.2.1.2 Effect of calcium and *Bradyrhizobium* and their interaction on the number of branches/plant

Calcium fertilization significantly influenced the number of branches per plant in 1997-98 and 1998-99 (Table 4.2.1.1). In 1997-98, the highest number of branch was produced in 150 kg Ca/ha treatment. Other doses of calcium produced identical number of branch with the highest one. Control plot produced significantly poorer number of branches per plant than that of calcium treated plot. In 1998-99, similar trend also showed by the fertilizer elements. The result revealed that calcium enhances the number of branches due to its effect on growth parameter of the plant.

Table4.2.1.1 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on plant height and number of branches/plant of groundnut

Treatment/Interaction	Plant height (cm)		Number of branch/plant	
	1997-98	1998-99	1997-98	1998-99
Ca dose (kg/ha)				
Ca_0	45.65	42.73	4.75	3.72
Ca_{50}	46.23	47.97	5.30	3.92
Ca_{100}	49.13	49.77	5.40	4.82
Ca_{150}	50.97	51.40	5.70	5.05
Ca_{200}	47.63	50.50	5.50	4.27
LSD (0.05)	2.273	3.27	0.378	0.410
Inoculation(g/kg seed)				
I_0	48.05	47.52	5.26	4.09
I_{50}	47.80	49.43	5.40	4.61
LSD (0.05)	NS	NS	NS	0.579
Calcium×Inoculation				
$Ca_0 \times I_0$	43.77	41.67	4.63	3.53
$Ca_{50} \times I_0$	47.53	43.80	4.87	3.90
$Ca_{100} \times I_0$	45.13	46.87	5.33	3.43
$Ca_{150} \times I_0$	47.33	49.07	5.27	4.40
$Ca_{200} \times I_0$	48.33	47.40	5.20	4.53
$Ca_0 \times I_{50}$	49.93	52.13	5.60	5.10
$Ca_{50} \times I_{50}$	53.47	53.07	5.80	4.87
$Ca_{100} \times I_{50}$	48.47	49.73	5.60	5.23
$Ca_{150} \times I_{50}$	49.53	48.60	5.33	4.10
$Ca_{200} \times I_{50}$	45.73	52.40	5.67	4.43
LSD (0.05)	3.214	NS	NS	NS

Bradyrhizobium fertilization produced greater number of branch per plant but the difference was not significant in 1997-98 and 1998-99 (Table 4.2.1.1). In 1997-98, the un-inoculated plants produced 5.26 branches per plant while inoculated plants produced 5.40 branches per plant. In 1998-99, the un-inoculated plants produced 4.09 branches per plant and inoculated plants produced 4.61 branches per plant. The result indicated that inoculation of groundnut with *Rhizobium* sp. encouraged branching and this variation in number of branching might be due to climatic variations among the years. Desmukh and Dev (1995) observed similar result.

The interaction of calcium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99 (Table 4.2.1.1). In 1997-98, the highest number of branch per plant was produced by the treatment 50 kg Ca/ha with *Bradyrhizobium* inoculation and the lowest number of branch plant was produced in control. In 1998-99 the highest number of branch was produced in the treatment of 0 kg Ca/ha with inoculation and the lowest number was produced in the treatment of 0 kg Ca/ha without inoculation. The result indicated that fertilizer treatments failed to produce distinctly different effects on number of branch per plant.

4.2.1.3 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on the number of mature pods/ plant

Calcium affected the number of mature pod per plant significantly in 1997-98 and 1998-99 (Table 4.2.1.2). The highest number of mature pods/plant was obtained in the treatment 150 kg Ca/ha in 1997-98 and the other treatments varied significantly though differences among means were not significant. In 1998-99, the highest number of mature pods/plant was obtained in the treatment of 150 kg Ca/ha which produced identical number with treatment 100 kg Ca/ha and 200 kg Ca/ha The lowest number of mature pods per plant was obtained in the treatment of 0 kg Ca/ha. The result revealed that calcium had encouraged the number of matured pods.

In 1997-98, the effect of *Bradyrhizobium* fertilization was significant on the number of mature pods per plant and there was a significant increment in number of mature pods per plant. In 1998-99, the inoculation affected the number of mature pod significantly and inoculation produced significantly superior number of mature pod over uninoculated one.

The number of mature pods/plant interacted significantly by calcium and *Bradyrhizobium* fertilization in 1997-98 only (Table 4.2.1.2). In 1997-98, the highest number of mature pod was produced with 100 kg Ca/ha with inoculation and the lowest number of matured pod per plant was produced in control. Other treatments produced intermediary results though the mean did not vary significantly. In 1998-99, the highest number of mature pod/plant was produced with 150 kg Ca/ha with inoculation, which produced very close number of matured pod per plant with inoculated plot with 0 kg Ca/ha. The lowest number of pod per plot was produced in of control. It might be due to the fact that better response of calcium was attributed in the presence of *Bradyrhizobium* fertilization.

4.2.1.4 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on the number of immature pods/ plant

The effect of calcium on number of immature pods/plant was not significant in 1997-98 and 1998-99 (Table 4.2.1.2). There was an increasing trend of pod setting at later stages with the application of calcium. These results are in partial agreement with Badiger *et al.* (1988) Das and Garnayak (1995). The number of immature pods/plant reduced with the application of inoculum in 1997-98 and 1998-99 (Table 4.2.1.2). The results indicated that *Bradyrhizobium* fertilization checked the later setting of fruits in groundnut.

The interaction of calcium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99 (Table 4.2.1.2). In 1997-98, the highest number of immature pods/plant was obtained from the treatment 200 kg Ca /ha without inoculation and the lowest was obtained in control. In 1998-99, the highest number of immature pods was obtained from the treatment 100 kg Ca/ha without inoculation and the lowest number was obtained in the inoculated plot without calcium. The results indicated that inoculation and calcium together acted as retardant of late flowering.

Table4.2.1.2 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on number of mature pods/plant and number of immature pods/plant

Treatment/Interaction	Number of mature pods/plant		Number of immature pods/plant	
	1997-98	1998-99	1997-98	1998-99
Ca dose (kg/ha)				
Ca_0	12.20	11.40	2.67	4.70
Ca_{50}	13.10	12.35	3.60	4.78
Ca_{100}	15.23	15.47	3.50	3.90
Ca_{150}	17.23	15.80	3.23	4.10
Ca_{200}	13.33	14.27	3.57	4.43
LSD (0.05)	1.519	0.425	NS	NS
Inoculation(g/kg seed)				
I_0	13.69	12.59	3.56	4.63
I_{50}	14.92	13.53	3.07	4.13
LSD (0.05)	2.148	0.603	NS	1.41
Calcium×Inoculation				
$Ca_0 \times I_0$	11.73	11.07	2.60	4.40
$Ca_{50} \times I_0$	12.67	11.73	2.73	5.00
$Ca_{100} \times I_0$	13.20	12.13	3.60	5.50
$Ca_{150} \times I_0$	13.00	12.57	3.60	4.07
$Ca_{200} \times I_0$	14.53	15.87	4.13	4.27
$Ca_0 \times I_{50}$	15.93	15.07	2.87	3.53
$Ca_{50} \times I_{50}$	16.33	16.40	3.53	4.20
$Ca_{100} \times I_{50}$	18.13	15.20	2.93	4.00
$Ca_{150} \times I_{50}$	12.67	14.47	3.93	4.80
$Ca_{200} \times I_{50}$	14.87	14.07	3.20	4.07
LSD (0.05)	2.149	NS	NS	NS

4.2.1.5 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on the Shelling percentage of groundnut seed

Calcium had a significant effect on the shelling percentage of groundnut in 1997-98 and 1998-99 (Table 4.2.1.3). In 1997-98, the highest percentage of shelling was obtained from the treatment of 100 kg Ca/ha and comparable percentage of shelling was also obtained from 150 kg Ca/ha and other treatments produced significantly poorer percentage of shelling in the same year. In 1998-99, the trend was similar and the lowest percentage was produced in control. The result might be due to the fact that calcium increased the weight of seed. These results are in full agreement with Ramachandrappa and Kulkarni (1992); Shahu *et al.* (1995) and Das and Garnayak (1995).

Bradyrhizobium fertilization affected the shelling percentage of groundnut seed significantly in 1997-98 (Table 4.2.1.3). The inoculation showed a gradual increase in shelling percentage in both years. The results indicated that inoculation improved the weight of kernel more than the shell and are in full agreement with Abu and Misari (1989).

The interaction of calcium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99 (Table 4.2.1.3).

Table4.2.1.3 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on % shelling and harvest index of groundnut

Treatment	% Shelling		Harvest index	
	1997-98	1998-99	1997-98	1998-99
Ca dose (kg/ha)				
Ca_0	65.18	60.30	30.91	31.98
Ca_{50}	67.59	61.89	31.63	32.53
Ca_{100}	70.00	63.39	35.29	36.99
Ca_{150}	69.65	64.11	37.68	37.94
Ca_{200}	67.43	62.05	35.38	35.59
LSD (0.05)	1.306	0.979	1.336	1.387
Inoculation(g/kg seed)				
I_0	67.52	62.13	33.87	34.44
I_{50}	68.85	62.57	34.49	35.57
LSD (0.05)	1.766	NS	NS	1.962

4.2.1.6 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on the harvest index

Harvest index of the crop was affected significantly by calcium in 1997-98 and 1998-99 (Table 4.2.1.3). In 1997-98, the highest harvest index was found in the treatment 150 kg Ca/ha and the lowest was obtained in control, which produced identical results with lower doses of calcium 50 kg Ca/ha. In 1998-99, 150 kg Ca/ha produced the highest harvest index that was at par with 100 kg Ca/ha and control. The lower doses of calcium produced similar results that were obtained in 1997-98. It may be concluded from the two years result that calcium has a positive effect on shell of fruits and it increased the weight of kernels. The results are in agreement that was obtained by Velasquez and Ramirez (1985).

There was a positive effect of *Bradyrhizobium* fertilization on the harvest index of groundnut but the effect was significant in 1998-99 only (Table 4.2.1.3). The percentage of shelling was increased in inoculation than uninoculated treatment. The result showed that inoculation increased the dry mass of the plants. Pulatova *et al.* (1998) obtained similar result.

The interaction of calcium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99. In 1997-98, the higher harvest index was produced with the treatment 50 kg Ca/ha with inoculation. The lower doses of calcium without inoculation produced poorer harvest index. In 1998-99, the highest harvest index was obtained with the treatment 100 kg Ca/ha with inoculation that also produced very close results with other treatments of inoculation with or without calcium. The result revealed that pod weight and total weight was unaffected by calcium and inoculation. The results are in agreement with Ashrif (1963).

4.2.1.7 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on 100 seed weight

100 seed weight of groundnut varied significantly with calcium application (Table 4.2.1.4). The heaviest seed in 1997-98 was produced with 150 kg Ca/ha, which produced at par weight with 100 kg Ca/ha. Other treatments produced significantly lower weighed seed and were identical with the control and the lightest seed was obtained in control. In 1998-99, a similar result was also obtained excepting that only 50 kg Ca/ha and control

produced identical results. The results indicated that lime enhanced the seed weight. Loader *et al.* (1988); Dubey and Patro (1993); Das and Garnayak (1995) obtained similar results.

Bradyrhizoloium fertilization had a positive effect on 100 seed weight but the difference between inoculation and uninoculated one was not significant 1997-98 and 1998-99 (Table 4.2.1.4). The results are in agreement with Joshi *et al.* (1987).

Table4.2.1.4 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on 100 seed weight and pod yield of groundnut

Treatment	100 seed weight		Pod yield kg/ha	
	1997-98	1998-99	1997-98	1998-99
Ca dose (kg/ha)				
Ca_0	26.33	23.20	1.538	1.533
Ca_{50}	27.17	24.18	1.565	1.573
Ca_{100}	29.75	28.08	1.688	1.690
Ca_{150}	30.17	29.45	1.818	1.735
Ca_{200}	27.50	26.44	1.650	1.653
LSD (0.05)	0.932	1.552	0.054	0.012
Inoculation (g/kg seed)				
I_0	27.90	25.98	1.63	1.62
I_{50}	28.47	26.56	1.68	1.66
LSD (0.05)	NS	2.195	0.073	0.017

The interaction of calcium and *Bradyrhizoloium* inoculation was not significant in 1997-98 and 1998-99.

4.2.1.8 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on pod yield (t / ha)

Calcium had a distinct and significant effect of the yield of groundnut (Table 4.2.1.4). In 1997-98, the highest yield was obtained with the treatment 150 kg Ca/ha and other treatments produced significantly lower yield but 50 kg Ca/ha and control produced identical yield. In 1998-99, similar results were also obtained and the highest yield was obtained with 150 kg Ca/ha and other treatments produced significantly poorer yield and the lowest yield was obtained in control. The result revealed that when calcium was not deficient application of calcium gave larger seed yield increases. Gajanan *et al.* (1991) and Zhang and Zao (1995) also obtained similar results.

Bradyrhizoboium fertilization showed a significant effect on the yield in 1997-98 and 1998-99 (Table 4.2.1.4) and produced higher yield than the uninoculated one. Abu and Msari (1989) obtained similar results.

The interaction of calcium and *Bradyrhizoloium* inoculation was not significant in 1997-98 and 1998-99. In 1997-98, higher yield was obtained in 100kg Ca/ha with inoculation. The lowest yield was obtained in control. The result revealed that limed plot with inoculation increased the pod yield.

4.2.1.9 Effect of calcium and *Bradyrhizobium* and their interaction on % oil content of seed

Calcium affected the oil content of the seed significantly in 1997-98 and 1998-99 (Table 4.2.1.5). In 1997-98, the highest percentage of oil was obtained with 100 kg Ca/ha, which produced identical percentage of oil with other treatments of calcium. The lowest percentage of oil was obtained in the control. In 1998-99, the highest percentage of oil was obtained in the treatment of 150 kg Ca/ha and the lowest in control. The result revealed that calcium increased the oil content of seed gradually with the increasing doses. The results are in agreement with the results obtained by Shahu *et al.* (1995).

Bradyrhizobium fertilization affected the oil content of the seed but not significantly. Inoculation of seed with *Bradyrhizobium* fertilizer increased the oil content of the seed in 1997-98 and 1998-99 (Table 4.2.1.5). The results are in partial agreement with Jana *et al.* (1994).

The interaction of calcium and inoculation was not significant in 1997-98 and 1998-99.

Table4.2.1.5 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on %oil content and %protein content of groundnut

Treatment	% Oil content		% Protein content	
	1997-98	1998-99	1997-98	1998-99
Ca dose (kg/ha)				
Ca_0	49.94	50.15	22.14	22.35
Ca_{50}	51.01	50.57	22.35	23.79
Ca_{100}	51.37	51.35	23.64	24.72
Ca_{150}	51.20	51.92	23.91	25.20
Ca_{200}	51.28	51.02	23.62	22.99
LSD (0.05)	0.568	0.376	0.646	1.180

4.2.1.10 Effect of calcium and *Bradyrhizobium* fertilization and their interaction on the% protein content of seed

The level of calcium affected the % protein content of seed significantly in 1997-98 and 1998-99 (Table 4.2.1.5). In the 1st year the highest percentage of protein was obtained by the treatment 150 kg Ca/ha while in the 2nd year the highest percentage of protein was obtained in the treatment of 200 kg Ca/ha. The lowest percentage of protein was obtained in the control plot. Other treatment produced intermediary results. The result indicated that seed protein content increased with the rate of calcium application. Ursal *et al.* (1994) obtained similar result

Bradyrhizobium fertilization had a positive effect on the percentage of protein content of groundnut seed and increased the protein percentage of seed in 1997-98 and 1998-99 (Table 4.2.1.5), but the effect was not significant. The results are in partial agreement with Jana *et al.* (1994).

The interaction of calcium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99. In 1997-98, the higher percentage of protein was obtained in the treatment of 100 kg Ca/ha with inoculation. In 1998-99, the higher percentage of protein was obtained with 150 kg Ca/ha with inoculation. From the above results it is evident that calcium affected much on the protein content of the seed with or without inoculation.

4.2.2.1 Effect of calcium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the germination percentage of stored seed

Seed obtained from different calcium treated plots showed significant effect on the germination percentage of stored seed. The seeds obtained from higher doses of calcium retained higher germination percentage at different intervals of storage and control seed retained the lowest percentage of germination at the later stages of storage in 1997-98 (Table 4.2.2.1). At an interval of 1-month, the highest germination percentage was retained with 150 kg Ca/ha. Other treatments retained significantly poorer percentage of germination. At an interval of 2-month, 150 kg Ca/ha treatments retained the highest percentage of germination, which was identical to 100 kg Ca/ha. The treatment, 200 and 50 kg Ca/ha retained significantly lower percentage of germination. The control retained lowest percentage of germination. At an interval of 3-month, the highest percentage was also retained in the treatment of 150 kg Ca/ha and other treatments retained significantly lower percentage of germination. Control and 50 kg Ca/ha retained identical percentage of germination. At an interval of 4 months, the highest percentage was retained by the treatment 150 kg Ca/ha. Other treatments retained significantly lower percentage of germination. At an interval of 5 months, the trend of retaining germination percentage was similar except that all the treatments retained significantly superior percentage of germination over control. In 1998-99, trend of retention of germination capacity of the seed was similar. The result indicated that calcium enriched seed improved the germination percentage of seed in storage. The results are in agreement with Crrie *et al.* (1978).

Germination percentage in all the months in 1997-98 was higher in inoculated seed over un-inoculated one (Table 4.2.2.1). The inoculated seed also showed similar trend in 1998-

99 except the seed at 1-month interval, where the uninoculated ones retained higher germination percentage. It might be concluded that the germination percentage of inoculated seed lowered with the increasing duration of seed in storage.

Storage container affected the germination percentage of seed significantly (Table 4.2.2.1). The germination percentage-reducing rate during storage period was higher in tin container than polythene bags. At and interval of 1-month, there was no differences in the percentage of germination between the two containers, but on the progress of storage period from the 2-month, the differences between the containers was distinct and statistically significant. The result stated that tin container failed to keep the germination percentage up to standard level whereas polythene bag maintained the standard germination percentage. Subbaraman and Selvaraj (1990) stated similar results.

Table 4.2.2.1 Effect of calcium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the germination percentage of stored seed

Treatments/Interaction	1997-98					1998-99				
	1 mon	2 mon	3 mon	4 mon	5 mon	1 mon	2 mon	3 mon	4 mon	5 mon
Ca level										
Ca_0	78.43	69.55	67.26	63.69	57.45	78.43	68.98	65.62	60.86	56.49
Ca_{50}	78.43	71.23	67.59	63.83	59.64	78.43	70.36	67.65	63.91	59.22
Ca_{100}	78.43	72.33	68.54	65.23	60.87	78.35	71.29	69.34	64.90	59.51
Ca_{150}	78.56	72.77	69.51	65.95	61.51	78.64	71.45	69.82	64.24	60.18
Ca_{200}	78.43	71.75	68.49	64.15	59.98	78.43	71.10	67.95	63.21	58.85
LSD (0.05)	0.094	0.551	0.569	0.538	0.524	0.116	0.594	0.116	1.408	0.837
Inoculum										
I_0	78.45	71.64	68.11	64.41	59.81	78.47	70.61	67.94	63.15	58.53
I_{50}	78.47	71.41	68.43	64.74	59.97	78.45	70.66	68.21	63.71	59.18
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
St.cont.										
Sc_1	78.47	69.29	65.89	62.16	57.64	78.42	66.39	64.98	60.73	56.06
Sc_2	78.45	73.75	70.65	66.98	62.14	78.50	74.88	71.28	66.12	61.65
LSD (0.05)	NS	1.744	1.800	1.864	1.816	0.402	5.763	4.941	4.87	2.907
M. level										
Ml_1	78.50	74.03	71.40	68.96	64.45	78.54	71.75	71.08	66.90	63.77
Ml_2	78.73	71.88	68.44	65.12	60.80	78.45	71.77	71.34	65.43	59.91
Ml_3	78.43	68.65	64.96	59.63	54.41	78.39	68.39	61.81	57.95	52.89
LSD (0.05)	0.073	0.39	0.402	0.148	0.406	0.090	1.289	1.105	1.091	0.649

Initial seed moisture content was very important in maintaining the standard germination percentage of seed over storage period (Table 4.2.2.1). Seeds with 7.25% moisture content maintained the ISTA standard level of germination up to 5-month of storage while 8.46% moisture content also maintained identical germination percentage up to 5-month of storage but 9.25% moisture failed to maintain the standard germination percentage after 4-month of storage. In 1997-98, at the interval of 1-month, 7.25% moisture showed significantly superior germination percentage and other two treatments showed identical germination percentage and in other 4 intervals of time, all the three-moisture level showed significant effect on the germination percentage significantly. In 1998-99, the effect of initial moisture level was significant at 1-month interval. At 2-month interval, the seeds with 7.25% and 8.46% initial moisture content of seed were significantly superior to 9.25% moisture level. And the seeds with 7.25% and 8.46% initial moisture content of seed retained identical germination percentage. At 3rd and 4th interval, they showed similar results with that of 2nd interval and at 5th interval, all the means were grouped into three in accordance with the level of moisture and they differed significantly. The results are in agreement with Zade *et al.* (1987).

4.2.2.2 Interaction of calcium and *Bradyrhizobium* fertilization on the germination percentage stored seed

The interaction on the germination percentage of the seed treated with calcium and *Bradyrhizobum* inoculation was not significant.

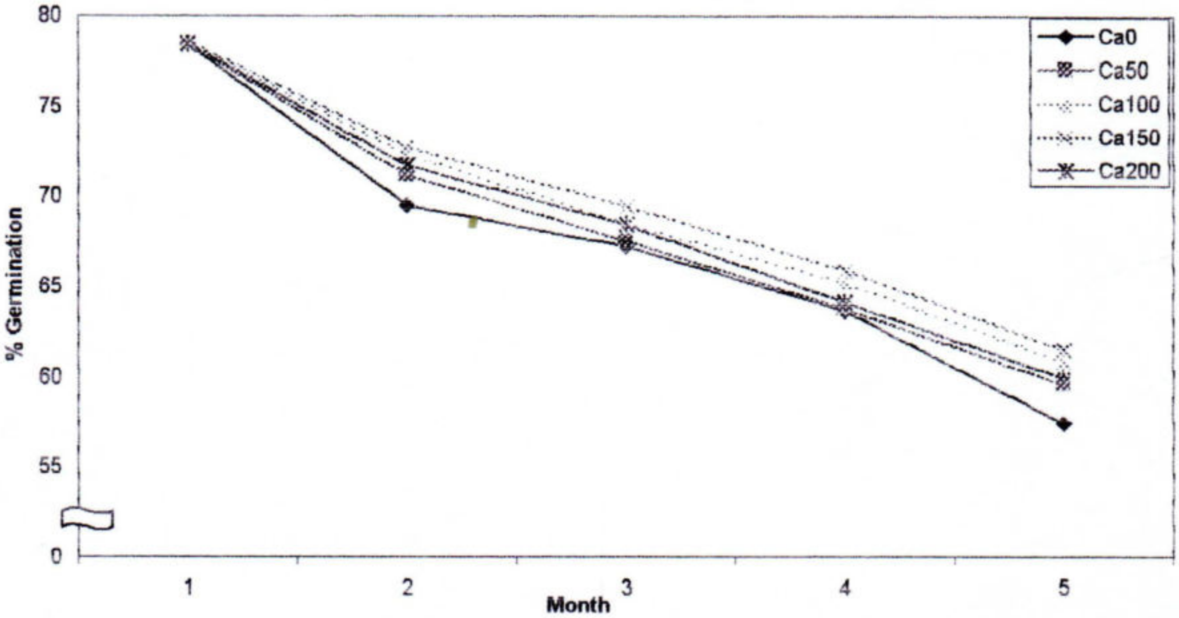


Fig 4.2.2.1.1 Effect of calcium on the germination percentage of stored seed in 1997-98

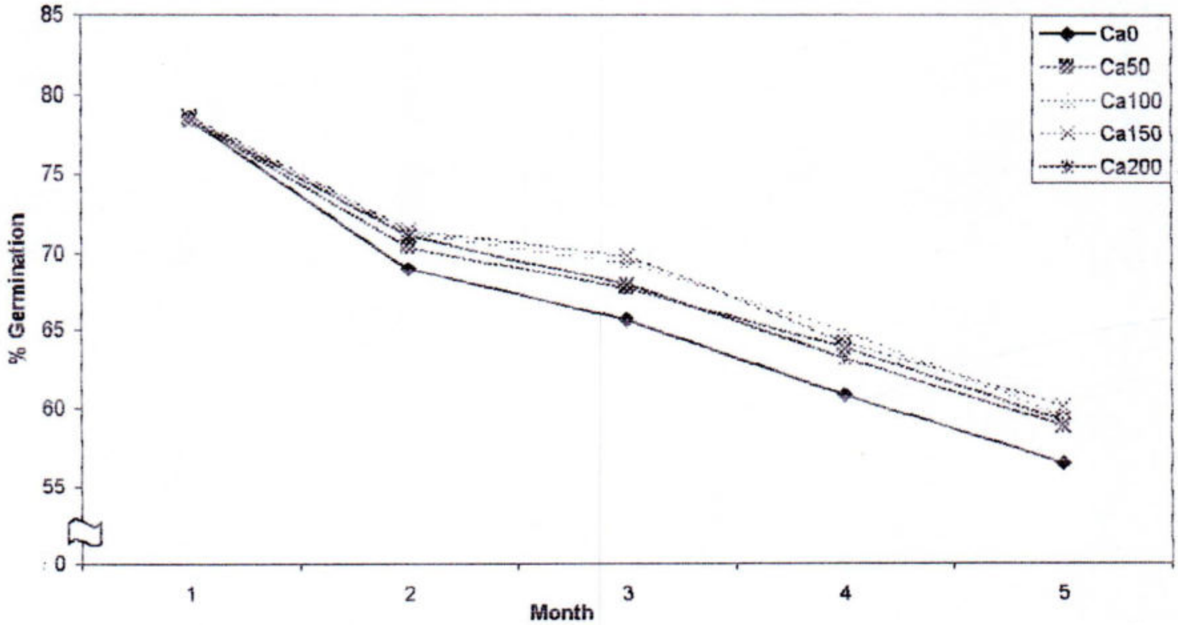
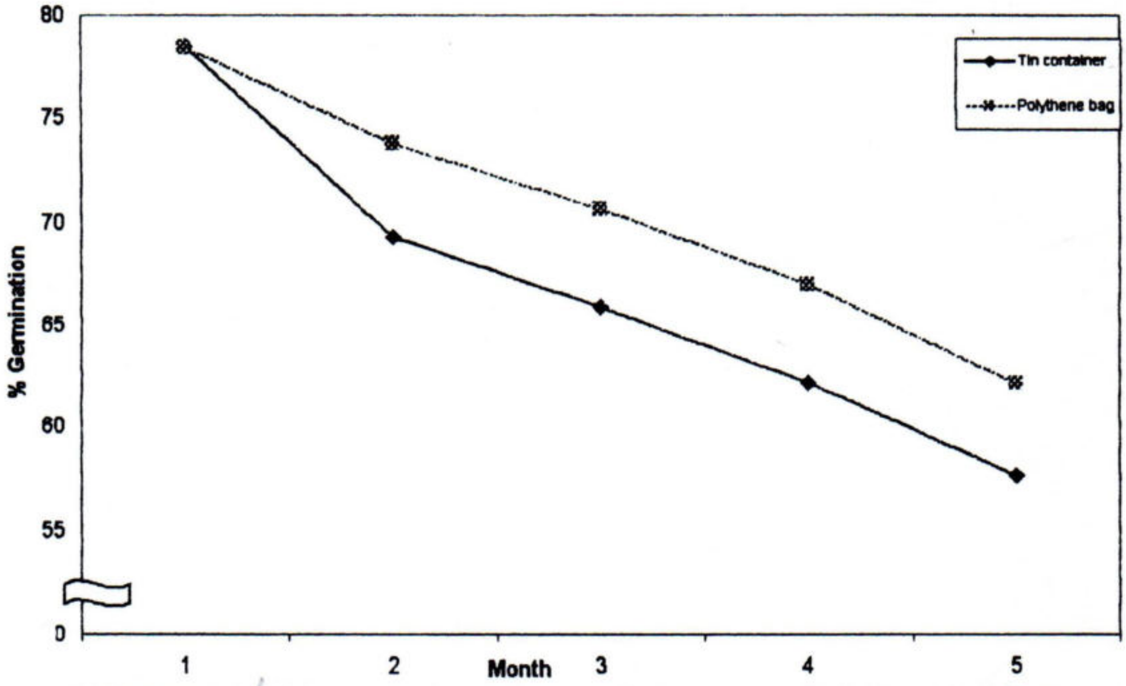


Fig 4.2.2.1.2 Effect of calcium on the germination percentage of stored seed in 1998-99



4.2.2.1.3 Effect of storage container on the germination percentage of stored seed in 1997-98

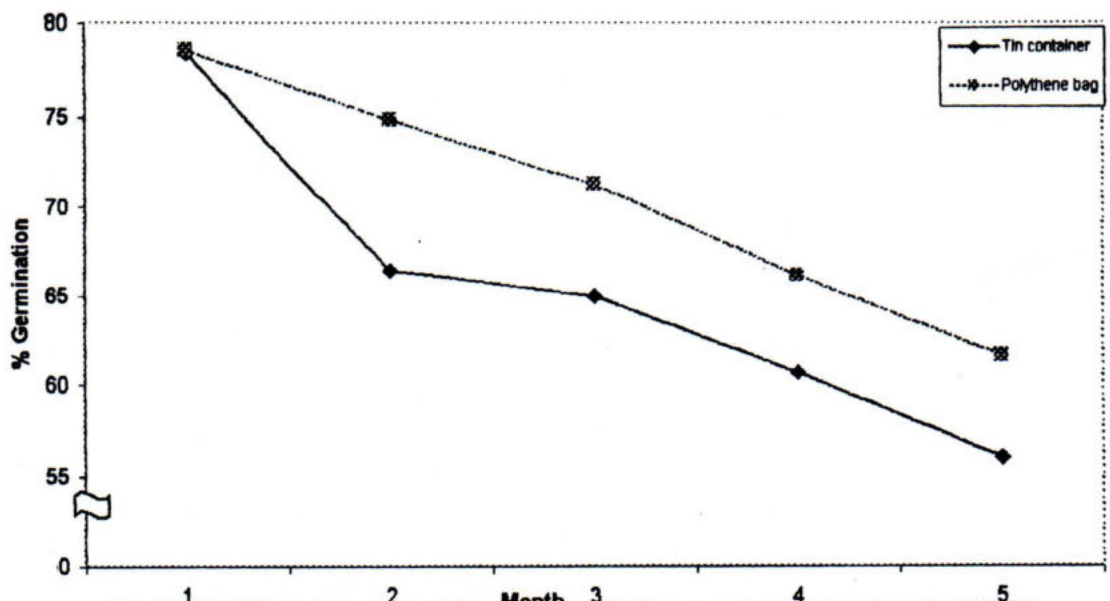
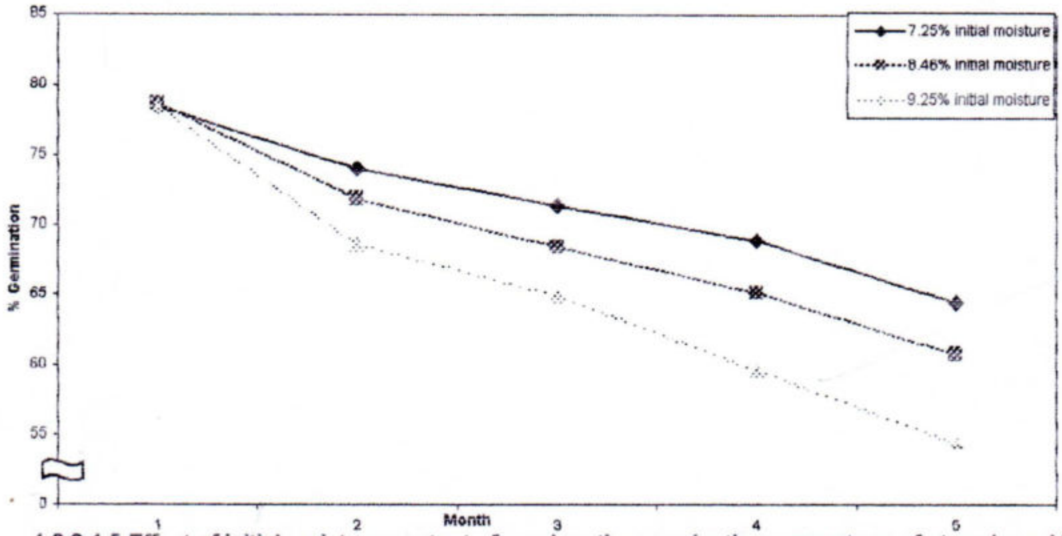
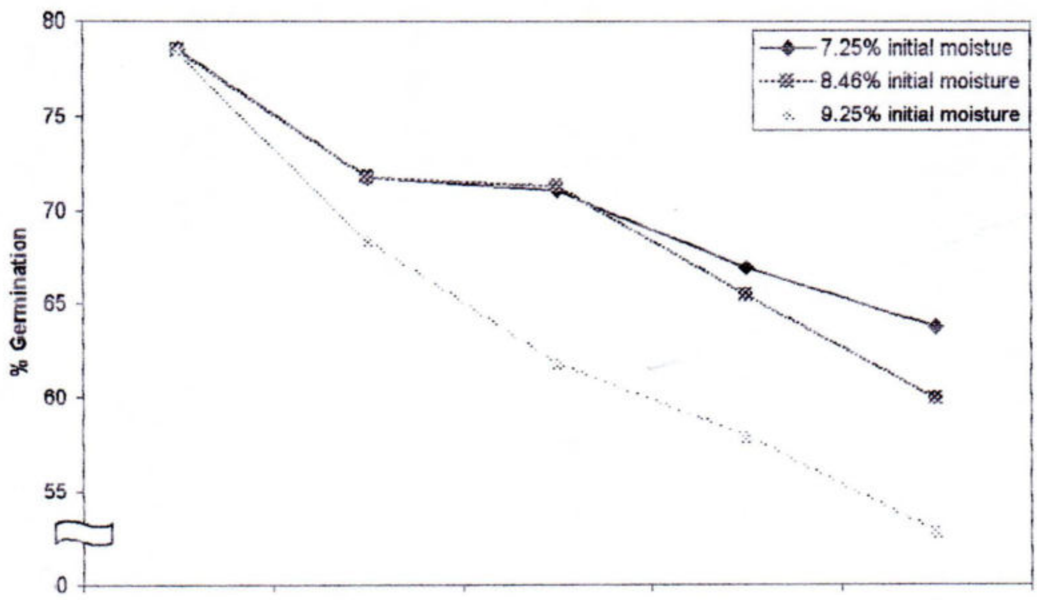


Fig 4.2.2.1.4 Effect of storage container on the germination percentage of stored seed in 1998-99



4.2.2.1.5 Effect of initial moisture content of seed on the germination percentage of stored seed in 1997-98



4.2.2.1.6 Effect of initial moisture content of the seed on the germination percentage of stored seed in 1998-99

4.2.2.3 Interaction of calcium and storage container on the germination percentage of stored seed

Interaction of calcium and storage container was significant in some of the intervals in 1997-98 and 1998-99 (Table 4.2.2.2). In 1997-98, at an interval of 2-month seeds with 150 and 100 kg Ca/ha stored in polythene bags retained the highest percentage of germination. Other treatments with lower and higher doses than the above two doses and stored in polythene bags retained lower percentage of germination. In the rest 3-month interval, the germination percentage of seed followed the same trend. In all the interval of germination tests, tin container with different doses of calcium retained lower percentage of germination. In the interaction of tin container with different doses of calcium, higher doses of calcium did better

Table4.2.2.2 Interaction of calcium and storage container on the germination percentage of stored seed

Interaction	1997-98					1998-99				
SulphurxSt.cont.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times Sc_1$	78.43	67.14	65.00	60.67	54.06	78.43	64.99	62.73	57.86	52.86
$Ca_0 \times Sc_2$	78.43	71.96	69.52	66.72	60.85	78.43	72.96	68.51	63.87	60.17
$Ca_{50} \times Sc_1$	78.43	69.24	65.84	61.29	57.39	78.43	66.45	64.39	61.52	56.37
$Ca_{50} \times Sc_2$	78.43	73.22	69.34	66.37	61.89	78.43	74.25	70.91	66.31	62.07
$Ca_{100} \times Sc_1$	78.43	69.92	66.06	62.59	58.52	78.35	66.29	66.26	62.37	57.19
$Ca_{100} \times Sc_2$	78.43	74.74	70.95	67.87	63.22	78.35	76.29	72.41	67.42	61.85
$Ca_{150} \times Sc_1$	78.61	70.10	66.36	63.48	59.53	78.43	68.19	66.95	61.80	57.71
$Ca_{150} \times Sc_2$	78.52	75.44	72.64	68.42	63.48	78.86	74.70	72.69	66.69	62.65
$Ca_{200} \times Sc_1$	78.43	70.09	66.16	62.78	58.67	78.43	66.02	64.01	60.12	56.16
$Ca_{200} \times Sc_2$	78.43	73.39	70.81	65.53	61.28	78.43	76.18	71.89	66.30	61.55
LSD (0.05)	NS	0.712	7.734	0.538	0.524	NS	NS	NS	NS	1.185

. In 1998-99 the trend of retaining the germination percentage was similar. In all the cases, seeds of control and stored in tin container retained the lowest percentage of germination. Nautiyal *et al.* (1996) obtained similar results.

4.2.2.4 Interaction of *Bradyrhizobium* fertilization and storage container on the germination percentage of stored seed

Interaction of *Bradyrhizobium* inoculation with storage container was not significant in 1997-98 and 1998-99. With the advance of time in storage inoculated seed in polythene bag retained higher germination percentage over seed from un-inoculated one in tin container. It is evident from the results that polythene bags could retain better germination percentage of seed in of storage.

4.2.2.5 Interaction of calcium, *Bradyrhizobium* fertilization and storage container on the germination percentage of stored seed

Interaction of calcium, inoculation and storage container was significant at an interval of 4-month only (Table 4.2.2.3). The seeds that was kept in polythene bags and treated with 150 kg Ca/ha with inoculation retained the highest percentage of germination.

Table4.2.2.3 Interaction of calcium, *Bradyrhizobium* fertilization and storage container on the germination percentage of stored seed

Treatments	1997-98					1998-99				
Ca. ×St. con.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times I_0 \times Sc_1$	78.43	67.28	64.69	60.42	53.82	78.43	64.95	62.91	58.57	52.63
$Ca_0 \times I_0 \times Sc_2$	78.43	71.85	69.17	66.26	60.82	78.43	72.93	68.07	62.21	59.53
$Ca_0 \times I_{50} \times Sc_1$	78.43	66.99	65.32	60.92	54.30	78.43	65.04	62.54	57.14	53.08
$Ca_0 \times I_{50} \times Sc_2$	78.43	72.06	69.87	67.19	60.88	78.43	72.99	68.96	65.54	60.74
$Ca_{50} \times I_0 \times Sc_1$	78.43	69.12	65.77	61.21	56.86	78.43	66.14	64.34	61.60	55.92
$Ca_{50} \times I_0 \times Sc_2$	78.43	73.26	69.28	66.20	61.69	78.43	73.94	70.37	65.79	61.76
$Ca_{50} \times I_{50} \times Sc_1$	78.43	69.35	65.90	61.37	57.91	78.43	66.78	64.44	61.46	56.82
$Ca_{50} \times I_{50} \times Sc_2$	78.43	73.19	69.40	66.54	62.09	78.43	74.58	71.45	66.83	62.34
$Ca_{100} \times I_0 \times Sc_1$	78.43	70.12	66.10	62.83	58.47	78.43	66.22	66.23	62.29	57.01
$Ca_{100} \times I_0 \times Sc_2$	78.43	75.03	70.86	67.30	63.37	78.43	75.88	72.89	68.36	61.62
$Ca_{100} \times I_{50} \times Sc_1$	78.43	69.71	66.01	32.35	58.58	78.43	66.36	66.30	62.45	57.37
$Ca_{100} \times I_{50} \times Sc_2$	78.43	74.45	71.04	68.44	63.07	78.43	76.71	71.93	66.48	62.08
$Ca_{150} \times I_0 \times Sc_1$	78.61	70.55	66.31	63.13	59.47	78.61	67.82	66.92	61.15	57.93
$Ca_{150} \times I_0 \times Sc_2$	78.43	75.23	72.57	69.19	63.26	78.43	76.28	72.85	66.44	61.95
$Ca_{150} \times I_{50} \times Sc_1$	78.61	69.65	66.46	63.83	59.60	78.61	68.55	66.99	62.44	57.49
$Ca_{150} \times I_{50} \times Sc_2$	78.61	75.66	72.69	67.65	63.70	78.61	73.13	72.52	66.94	63.35
$Ca_{200} \times I_0 \times Sc_1$	78.43	70.62	65.69	62.29	59.07	78.43	65.81	63.20	59.26	55.51
$Ca_{200} \times I_0 \times Sc_2$	78.43	73.33	70.69	65.23	61.32	78.43	76.13	71.60	65.80	61.43
$Ca_{200} \times I_{50} \times Sc_1$	78.43	69.57	66.63	63.26	58.28	78.43	66.24	64.82	60.98	56.79
$Ca_{200} \times I_{50} \times Sc_2$	78.43	73.46	70.93	65.82	61.24	78.43	76.23	72.17	66.80	61.67
LSD (0.05)	NS	NS	NS	0.322	NS	NS	NS	NS	NS	NS

It was also observed that higher doses of calcium up to 150 kg/ha with or with out inoculation retained similar germination percentage while lower percentage of calcium with inoculation in polythene bag retained similar percentage of germination and the lowest percentage of germination obtained in the seeds of control kept in tin container. With the progress of time the inoculated seed in polythene bags with higher doses of calcium retained better germination percentage over the seed of tin container with different doses of calcium and without inoculation. The result showed that calcium and storage container with inoculation encouraged the germination percentage of stored seed.

4.2.2.6 Interaction of calcium and initial moisture content of seed on the germination percentage of stored seed

The interaction of calcium and initial moisture content of seed was significant at some interval (Table 4.2.2.4). The seeds with 7.25% initial moisture with 150 kg Ca/ha retained significantly higher germination percentage and other retained identical germination percentage at 1-month interval.

Table4.2.2.4 Interaction of calcium and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
Ca×Mlevel	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times Ml_1$	78.43	71.66	70.37	67.98	62.40	78.43	70.67	68.88	63.75	62.03
$Ca_0 \times Ml_2$	78.43	70.21	68.03	64.49	58.83	78.43	69.57	68.28	63.49	57.29
$Ca_0 \times Ml_3$	78.43	66.77	63.39	58.62	51.14	78.43	66.70	59.70	55.36	50.17
$Ca_{50} \times Ml_1$	78.43	73.84	71.09	68.25	64.27	78.43	71.95	70.70	67.65	64.49
$Ca_{50} \times Ml_2$	78.43	71.41	67.35	64.47	60.68	78.43	71.32	71.26	66.03	60.75
$Ca_{50} \times Ml_3$	78.43	68.44	64.34	58.77	53.99	78.43	67.81	60.99	58.07	52.14
$Ca_{100} \times Ml_1$	78.43	75.11	71.33	69.39	65.20	78.43	72.93	71.58	68.28	64.71
$Ca_{100} \times Ml_2$	78.43	72.74	68.78	65.34	61.23	78.43	71.97	73.65	67.04	60.46
$Ca_{100} \times Ml_3$	78.43	69.13	65.40	60.67	55.79	78.20	68.99	62.78	59.36	53.38
$Ca_{150} \times Ml_1$	78.43	75.54	72.70	70.57	65.20	78.95	71.52	72.54	67.60	64.36
$Ca_{150} \times Ml_2$	78.43	73.02	69.54	66.14	62.15	78.56	72.83	73.23	65.36	61.21
$Ca_{150} \times Ml_3$	78.43	69.76	66.28	61.13	56.40	78.43	69.99	63.69	59.76	54.97
$Ca_{200} \times Ml_1$	78.43	74.00	71.52	68.62	64.44	78.43	71.68	71.68	67.21	63.24
$Ca_{200} \times Ml_2$	78.43	72.05	68.52	64.86	60.72	78.43	73.14	70.26	65.24	59.82
$Ca_{200} \times Ml_3$	78.43	69.18	65.42	58.98	54.77	78.43	68.49	61.91	57.19	53.50
LSD (0.05)	0.163	NS	NS	NS	0.909	0.202	NS	NS	NS	NS

At 5-month interval seed with 7.25% initial moisture content and 150kg Ca/ha retained superior germination percentage and seed containing 7.25% initial moisture with 20 and 50 kg Ca/ha produced similar germination percentage with seed of 8.46% initial moisture content and 150kg Ca/ha. Other treatments of higher initial moisture content at different doses of calcium retained poorer percentage of germination. In 1998-99 at 1-month interval similar trend was shown by different treatments except 150 kg Ca/ha with 7.25% initial moisture retained significantly superior germination percentage and other retained identical percentage of germination. The result indicated that calcium and initial moisture content of seed affected the germination percentage but the effect in most cases modified because of storage duration.

4.2.2.7 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the germination percentage of stored seed

The interaction of inoculation and initial moisture content of seed was not significant. With the progress of time the initial moisture content of the seed affected the germination percentage of seed.

4.2.2.8 Interaction of calcium, *Bradyrhizobium* fertilization and initial moisture content on the germination percentage stored seed

Table 4.2.2.5 Interaction of calcium, *Bradyrhizobium* fertilization and initial moisture content on the germination percentage stored seed

Interaction	1997-98					1998-99				
Ca.×I×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
Ca$_0$xI$_0$xMl$_1$	78.43	71.66	69.69	67.69	62.19	78.43	70.62	68.69	62.58	61.78
Ca$_0$xI$_0$x Ml$_2$	78.43	70.40	67.91	64.37	58.66	78.43	69.44	68.08	63.49	57.25
Ca$_0$xI$_0$x Ml$_3$	78.43	66.63	63.19	57.95	51.09	78.43	66.77	59.70	54.36	49.22
Ca$_0$xI$_{50}$x Ml$_1$	78.43	71.66	71.05	68.27	62.60	78.43	70.72	69.08	64.92	62.29
Ca$_0$xI$_{50}$x Ml$_2$	78.43	70.02	68.15	64.61	58.99	78.43	69.70	68.48	62.94	57.34
Ca$_0$xI$_{50}$x Ml$_3$	78.43	66.91	63.58	59.28	51.18	78.43	66.64	59.70	56.16	51.12
Ca$_{50}$xI$_0$x Ml$_1$	78.43	73.67	70.92	68.00	64.10	78.43	70.77	70.31	67.05	64.13
Ca$_{50}$xI$_0$x Ml$_2$	78.43	71.68	67.26	64.57	60.47	78.43	71.04	71.06	66.00	60.53
Ca$_{50}$xI$_0$x Ml$_3$	78.43	68.21	64.40	58.55	53.25	78.43	67.30	60.70	58.02	51.87
Ca$_{50}$xI$_{50}$x Ml$_1$	78.43	74.00	71.25	68.51	64.43	78.43	72.13	71.09	68.24	64.85
Ca$_{50}$xI$_{50}$x Ml$_2$	78.43	71.14	67.44	64.37	60.89	78.43	71.61	71.47	66.06	60.98
Ca$_{50}$xI$_{50}$x Ml$_3$	78.43	68.67	64.27	58.98	54.69	78.43	68.31	61.28	58.12	52.96
Ca$_{100}$xI$_0$x Ml$_1$	78.43	74.86	71.47	69.37	64.93	78.43	72.48	71.65	68.93	64.59
Ca$_{100}$xI$_0$x Ml$_2$	78.43	73.31	68.71	65.55	61.35	78.43	71.77	73.88	67.54	60.47
Ca$_{100}$xI$_0$x Ml$_3$	78.43	69.56	65.27	60.29	56.48	78.43	68.90	63.16	59.51	52.88
Ca$_{100}$xI$_{50}$x Ml$_1$	78.43	75.37	71.19	69.42	65.46	78.43	73.38	71.51	67.62	64.83
Ca$_{100}$xI$_{50}$x Ml$_2$	78.43	72.16	68.85	65.72	61.91	78.43	72.16	73.42	66.55	60.45
Ca$_{100}$xI$_{50}$x Ml$_3$	78.43	68.71	65.53	61.05	55.10	78.97	69.07	62.41	59.22	53.88
Ca$_{150}$xI$_0$x Ml$_1$	78.69	75.99	72.67	70.50	65.83	78.95	73.93	72.41	66.94	64.20
Ca$_{150}$xI$_0$x Ml$_2$	78.43	72.98	69.56	66.51	62.27	78.43	72.82	73.87	64.52	61.01
Ca$_{150}$xI$_0$x Ml$_3$	78.43	69.71	66.09	61.46	55.99	78.43	69.40	63.37	59.92	54.60
Ca$_{150}$xI$_{50}$x Ml$_1$	78.95	75.09	72.74	70.64	66.10	78.95	69.10	72.67	68.27	64.53
Ca$_{150}$xI$_{50}$x Ml$_2$	78.43	73.05	69.52	65.77	62.04	78.69	72.84	72.59	66.20	61.40
Ca$_{150}$xI$_{50}$x Ml$_3$	78.43	69.82	66.48	60.80	56.80	78.43	70.58	64.00	59.61	55.34
Ca$_{200}$xI$_0$x Ml$_1$	78.43	74.44	71.44	68.55	64.55	78.43	71.57	71.72	66.78	62.86
Ca$_{200}$xI$_0$x Ml$_2$	78.43	72.76	68.09	64.79	61.11	78.43	72.84	68.64	63.83	59.48
Ca$_{200}$xI$_0$x Ml$_3$	78.43	68.73	65.05	57.94	54.92	78.43	68.50	61.85	56.99	53.08
Ca$_{200}$xI$_{50}$x Ml$_1$	78.43	73.57	71.60	68.69	64.33	78.43	71.80	71.64	67.63	63.61
Ca$_{200}$xI$_{50}$x Ml$_2$	78.43	71.34	68.96	64.92	60.32	78.43	73.44	71.88	66.65	60.15
Ca$_{200}$xI$_{50}$x Ml$_3$	78.43	69.63	69.63	60.02	54.63	78.43	68.47	61.97	57.40	53.94
LSD (0.05)	NS	NS	NS	NS	1.284	NS	NS	NS	NS	NS

In 1997-98 the interaction of calcium, inoculation and initial moisture content was not significant from 1 to 4 month interval but was significant at 5-month interval (Table 4.2.2.5). In 5 month interval seeds with initial moisture of 9.25% with different doses of calcium with or with out inoculation retained significantly poor percentage of germination than other two levels of initial moisture content (7.25% and 8.46%). Seeds with initial moisture content of 7.25% and 8.46% at different doses of calcium and inoculation retained identical percentage of germination. The result indicated that calcium and inoculation affected the germination percentage but the effect was not distinct because of tremendous effect of initial moisture content of seed.

4.2.2.9 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

In 1997-98 the interaction of storage container and initial moisture content of the seed was significant at 3-month interval (Table 4.2.2.6) and seeds with 7.25% initial moisture content stored in polythene bags retained significantly superior germination percentage over other treatments. Seed with 8.46% initial moisture content stored in polythene bags retained significantly superior percentage of germination over seeds with initial moisture content of 9.25% stored in polythene bags and seed with initial moisture content 8.46% stored in tin container. At an interval of 4 and 5- month the highest percentage of germination was retained by the seeds with 7.25% initial moisture and kept in polythene bags and the lowest percentage of germination was retained by the seeds containing 9.25% initial moisture and kept in tin container. In 1998-99 at an interval of 2-month, seed kept in polythene bags with different levels of initial moisture content retained identical germination percentage over the seeds kept in tin container. At an interval of 3-month seeds with initial moisture content of 7.25% and 8.46% in polythene bags retained identical percentage of germination and significantly superior over seeds stored in tin container with initial moisture content of 9.25%. At an interval of 4 and 5-month, the trend of retaining moisture percentage was similar to that of 1997-98. The result might be due to the fact that storage container and initial moisture content of seed modified the physiological deterioration of stored seed.

Table 4.2.2.6 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
St.cont. ×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	77.74	72.11	66.51	63.17	59.68	78.43	68.52	66.98	63.72	61.11
$Sc_1 \times Ml_2$	77.35	69.54	64.81	60.66	54.54	78.43	68.45	68.06	62.98	57.40
$Sc_1 \times Ml_3$	76.56	66.32	62.97	52.80	47.78	78.38	62.20	59.89	55.49	49.65
$Sc_2 \times Ml_1$	78.64	73.73	70.96	67.21	64.55	78.64	74.97	75.50	70.07	66.42
$Sc_2 \times Ml_2$	77.93	70.93	67.40	62.84	60.39	78.48	75.08	74.61	67.88	62.41
$Sc_2 \times Ml_3$	77.39	68.04	65.11	60.76	54.86	78.39	74.58	63.73	60.40	56.12
LSD (0.05)	NS	NS	0.569	0.589	0.574	NS	1.82	1.562	1.260	NS

4.2.2.10 Interaction of calcium, storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of calcium, storage container and initial moisture content was not significant at early stage of storage in 1997-98. At an interval of 4 and 5-month the seeds with high doses of calcium with lower percentage of initial moisture content and stored in polythene bags retained significantly superior percentage of germination over others and the lowest percentage of germination was retained by the seeds of control. Lower doses of calcium with high initial moisture content and stored in tin container retained lower percentage of germination and they differ with others significantly. In 1998-99 the trend of retaining moisture percentage was similar, the highest percentage of germination was observed in the treatment with 150 kg Ca/ha and initial moisture content 7.25% and stored in polythene bag.

Table 4.2.2.7 Interaction of calcium, storage container and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
Ca×St.con ×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times Sc_1 \times Ml_1$	78.54	69.42	67.88	65.50	58.78	78.54	67.60	65.38	60.66	58.67
$Ca_0 \times Sc_1 \times Ml_2$	78.43	67.74	65.13	61.78	55.74	78.43	66.18	65.30	60.49	53.01
$Ca_0 \times Sc_1 \times Ml_3$	78.43	64.26	62.01	54.73	47.66	78.43	61.21	57.50	52.42	46.89
Ca_0xI $Sc_2 \times Ml_1$	78.43	73.90	72.86	70.45	66.00	78.43	73.74	72.39	66.83	65.39
$Ca_0 \times Sc_2 \times Ml_2$	78.43	72.68	70.93	67.20	61.92	78.43	72.95	71.26	66.50	61.57
$Ca_0 \times Sc_2 \times Ml_3$	78.43	69.28	64.76	62.51	54.62	78.43	72.20	61.90	58.29	53.44
$Ca_{20} \times Sc_1 \times Ml_1$	78.43	71.88	68.59	65.89	62.01	78.43	68.71	66.54	64.61	61.78
$Ca_{20} \times Sc_1 \times Ml_2$	78.43	69.42	65.39	62.13	59.11	78.43	68.51	67.52	63.81	57.94
$Ca_{20} \times Sc_1 \times Ml_3$	78.43	66.41	63.54	55.85	51.04	78.43	62.16	59.13	56.16	49.39
$Ca_{20} \times Sc_2 \times Ml_1$	78.43	75.79	73.58	70.61	66.53	78.43	75.19	74.87	70.69	67.20
$Ca_{20} \times Sc_2 \times Ml_2$	78.43	73.41	69.31	66.80	62.25	78.43	74.14	75.01	68.25	63.56
$Ca_{20} \times Sc_2 \times Ml_3$	78.43	70.47	65.14	61.68	56.90	78.43	73.45	62.85	59.99	55.44
$Ca_{40} \times Sc_1 \times Ml_1$	78.43	72.73	68.00	66.93	63.07	78.43	68.74	67.07	64.43	62.63
$Ca_{40} \times Sc_1 \times Ml_2$	78.43	70.46	66.03	63.66	60.09	78.43	68.09	70.91	65.59	58.57
$Ca_{40} \times Sc_1 \times Ml_3$	78.43	66.56	64.14	59.19	52.42	78.43	62.03	60.81	57.10	50.37
$Ca_{40} \times Sc_2 \times Ml_1$	78.43	77.51	74.65	71.86	67.33	78.20	77.11	76.08	72.13	66.80
$Ca_{40} \times Sc_2 \times Ml_2$	78.43	75.02	71.54	67.60	63.18	78.43	75.84	76.38	68.50	62.36
$Ca_{40} \times Sc_2 \times Ml_3$	78.43	71.71	66.66	64.16	59.15	78.43	75.94	64.76	61.63	56.39
$Ca_{60} \times Sc_1 \times Ml_1$	78.43	72.87	68.99	67.59	63.65	78.20	70.64	68.01	65.29	62.02
$Ca_{60} \times Sc_1 \times Ml_2$	78.43	70.62	66.02	64.38	60.53	78.43	69.41	70.85	63.22	59.45
$Ca_{60} \times Sc_1 \times Ml_3$	78.43	66.81	64.14	58.45	54.41	78.43	64.51	61.99	56.88	51.65
$Ca_{60} \times Sc_2 \times Ml_1$	78.69	78.20	76.42	73.53	68.28	78.43	72.40	77.06	69.92	66.70
$Ca_{60} \times Sc_2 \times Ml_2$	78.43	75.42	73.06	67.90	63.77	78.47	76.25	75.60	67.51	62.96
$Ca_{60} \times Sc_2 \times Ml_3$	78.43	72.72	68.43	63.79	58.38	78.43	75.47	65.38	62.64	58.28
$Ca_{80} \times Sc_1 \times Ml_1$	78.43	71.56	68.02	66.00	62.36	78.43	66.93	66.28	63.64	60.44
$Ca_{80} \times Sc_1 \times Ml_2$	78.43	70.51	66.43	63.32	59.65	78.43	70.03	65.73	61.81	58.04
$Ca_{80} \times Sc_1 \times Ml_3$	78.43	68.21	64.03	59.02	54.01	78.43	61.11	60.04	54.91	49.98
$Ca_{80} \times Sc_2 \times Ml_1$	78.43	76.44	75.02	71.23	66.53	78.43	76.44	77.09	70.77	66.03
$Ca_{80} \times Sc_2 \times Ml_2$	78.43	73.59	70.61	66.41	61.78	78.43	76.25	74.80	68.67	61.60
$Ca_{80} \times Sc_2 \times Ml_3$	78.43	70.16	66.80	58.94	55.53	78.43	75.86	63.78	59.47	57.03
LSD (0.05)	NS	NS	NS	1.318	1.284	0.285	NS	NS	NS	NS

4.2.2.11 Interaction of *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of inoculation, storage container and initial moisture content the seed did not show significant impact on the retention of germination percentage of seed.

4.2.2.12 Interaction of calcium, *Bradyrhizobium* fertilization, storage container and initial seed moisture content on the germination percentage of stored seed

The interaction of calcium, inoculation, storage container and initial moisture content of the seed was not significant. The seeds of with 150kg Ca/ha and initial moisture content of 7.25% stored in polythene or tin container and with or with out inoculation retained the higher percentage of germination. At later interval of months the seed with higher doses of calcium and lower initial moisture content and stored in polythene bag storage showed higher percentage of germination over others. Higher dose of calcium proved superiority over lower doses of calcium and the inoculation also showed a positive effect.

4.2.3.1 Effect of calcium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the vigour index of stored seed

The speed of germination of stored seed was significant in the entire interval except 1-month interval in 1998-99(Table 4.2.3.1). From the interval of 2-month the speed of germination of the seeds containing 150 kg Ca/ha retained the highest speed of germination and the lowest speed of germination was obtained with the control. The seeds containing calcium higher than 150kg/ha retained lower speed of germination and it retained identical speed of germination with least doses of calcium indicating that from the early stages of storage doses of calcium affected the speed of germination. With the increased doses of calcium starting from 50 kg Ca/ha the speed of germination gradually increased up to the level of 150kg Ca/ha and then it declines. The higher doses of calcium than the optimum for highest seedling vigour fluctuates with time, in the early period of storage it retained at par speed of germination with 50kg Ca/ha and at later stage it retained better speed of germination than 100kg Ca/ha. The result indicated that higher doses of calcium than the optimum might be beneficial at the later stage of storage though at early stage it hampered the speed of germination. The results are in agreement with Nakagowa *et.al* (1992) and Rossetto *et.al.*1996.

In 1997-98 the effect of inoculation on the speed of germination was not significant. At an interval of 2-month the inoculation treatment was significant (Table 4.2.3.1). In 1998-99 the effect of inoculation on the speed of germination showed similar trend. Increased speed of germination was found in all the treatments. The result indicated that inoculation of seed with *Bradyrhizobium* inoculation was able to affect positively up to mid duration of the storage and after that it lost its superiority over uninoculated one.

The effect of storage container on the speed of germination was significant from the early stage of the storage in 1997-98 and 1998-99(Table 4.2.3.1). At an early stage of storage the effect of container was at par and retained significantly lower speed of germination and in 1997-98 the effect in early stage was significant. With the progress of time the tin container fails to maintain the speed of germination of the stored seed and the seed of tin container took much time to germinate and made a significant variation with the seed stored in polythene bag.

Table 4.2.3.1 Effect of calcium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the vigour index of stored seed

Treatments	1997-98					1998-99				
	1 mon	2 mon	3 mon	4 mon	5 mon	1 mon	2 mon	3 mon	4 mon	5 mon
Cal. level										
Ca_0	22.39	18.41	17.39	16.36	14.92	21.89	18.43	17.21	15.92	14.82
Ca_{50}	22.48	18.90	17.81	17.01	15.68	22.23	18.74	17.70	16.62	15.74
Ca_{100}	22.74	19.11	17.99	17.18	15.90	22.43	18.83	17.83	16.91	15.86
Ca_{150}	22.82	19.31	18.11	17.30	16.04	22.59	18.98	17.99	17.11	16.13
Ca_{200}	22.61	18.92	17.68	16.96	15.84	22.34	18.65	17.76	16.93	15.92
LSD (0.05)	0.094	0.552	0.735	0.538	0.524	NS	1.488	1.426	1.426	0.838
Inoculatio										
I_0	22.98	18.90	17.77	16.93	15.65	22.29	18.70	17.63	16.64	15.69
I_{50}	22.64	18.96	18.83	16.99	15.71	22.31	18.75	17.77	16.76	15.70
LSD (0.05)	NS	0.346	NS	NS	NS	NS	NS	0.583	0.546	NS
St.cont.										
Sc_1	22.97	18.16	17.25	16.44	14.47	22.18	18.16	16.95	15.76	14.60
Sc_2	22.65	19.70	18.34	17.48	16.89	22.41	19.29	18.45	17.64	16.79
LSD (0.05)	0.016	0.347	0.582	0.389	0.379	NS	NS	0.582	0.546	0.596
M. level										
Ml_1	22.65	20.99	20.30	19.64	18.71	22.66	21.18	20.09	19.46	18.72
Ml_2	22.63	19.88	19.20	18.26	16.95	22.63	19.92	18.51	18.16	17.20
Ml_3	23.15	15.92	13.90	12.98	11.37	21.60	15.07	14.49	12.47	11.17
LSD (0.05)	0.003	0.346	0.130	0.085	0.087	0.004	0.122	0.063	0.130	0.122

St. cont.- Storage container, M level- Initial moisture content of the seed

The initial moisture content of the seed showed a significant effect on the speed of germination of the seed from the early stage of storage (Table 4.2.3.1). At the initial stage after 1-month of storage the seeds with lower initial moisture content retained significantly higher speed of germination than the treatment, highest initial moisture content of the seed. The treatment of 8.46% initial moisture content retained identical speed of germination with the 7.25% initial moisture content of the seed but in the later stage of storage the 8.46% initial moisture content of the seed fail to show similar speed of germination. The result indicated that the speed of germination of stored seed was highly sensitive to its initial moisture content and with the increase of initial moisture content of the seed the speed of germination reduced drastically.

4.2.3.2 Interaction of calcium and *Bradyrhizobium* fertilization on the vigour index of stored seed

The interaction of calcium and inoculation was not significant (Table 4.2.3.2).

Table 4.2.3.2 Interaction of calcium and *Bradyrhizobium* fertilization on the vigour index of stored seed

Interaction	1997-98					1998-99				
Calcium×Inocul.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times I_0$	22.39	18.33	17.33	16.30	14.88	21.84	18.39	17.12	15.85	14.84
$Ca_0 \times I_{50}$	22.38	18.48	17.46	16.42	14.96	22.95	18.47	17.29	15.99	14.81
$Ca_{50} \times I_0$	24.35	18.88	17.78	16.95	15.65	22.21	18.74	17.67	16.55	15.70
$Ca_{50} \times I_{50}$	22.62	18.92	17.84	17.06	15.72	22.24	18.73	17.73	16.69	15.79
$Ca_{100} \times I_0$	22.69	19.07	17.94	17.16	15.85	22.38	18.79	17.79	16.84	15.88
$Ca_{100} \times I_{50}$	22.80	19.14	18.03	17.21	15.96	22.49	18.87	17.87	16.97	15.84
$Ca_{150} \times I_0$	22.81	19.31	18.12	17.29	16.02	22.60	18.94	17.96	17.04	16.09
$Ca_{150} \times I_{50}$	22.83	19.31	18.11	17.31	16.06	22.58	18.01	18.02	17.17	16.17
$Ca_{200} \times I_0$	22.67	18.89	17.65	16.95	15.84	22.41	18.63	17.61	16.89	15.93
$Ca_{200} \times I_{50}$	22.56	18.94	17.71	16.97	15.84	22.28	18.67	17.91	16.96	15.92

At the later interval of months the superiority of treatment 150kg Ca/ha was visible and this treatment retained the higher speed of germination. The treatment 100kg Ca/ha with or without inoculation retained very close speed of germination with the treatment 150kg Ca/ha with or without inoculation. The lowest speed of germination was retained by the control plot with or with out inoculation. Often, inoculated seed retained higher speed of germination than the uninoculated one.

4.2.3.3 Interaction of calcium and storage container on the vigour index of stored seed

The interaction of calcium and storage container was significant at an interval of 2-month (Table 4.2.3.3).

Table4.2.3.3 Interaction of calcium and storage container on the vigour index of stored seed

Interaction	1997-98					1998-99				
Ca×St.cont.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times Sc_1$	22.37	17.84	16.78	15.96	13.93	21.74	17.75	16.53	15.02	13.77
$Ca_0 \times Sc_2$	22.40	18.97	18.00	16.76	15.91	22.04	19.12	17.89	16.82	15.88
$Ca_{50} \times Sc_1$	24.36	18.08	17.27	16.42	14.39	22.11	18.20	16.92	15.65	14.68
$Ca_{50} \times Sc_2$	22.61	19.72	18.36	17.59	16.98	22.34	19.27	18.48	17.59	16.81
$Ca_{100} \times Sc_1$	22.71	18.28	17.46	16.66	14.64	22.29	18.29	17.06	15.92	14.68
$Ca_{100} \times Sc_2$	22.78	19.93	18.51	17.71	17.17	22.57	19.37	18.61	17.89	17.04
$Ca_{150} \times Sc_1$	22.78	18.44	17.55	16.74	14.81	22.46	18.45	17.19	16.19	15.04
$Ca_{150} \times Sc_2$	22.86	20.18	18.68	17.86	17.27	22.72	19.51	18.79	18.02	17.22
$Ca_{200} \times Sc_1$	22.62	18.13	17.19	16.42	14.58	22.29	18.12	17.04	16.00	14.83
$Ca_{200} \times Sc_2$	22.60	19.71	18.17	17.50	17.11	22.39	19.17	18.48	17.86	17.02
LSD (0.05)	NS	0.101	0.238	0.159	0.155	NS	0.223	0.114	0.238	0.223

At an interval of 3-month the mean started to segregate and showed significant difference between the mean and this result continued up to 5-month interval of stored seed. The seeds with higher dose of calcium and stored in polythene bags retained the highest speed of germination in all the intervals and the seeds of control plot stored in tin container retained the lowest speed of germination in all the intervals. The result indicated that storage container and calcium started to exerting their effect from the early months of storage but the inherent potentiality of the stored seed to germinate with adequate speed hidden the effects of the treatments at early stage of storage.

4.2.3.4 Interaction of *Bradyrhizobium* fertilization and storage container on the vigour index of stored seed

The interaction of inoculation and storage container was not significant from the early stage of storage. The seeds that were stored in polythene bags retained superior speed of germination over the seed stored in tin container. Inoculation had a positive effect on the speed of germination of seeds in both the containers. The results revealed that storage container play a vital role in restoring the speed of germination of stored seed and polythene bag was better storage materials.

4.2.3.5 Interaction of calcium, *Bradyrhizobium* fertilization and storage container on the vigour index of stored seed

The speed of germination did not vary by the interaction of calcium, inoculation and storage container. The seed containing higher doses of calcium and stored in polythene bags showed superiority over seeds with lower doses of calcium and stored in polythene bags. The seed stored in tin container with or without inoculation fails to maintain the speed of germination of stored seed to the level that was retained by the seed stored in polythene bags with different level of calcium. The results indicate that inoculation play very little role in the interaction process of the stored seed.

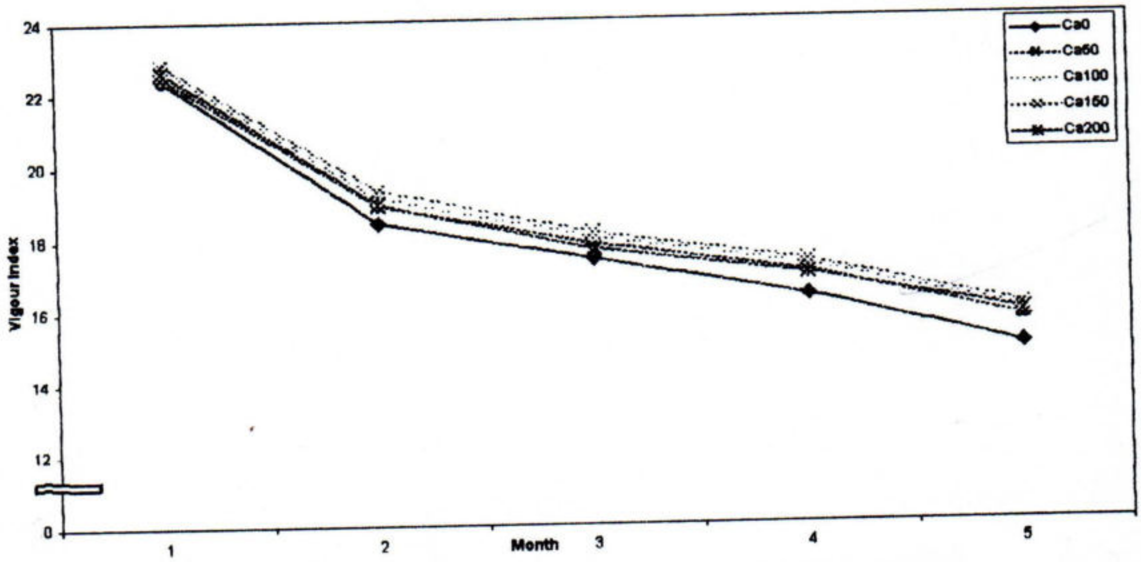


Fig 4.2.3.1.1 Effect of calcium on the vigour index of stored seed in 1997-98

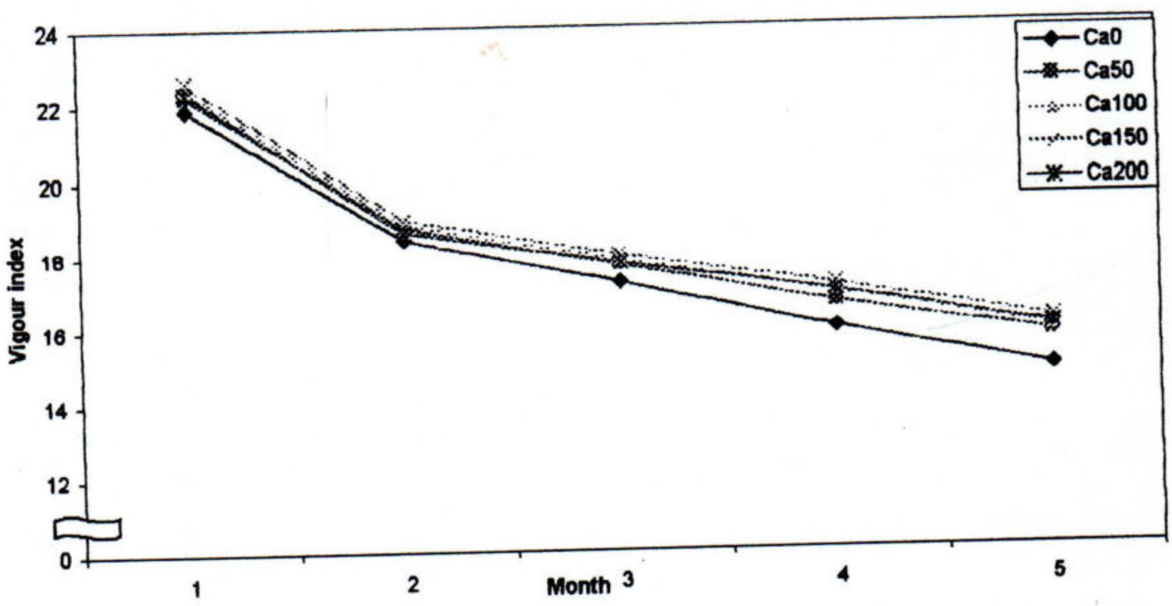


Fig 4.2.3.1.2 Effectof calcium on the vigour index of stored seed in 1998-99

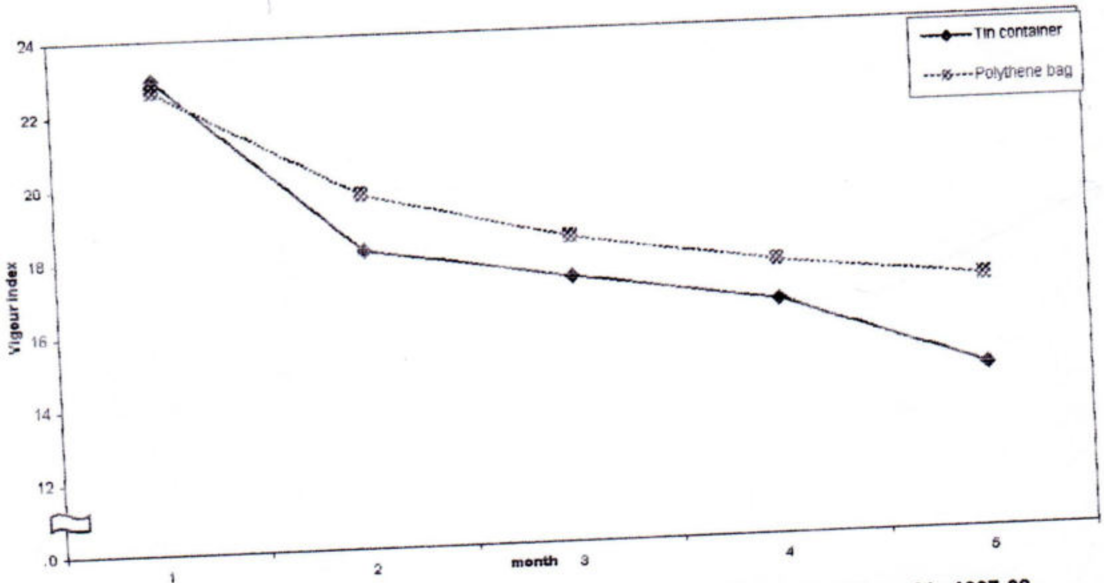


Fig 4.2.3.1.3 Effect of storage container on the vigour index of stored seed in 1997-98

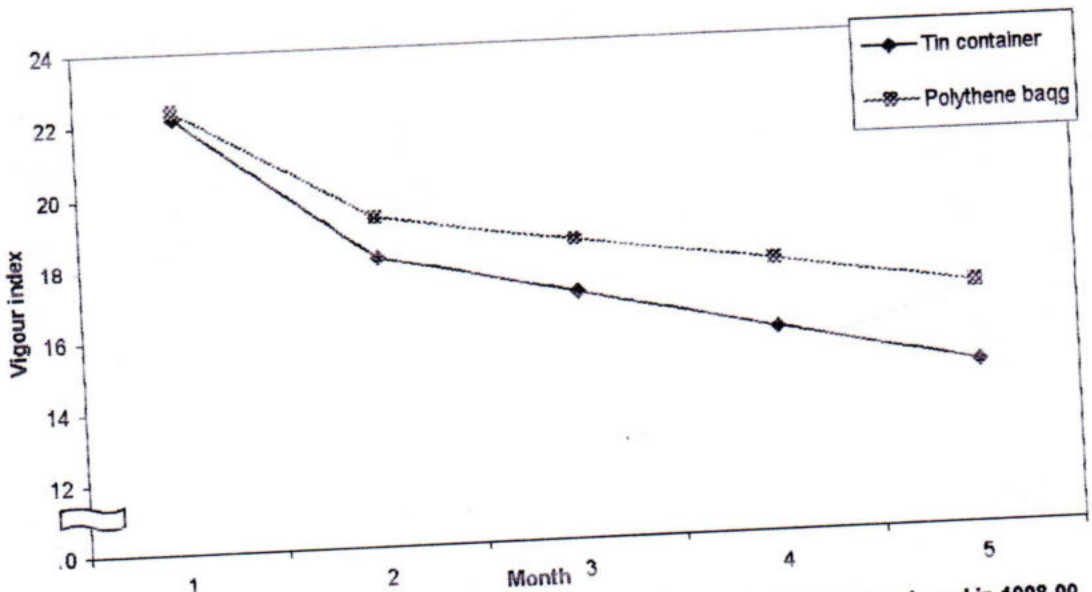


Fig 4.2.3.1.4Effect of storage container on the germination percentage of stored seed in 1998-99

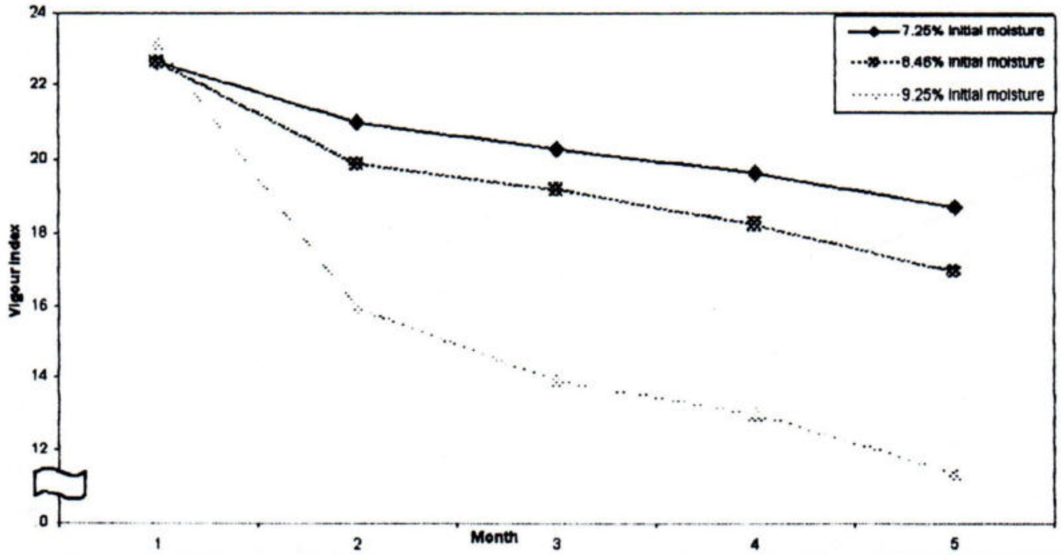


Fig 4.2.3.1.5Effect of initial moisture content of the seed on the vigour index of stored seed in 1997-98

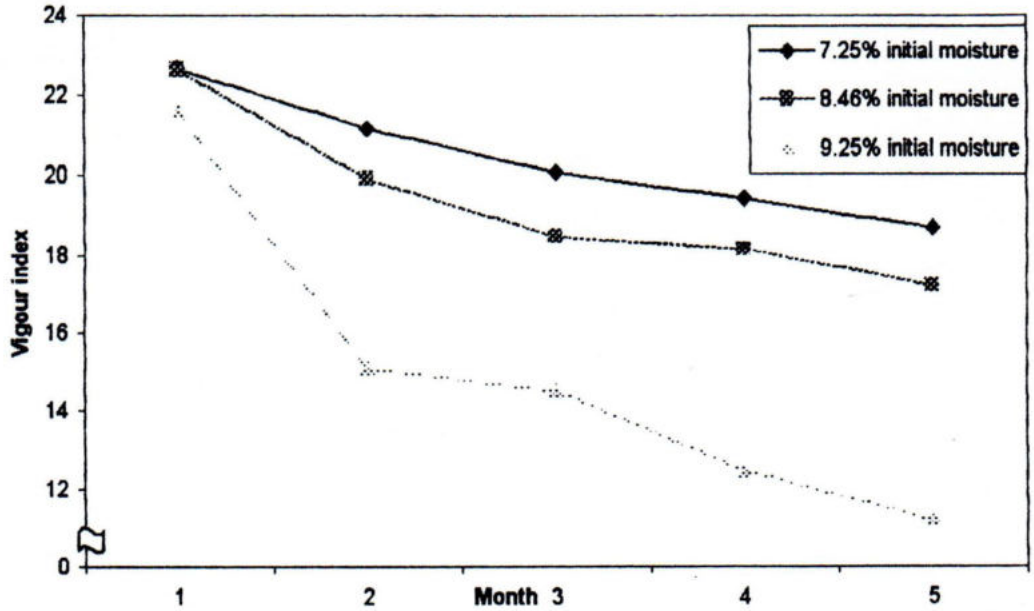


Fig 4.2.3.1.6 Effect of initial moisture content of seed on the vigour indexof stored seed in 1998-99

4.2.3.6 Interaction of calcium and initial moisture content of seed on the vigour index of stored seed

The interaction of calcium and initial seed moisture content was distinct and significant from the early stage of storage in 1997-98 (Table-4.2.3.4). Seed with 7.25% initial moisture content with higher doses of calcium retained the highest speed of germination. The seed of higher doses of calcium with 8.46% initial moisture content retained its superiority over seed with 9.25% initial moisture content. Higher doses of calcium retained at par speed of germination with lower or zero dose of calcium at 7.25% initial moisture content up to 3-month of interval. After that the seeds with 7.25% initial moisture content with higher doses of calcium showed significant superiority over seeds with 8.46% initial moisture content with lower doses of calcium.

Table 4.2.3.4 Interaction of calcium and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
Ca×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0 \times Ml_1$	22.42	20.67	19.73	18.87	17.92	22.42	21.01	19.28	18.38	17.15
$Ca_0 \times Ml_2$	22.36	19.62	18.88	17.83	16.14	22.35	19.40	18.13	17.38	16.52
$Ca_0 \times Ml_3$	22.38	14.93	13.57	12.38	10.69	20.92	14.89	14.21	11.99	10.80
$Ca_{50} \times Ml_1$	22.59	20.94	20.40	19.70	18.70	22.58	21.13	20.23	19.41	18.87
$Ca_{50} \times Ml_2$	22.57	19.77	19.17	18.29	17.00	22.58	19.96	18.49	18.15	17.23
$Ca_{50} \times Ml_3$	22.29	15.98	13.87	13.02	11.35	22.52	15.12	14.38	12.31	11.13
$Ca_{100} \times Ml_1$	22.77	21.14	20.57	19.97	18.95	22.75	21.26	20.33	19.70	19.12
$Ca_{100} \times Ml_2$	22.77	19.99	19.34	18.40	17.22	22.75	20.08	18.67	18.40	17.17
$Ca_{100} \times Ml_3$	22.70	16.19	14.05	13.18	11.54	22.80	15.15	14.51	12.62	11.28
$Ca_{150} \times Ml_1$	22.83	21.28	20.67	20.08	19.06	22.87	21.42	20.47	19.98	19.34
$Ca_{150} \times Ml_2$	22.82	20.18	19.48	18.53	17.33	22.88	20.23	18.80	18.55	17.67
$Ca_{150} \times Ml_3$	22.80	16.47	14.19	13.30	11.73	22.02	15.28	14.70	12.78	11.39
$Ca_{200} \times Ml_1$	22.63	20.90	20.12	19.58	18.91	22.68	21.08	20.13	19.83	19.10
$Ca_{200} \times Ml_2$	22.63	19.83	19.13	18.26	17.07	22.60	19.93	18.47	18.30	17.42
$Ca_{200} \times Ml_3$	22.57	16.02	13.80	13.04	11.55	21.74	14.93	14.68	12.66	11.25

The seed with 9.25% initial moisture content of seed retained the lowest speed of germination of stored seed. The result indicated that the interaction of moisture with calcium showed dominance with passes of time. In 1998-99 at the early stage of storage the treatments failed to show any significant effect on speed of germination of stored seed. Other interval showed similar trend with 1997-98.

4.2.3.7 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed.

The interaction of inoculation and initial moisture content of the seed did not show significant effect on the speed of germination of stored seed in 1997-98 and 1998-99.

4.2.3.8 Interaction of calcium, *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed.

The interaction of calcium, inoculation and initial moisture content of the seed was not significant in 1997-98 and 1998-99.

4.2.3.9 Interaction of storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of storage container and initial moisture content of seed affected the speed of germination of the stored seed significantly (Table- 4.2.3.5). At an interval of 1-month the interaction on the speed of germination was not significant because of inherent potentiality of the seed to germinate with uniform speed. From the interval of 2-month the seed with higher initial moisture content stored in polythene bags retained identical speed of germination with seeds with lower initial moisture content and stored in tin container. From the 3-month interval all the treatment interacted significantly. Seeds with 7.25% initial moisture content, stored in polythene bags retained the highest speed of germination while seeds with 9.25% initial moisture content and stored in tin container retained the lowest speed of germination of the stored seed. The results are in agreement with Suchanya *et.al.* (1986).

Table 4.2.3.5 Interaction of storage container and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
St.con×M.lev.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	22.64	20.57	19.69	18.74	17.26	22.65	20.66	19.55	18.74	18.15
$Sc_1 \times Ml_2$	22.60	19.28	18.76	18.03	16.52	22.62	19.26	17.65	17.28	15.88
$Sc_1 \times Ml_3$	23.67	14.62	13.30	12.54	9.63	21.28	14.57	13.63	11.24	9.77
$Sc_2 \times Ml_1$	22.66	21.41	20.90	20.53	20.16	22.67	21.70	20.62	20.18	19.28
$Sc_2 \times Ml_2$	22.65	20.48	19.64	18.49	17.39	22.65	20.58	19.37	19.03	18.53
$Sc_2 \times Ml_3$	22.63	17.22	14.49	13.43	13.11	21.93	15.58	15.36	13.70	12.57
LSD (0.05)	NS	0.110	0.184	0.120	0.123	NS	0.173	0.089	0.184	0.173

4.2.3.10 Interaction of calcium, storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of calcium, storage container and initial moisture content of the seed was not significant at an interval of 1-month in 1997-98 and 1998-99 (Table 4.2.3.6).

Table 4.2.3.6 Interaction of calcium, storage container and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
Ca×St.con×Mlevel	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Ca_0\times Sc_1\times Ml_1$	22.42	20.37	19.15	18.18	16.53	20.42	20.47	18.87	17.67	16.52
$Ca_0\times Sc_1\times Ml_2$	22.33	19.07	18.32	17.65	16.02	22.40	18.43	17.45	16.67	15.45
$Ca_0\times Sc_1\times Ml_3$	22.37	14.10	12.88	12.05	9.25	22.42	14.35	13.27	10.72	9.35
$Ca_0\times$I $Sc_2\times Ml_1$	22.43	20.97	20.30	19.55	19.32	22.42	21.55	19.70	19.10	17.78
$Ca_0\times Sc_2\times Ml_2$	22.38	20.17	19.43	18.02	16.27	22.30	20.37	18.82	18.10	17.60
$Ca_0\times Sc_2\times Ml_3$	22.38	15.77	14.27	12.70	12.13	21.42	15.43	15.15	13.27	12.25
$Ca_{50}\times Sc_1\times Ml_1$	22.55	20.57	19.78	18.75	17.17	22.53	20.62	19.67	18.75	18.47
$Ca_{50}\times Sc_1\times Ml_2$	22.53	19.13	18.73	17.99	16.45	22.53	19.32	17.65	17.10	15.85
$Ca_{50}\times Sc_1\times Ml_3$	28.00	14.55	13.28	12.52	9.55	21.27	14.67	13.43	11.10	9.73
$Ca_{50}\times Sc_2\times Ml_1$	22.63	21.32	21.02	20.65	20.23	22.62	21.65	20.80	20.07	19.27
$Ca_{50}\times Sc_2\times Ml_2$	22.60	20.42	19.62	18.60	17.55	22.62	20.60	19.33	19.20	18.62
$Ca_{50}\times Sc_2\times Ml_3$	22.58	17.42	14.45	13.53	13.15	21.78	15.57	15.32	13.52	12.53
$Ca_{100}\times Sc_1\times Ml_1$	22.75	20.70	19.95	19.05	17.52	22.70	20.77	19.77	18.90	18.58
$Ca_{100}\times Sc_1\times Ml_2$	22.73	19.37	18.95	18.18	16.68	22.70	19.45	17.78	17.47	15.57
$Ca_{100}\times Sc_1\times Ml_3$	22.65	14.78	13.48	12.75	9.72	21.48	14.65	13.62	11.40	9.88
$Ca_{100}\times Sc_2\times Ml_1$	22.78	21.58	21.18	20.88	20.38	22.80	21.75	20.88	20.50	19.65
$Ca_{100}\times Sc_2\times Ml_2$	22.80	20.62	19.73	18.62	17.75	22.80	20.70	19.55	19.33	18.78
$Ca_{100}\times Sc_2\times Ml_3$	22.75	17.60	14.62	13.62	13.37	22.12	15.65	15.40	13.83	12.68
$Ca_{150}\times Sc_1\times Ml_1$	22.80	20.78	19.98	19.07	17.68	22.85	20.90	19.92	19.27	18.75
$Ca_{150}\times Sc_1\times Ml_2$	22.80	19.58	19.07	18.33	16.82	22.83	19.68	17.88	17.70	16.35
$Ca_{150}\times Sc_1\times Ml_3$	22.75	14.95	13.60	12.83	9.92	21.70	14.77	13.77	11.60	10.03
$Ca_{150}\times Sc_2\times Ml_1$	22.87	21.78	21.35	21.08	20.43	22.88	21.93	21.02	20.70	19.93
$Ca_{150}\times Sc_2\times Ml_2$	22.85	20.78	19.90	18.73	17.85	22.93	20.78	19.72	19.40	18.98
$Ca_{150}\times Sc_2\times Ml_3$	22.85	17.98	14.78	13.77	13.53	22.35	15.80	15.63	13.97	12.75
$Ca_{200}\times Sc_1\times Ml_1$	22.67	20.42	19.57	18.67	17.40	22.73	20.53	19.53	19.13	18.45
$Ca_{200}\times Sc_1\times Ml_2$	22.62	19.25	18.73	18.02	16.62	22.62	19.42	17.50	17.47	16.17
$Ca_{200}\times Sc_1\times Ml_3$	22.57	14.72	13.27	12.57	9.73	21.52	14.42	14.08	11.40	9.87
$Ca_{200}\times Sc_2\times Ml_1$	22.60	21.38	20.67	20.48	20.42	22.63	21.62	20.72	20.52	19.75
$Ca_{200}\times Sc_2\times Ml_2$	22.63	20.40	19.52	18.50	17.53	22.58	20.45	19.43	19.13	18.67
$Ca_{200}\times Sc_2\times Ml_3$	22.58	17.33	14.33	13.52	13.37	21.97	15.45	15.28	13.92	12.63
SD (0.05)	NS	0.245	0.412	0.268	0.275	NS	0.386	0.198	0.412	0.386

From the interval of 2-month the interaction of the treatments were significant. The highest speed of germination was retained by the treatments 150kg Ca/ha with 7.25% initial moisture content of seed and stored in polythene bags and the lowest speed of germination was obtained by treatment 200 kg Ca /ha with 9.25% initial moisture content of the seed and stored in tin container. The result indicated that calcium, storage container and initial moisture content of the seed played the most dominant role in maintaining the vigour index of stored seed.

4.2.23.11 Interaction of *Bradyrhizobium* fertilization, storage container and initial moisture content of the seed on the vigor index of stored seed

The interaction of inoculation, storage container and initial moisture content of the seed was significant from the interval of 2-month (Table 4.2.3.7). The seeds with 7.25% initial moisture content with inoculation and stored in polythene bags retained significantly higher speed of germination than the seed with the same treatment and without inoculation. The seeds with 8.46% of initial moisture content stored in polythene bags retained identical speed of germination. The seeds with 9.25% moisture content with or with out inoculation but stored in tin container differed significantly with the former treatments.

Table 4.2.23.7 Interaction of inoculation, storage container and initial moisture content of seed on vigour index of stored seed

Interaction	1997-98					1998-99				
Ca×S.cont×M.lev el	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$I_0 \times Sc_1 \times Ml_1$	22.62	20.53	19.68	18.73	17.25	22.67	20.62	19.46	18.69	18.12
$I_0 \times Sc_1 \times Ml_2$	22.59	19.27	18.73	18.00	16.49	22.63	19.21	17.63	17.25	15.99
$I_0 \times Sc_1 \times Ml_3$	22.76	14.61	13.26	12.51	9.61	21.25	14.59	13.44	11.19	9.73
$I_0 \times Sc_2 \times Ml_1$	22.65	21.39	20.86	20.53	20.13	22.67	21.68	20.61	20.06	19.24
$I_0 \times Sc_2 \times Ml_2$	22.65	20.46	19.61	18.43	17.35	22.62	20.57	19.32	18.97	18.50
$I_0 \times Sc_2 \times Ml_3$	22.62	17.12	14.45	13.38	13.07	21.88	15.53	15.31	13.66	12.55
$I_{50} \times Sc_1 \times Ml_1$	22.65	20.16	19.69	18.76	17.27	22.62	20.69	19.64	18.80	18.19
$I_{50} \times Sc_1 \times Ml_2$	22.62	19.29	18.79	18.07	16.55	22.60	19.31	17.67	17.31	15.76
$I_{50} \times Sc_1 \times Ml_3$	22.57	14.63	13.35	12.57	9.65	21.31	14.55	13.83	11.30	9.82
$I_{50} \times Sc_2 \times Ml_1$	22.68	21.42	20.95	20.53	20.19	22.67	21.72	20.63	20.29	19.31
$I_{50} \times Sc_2 \times Ml_2$	22.66	20.49	19.67	18.55	17.43	22.67	20.59	19.42	19.09	18.56
$I_{50} \times Sc_2 \times Ml_3$	22.63	17.32	14.53	13.47	13.15	21.97	15.63	15.40	13.74	12.59
LSD (0.05)	NS	0.155	0.261	0.170	0.174	NS	0.244	0.125	0.261	0.244

From the interval of 3-month the seeds with 8.46% initial moisture content lost its superiorly and retained lower speed of germination. With the advance of time in storage the seeds with initial moisture content of 7.25% with or without inoculation and stored in polythene bags retained significantly highest speed of germination and the lowest speeds of germination was obtained by seeds with 9.25% initial moisture content without inoculation and stored in tin containers. The result revealed that the effect of inoculation did not retained through the entire storage period.

4.2.23.12 Interaction of calcium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the vigor index of stored seed

The interaction of all the 4 treatments was not significant on the speed of germination. The higher speed of germination was retained by the treatment 100kg Ca /ha with inoculation stored in polythene bags with 7.25% initial moisture content of seed.

4.3.1 Effect of magnesium and *Bradyrhizobium* fertilization on the growth and yield of groundnut

4.3.1.1 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on plant height

Plant height did not differ significantly in 1997-98 and 1998-99 with different level of magnesium (Table 4.3.1.1). There was an irregular trend in the height of the plant. In 1997-98 the longest plant was produced in the treatment of 5kg Mg/ha and the shortest plant was produced in the treatment 10kg Mg/ha and in 1998-99 the longest plant was produced in the treatment of 15kg Mg/ha and the shortest plant was produced in control plot. Other treatment produced intermediary results in both the years. The result showed that magnesium has no definite effect on the height of the plant.

Bradyrhizobium fertilization had not affected the plant height significantly. In 1997-98-inoculation fail to improve the height of the plant but in 1998-99 it increased the height of the plant.

The height of the plant had a mixed effect due to interaction of magnesium and inoculation. In 1997-98 the interaction did not affect the height of the plant significantly but the longest plant was obtained in the treatment of 15kg Mg/ha without inoculation and the shortest plant was produced in the control plot. In 1998-99 the height of the plant showed the similar trend.

4.3.1.2 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on number of branches/plant

Magnesium affected the number of branches per plant significantly in 1997-98 but was not significant in 1998-99 (Table 4.3.1.1). In the first year the highest number of branches per plant was obtained in the treatment of 15kg Mg/ha that was followed by the treatment of 20kg Mg/ha and 10kg Mg/ha. 5kg Mg/ha and control plot produced significantly lower number of branches per plant. In 1998-99 the mean showed an irregular variation. The result might be due to the fact that magnesium encouraged branching.

Table 4.3.1.1 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on plant height and number of branches/plant

Treatment	Plant height (cm)		Number of branches/plant	
	1997-98	1998-99	1997-98	1998-99
Mg dose (kg/ha)				
M_0	49.21	42.33	3.933	4.23
M_5	50.15	43.70	4.050	4.03
$M1_0$	48.97	42.80	5.033	4.43
M_{15}	49.66	47.30	5.100	4.20
M_{20}	49.21	44.30	4.683	4.83
LSD (0.05)	NS	NS	0.597	NS

The effect of *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99. The average number of branches/plant was higher in the first year than that of second year. The result revealed that inoculation of groundnut with *Rhizobium* species increases the number of branches. Desmukh and Dev (1995) observed similar result.

Interaction of magnesium and inoculation was not significant in 1997-98 and 1998-99.

4.3.1.3 Effect of magnesium and *Bradyrhizobium* and their interaction on number of mature pods/ plant

The effect of magnesium was significant on the number of mature pod per plant in 1997-98 and 1998-99 (Table 4.3.1.2). In 1997-98 the highest number of pod per plant was produced in the treatment of 10kg Mg/ha and the treatment 15kg Mg/ha produced at par number with the former treatment. Other treatment produced poorer number of mature pod per plant and the lowest one was obtained in the control plot. In 1998-99 similar trend was observed except that 15kg Mg/ha produced significantly different number of mature pod per plant than 10kg Mg/ha. The result showed that magnesium encourages the number of matured pod by improving the friutsetting. Walker *et.al.* (1988), Taufiq and Sudaryono (1997), Sudhir *et. al.* (1987) found similar results.

The effect of *Bradyrhizobium* fertilization was significant in 1997-98 and 1998-99 the number of mature pods per plant. Inoculation affected number of mature pod per plant and produced higher number of mature pod per plant over uninoculated one. The result might be due to the fact that *Rhizobium* inoculum increased the number of pod per plant. Lee *et al.* (1990) obtained similar result.

The interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1998-99 only. The highest number of pod in 1998-99 was produced in the inoculated plot without magnesium, which produced at par number of mature pod with 10kg Mg/ha with inoculation. Others produced lower number of mature pod and the lowest was produced in the control plot. In 1997-98 the trend of number of mature pod was similar.

4.3.1.4 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on number of immature pods/ plant

Magnesium did not show a significant effect on the number of immature pod per plant in both the year (Table 4.3.1.2).

Table 4.3.1.2 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on mature and immature pods/plant

Treatment	Number of mature pod/plant		Number of immature pod /plant	
	1997-98	1998-99	1997-98	1998-99
Mg dose (kg/ha)				
M_0	10.70	10.13	3.550	3.233
M_5	11.67	11.77	4.083	2.667
$M1_0$	13.63	13.43	3.650	3.267
M_{15}	14.72	12.47	4.917	3.133
M_{20}	13.18	11.93	4.433	3.500
LSD (0.05)	1.582	0.7823	1.166	NS
Inoculation(g/kg seed)				
I_0	12.55	11.25	4.28	3.01
I_{50}	13.01	12.64	3.97	23.72
LSD (0.05)	0.499	0.783	NS	NS
Magnesium×Inoculation				
$Mg_0 \times I_0$	10.50	9.80	3.600	3.267
$Mg_5 \times I_0$	10.90	10.47	3.500	3.200
$Mg_{10} \times I_0$	11.60	11.00	3.900	2.933
$Mg_{15} \times I_0$	11.73	12.53	4.267	2.400
$Mg_{20} \times I_0$	13.37	12.33	3.900	2.867
$Mg_0 \times I_{50}$	13.90	14.53	3.400	3.667
$Mg_5 \times I_{50}$	14.47	11.53	5.633	2.867
$Mg_{10} \times I_{50}$	14.97	13.40	4.200	3.400
$Mg_{15} \times I_{50}$	12.83	11.60	4.367	3.133
$Mg_{20} \times I_{50}$	13.53	12.27	4.500	3.867
LSD (0.05)	NS	0.7823	NS	NS

The number of immature pod did not followed any specific trend in the first year, higher number of immature pod was produced due to excess magnesium whereas in 1998-99 it followed an irregular trend. Taufiq and Sudaryono (1997) found similar results.

Bradyrhizobium fertilization lowered the number of immature pod per plant significantly in 1997-98 and 1998-99. Plot with out inoculation produced significantly higher number of immature pod per plant and the same trend was followed in the successive year.

The interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1997-98 and 1998-99 (Table 4.3.1..2). The trend of number of immature pod per plant did not follow any specific trend due to interaction but there was a general trend of higher number of immature pod in the treatment of higher magnesium with inoculation.

4.3.1.5 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on %shelling

Percentage of shelling was affected significantly by magnesium in 1997-98 and 1998-99 (Table 4.3.1.3). The highest percentage of shelling was obtained in the treatment of 10kg Mg/ha, which was followed by 15kg Mg/ha. Other treatments produced lower percentage of shelling and the lowest percentage of shelling was produced in control. In 1998-99 10kg Mg/ha and 5kg Mg/ha produced identical percentage of shelling while other produced poorer percentage of shelling and the mean did not differ significantly. The result showed that application of magnesium had a consistent effect on the shelling percentage of groundnut. Inoculation affected the shelling percentage at 5% level of significance in 1997-98 and 1998-99. The inoculated plants produced significantly higher percentage of shelling over uninoculated one. In 1998-99 the inoculated plant produced superior shelling percentage.

The interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1998-99. The highest percentage of shelling was obtained in the inoculated plot with out magnesium and the lowest was produced in the control plot and other treatment produced intermediary results. In 1997-98 the interaction was not significant.

Table 4.3.1.3 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on % shelling and harvest index

Treatment	%Shelling		Harvest index	
	1997-98	1998-99	1997-98	1998-99
Mg dose (kg/ha)				
M_0	64.10	61.29	31.70	32.62
M_5	65.70	63.51	31.98	34.21
$M1_0$	67.55	64.94	33.84	35.89
M_{15}	67.34	62.85	34.08	34.75
M_{20}	66.19	61.49	34.22	34.69
LSD (0.05)	1.009	1.799	1.432	1.591
Inoculation(g/kg seed)				
I_0	65.67	62.11	33.01	34.50
I_{50}	66.68	63.52	33.32	34.36
LSD (0.05)	1.009	1.799	NS	NS

4.3.1.6 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on harvest index

The effect of magnesium on the harvest index was significant in 1997-98 and 1998-99(Table 4.3.1.4). In 1997-98 highest harvest index was obtained in the treatment of 20kg Mg/ha that was followed by 15kg Mg/ha, 10kg Mg/ha, and 5kg Mg/ha and control plot produced significantly lower harvest index. In 1998-99 the highest harvest index was obtained in 10kg Mg/ha and other treatment produced lower harvest index. The result indicated that magnesium increased much the pod yield in comparison to total biological yield.

Bradyrhizobium fertilization affected the harvest index of the crop but increment in index due to inoculum was not significant. In both the years inoculation increased the harvest index but the increment rate was lower in 1997-98.

The interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1998-99. In 1997-98 inoculated plot without magnesium produced the highest harvest index, which was followed by 15kg Mg/ha aand10kg Mg/ha with inoculation. Similar results were also obtained in 1998-99. In the later year the highest harvest index was obtained in the treatment of 20kg Mg/ha with out inoculation and the second highest was obtained in the plot inoculation with no magnesium.

4.3.1.7 Effect of magnesium and *Bradyrhizobium* and their interaction on 100 seed weight

The effect of magnesium on the 100 seed weight was significant in 1997-98 and 1998-99. In 1997-98 the highest 100 seed weight was produced in the treatment of 15kg Mg/ha while 10 and 20kg Mg/ha produced comparable weight of 100 seed. The lightest seed was produced in the control plot, which was at par in weight with 5kg Mg/ha. In 1998-99 the heaviest weight 100 seed was produced in 10kg Mg/ha, which produced identical weight of seed with 5kg Mg/ha, and 15kg Mg/ha. The result indicated that dry matter production increased with the application of increasing magnesium doses and the 100 seed weight of groundnut also increased.

Bradyrhizobium fertilization did not affect the 100 seed weight significantly in 1997-98 and 1998-99 but there was regular increase in weight of 100 seed due to inoculation. The results indicate that inoculation with *Bradyrhizobium* inoculation increases the 100 seed weight of groundnut. Similar results were also obtained by Pulatova *et.al.*(1999).

The interaction of magnesium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99 (Table 4..3.1.4). In 1997-98 the heaviest 100 seed was obtained in the treatment of 10kg Mg/ha with inoculation and lightest one was produced in the treatment 5kg Mg/ha and control plot. Other treatment of magnesium alone produced poorer weight of 100 seed except the treatment 20kg Mg/ha with out inoculation which produced at par weight with the inoculated plots. In 1998-99 the heaviest weight of 100 seed was produced in the treatment of inoculation with no magnesium and the lightest seed was produced in the control plot. Other treatment produced intermediary results though the mean did not vary significantly. The result might be due to the fact that higher doses of magnesium improve the 100 seed weight but other characteristics did not followed the same trend.

Table 4.3.1.4 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on 100 seed weight and pod yield

Treatment	100 seed weight (g)		Nut yield kg/ha	
	1997-98	1998-99	1997-98	1998-99
Mg dose (kg/ha)				
M_0	25.22	23.06	1.48	1.55
M_5	26.13	25.99	1.55	1.62
MI_0	29.00	26.12	1.63	1.74
M_{15}	29.42	24.53	1.58	1.72
M_{20}	28.17	22.72	1.55	1.66
LSD (0.05)	1.787	1.698	0.0767	0.0939
Inoculation(g/kg seed)				
I_0	27.42	24.32	1.54	1.63
I_{50}	27.75	24.64	1.57	1.68
LSD (0.05)	NS	NS	0.0767	0.0939

4.3.1.8 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on pod yield

Magnesium affected the yield of groundnut significantly in 1997-98 and 1998-99(Table4..3.1.4) In 1997-98 magnesium treated plot produced superior yield over control though 20kg Mg/ha and 5kg Mg/ha produced identical yield with control plot. In 1998-99 the highest yield was obtained in 10kg Mg/ha and higher doses of magnesium produced identical yield with highest yield and lower doses of magnesium produced at par yield with control plot. In 1997-98 and 1998-99 control plot produced the lowest yield. The result might be due to the fact that higher doses of magnesium improve the pod yield of groundnut as the dry matter production increased with the application of increasing magnesium doses. Walker *et.al.* (1990), Kale, (1991), Sudhir *et al.* (1987) and Maliwal and Tank (1988) observed similar results.

Bradyrhizobium fertilization increased the yield of groundnut in 1997-98 and 1998-99 but was not significant. The rate of increment in yield was higher in the later year. This might be due to the influence of other edaphic and environmental factors. The results are in partial agreement with Kulkarni *et al.* (1989).

The interaction of magnesium and *Bradyrhizobium* fertilization was not significant in 1997-98 and 1998-99. The higher yield was obtained in inoculated plot with no magnesium and the lowest yield was obtained in the control plot. Other treatment produced intermediary results and the trend of increment in yield did not follow the same trend.

4.3.1.9 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on % oil content of seed

The oil content of the seed was influenced significantly by different doses of magnesium in 1997-98 and 1998-99(Table 4..3.1.5). In 1997-98 the highest percentage of oil was produced in the treatment of 10kg Mg/ha that produced identical percentage with 15kg Mg/ha. Other treatment of magnesium produced statistically poorer percentage of oil content and the lowest percentage of oil content was produced in the control plot. In 1998-99 similar trend of oil content was also obtained i.e., magnesium increased the oil content of groundnut seed up to 10kg/ha and doses above or below the optimum dose reduces the oil content of the seed. The result showed that seed oil content increased with the application of magnesium as it influences the oil production of groundnut. The results are in agreement with Kale (1991).

Inoculation modified the oil content of the seed but was not significant. In 1997-98 and 1998-99 inoculation increased the oil content of the seed and in the later year the increment in oil content was higher (Table 4.3.1.5).

Table 4.3.1.5 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on %protein and %oil content of seed

Treatment	%Protein content of seed		% Oil content of seed	
	1997-98	1998-99	1997-98	1998-99
		Mg dose (kg/ha)		
M_0	20.77	22.54	50.06	50.06
M_5	21.63	23.99	51.48	51.48
$M1_0$	23.13	25.20	52.21	52.21
M_{15}	23.14	23.84	51.22	51.22
M_{20}	22.58	23.65	50.34	50.34
LSD (0.05)	0.7378	1.102	0.8628	0.9317
		Inoculation(g/kg seed)		
I_0	22.00	23.16	50.86	50.86
I_{50}	22.50	24.53	51.27	51.27
LSD (0.05)	0.7378	1.102	NS	0.9317

The interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1997-98 and 1998-99. In the entire years inoculated plot with no magnesium and the control plot produced highest and lowest percentage of oil content, respectively. Other treatment produced intermediary results and the trend of increment in yield did not follow any specific trend but there was a similarity in the trend. The results indicated that inoculation and magnesium increased the oil content of groundnut seed but excess magnesium with inoculation reduces the oil content of the seed.

4.3.1.10 Effect of magnesium and *Bradyrhizobium* fertilization and their interaction on % protein content of seed

Protein content of seed was greatly influenced by magnesium in 1997-98 and 1998-99(Table 4..3.1.5). The effect of magnesium on protein content was highly significant. In 1997-98 the highest percentage of protein content was obtained in the plot 15kg Mg/ha, which was identical with other two higher, doses of magnesium. 5kg Mg/ha and control plot produced identical yield. In 1998–99the highest percentage of protein content was obtained with the treatment 10kg Mg/ha other doses of magnesium produced significantly higher parentage of protein content over control plot but significantly poorer than that of 10 kg Mg/ha. The results indicate that magnesium has a profound effect on the protein content of groundnut seed as it the integral pant of protein.

Bradyrhizobium inoculation increased the protein content of the seed. In 1997-98 the increase in protein content of seed was not significant but in 1998-99 the increment was significantly superior over uninoculated one.

Interaction of magnesium and *Bradyrhizobium* fertilization was significant in 1997-98 and 1998-99. In 1997-98 the highest percentage of protein content was obtained with the treatment of 10kg Mg/ha with inoculation and lowest percentage was produced in control plot. In 1998-99 similar pattern of protein content in seed was obtained except the highest content of protein was obtained with inoculated plot with no magnesium. It indicates that inculcation with lower doses of magnesium has a positive effect on the protein content of the seed but as the doses of magnesium increases the protein content of seed also declines.

4.3.2.1 Effect of magnesium, *Bradyrhizobium* fertilization, storage container and initial seed moisture content on the germination percentage of stored seed

At an interval of 1-month, the effect of magnesium on the germination percentage of seed was insignificant in 1997-98 and significant in 1998-99(Table 4.3.2.1). At an interval of 2- month the magnesium content of the seed affected the germination percentage of stored seed. In 1997-98 10kg Mg /ha retained the highest percentage of germination over other, similar results were also obtained in 1998-99. From the interval of 3-month the seed with 10kg Mg/ha retained the highest germination percentage and the lowest percentage was obtained in the control. The result indicated that magnesium content of the seed did not affect the germination percentage of stored seed at early stage of storage because of the fact that the viability and vigour of the seed at an interval of 1 month did not deteriorate and after that it started to deteriorate and from then the effect of magnesium became distinct. Juangiun and Sumran (1991) obtained similar results.

The effect of *Bradyrhizobium* fertilization was not significant on the percentage of germination at all the intervals in 1997-98 except the interval of 2-month. In 1998-99 the effect of inoculation on the percentage of germination was significant at all the intervals except at an interval of 1-month. The result indicated that inoculation of seed play a notable role in increasing the germination percentage of stored seed.

The effect of storage container on the germination percentage of stored seed was significant in 1997-98 and 1998-99. The potentiality of the seed to germinate at standard percentage as approved by the ISTA was found to decrease with the passage of time. The seed stored in polythene bag retained the standard germination percentage up to 5-month interval whereas the seed stored in tin container lost it with in 4 month. Similar result was shown in both the years. Choudhury *et.al.*(1990) reported same results. The effect of initial moisture of the seed was significant in 1997-98 and 1998-99 from 1-month of storage and this result continues up to 5-month interval. The highest percentage of germination was retained by the treatment 7.25% initial moisture content of seed and the lowest percentage was obtained in 9.25% initial moisture content. The result indicated that the initial moisture content of the seed is very important for retaining germination percentage of seed and lower the initial moisture content of seed the higher the duration of viability of seed in storage. The results are in agreement with Prasat (1990).

4.3.2.2 Interaction of *Bradyrhizobium* fertilization and magnesium on the germination percentage of stored seed

The interaction of *Bradyrhizobium* fertilization and magnesium was not significant in 1997-98 and 1998-99. From the interval of 3-month effect of magnesium on the

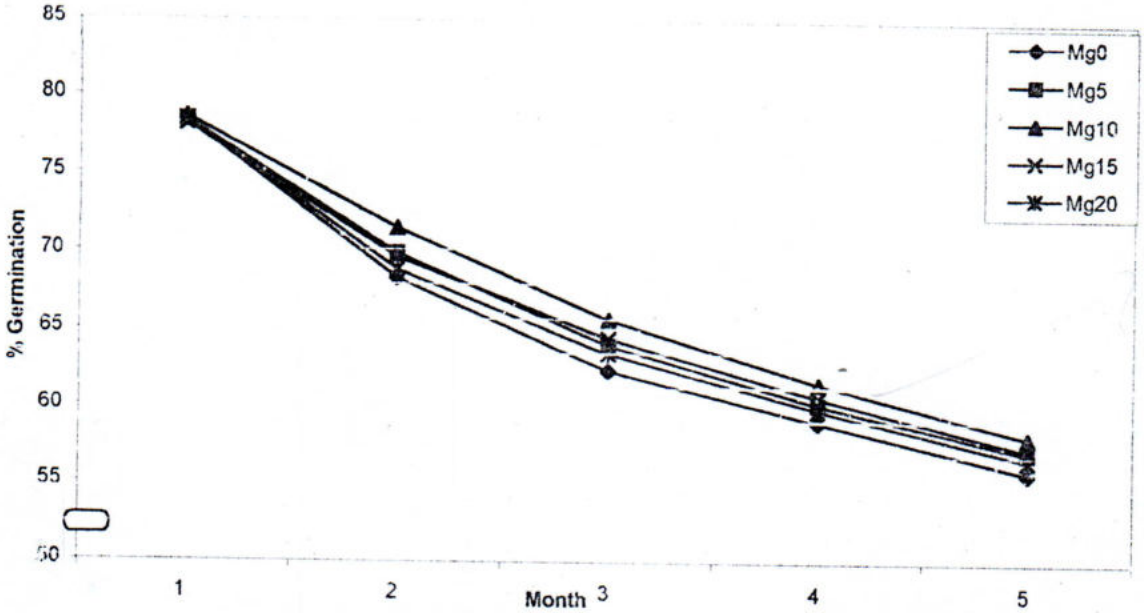


Fig 4.3.2.2.1Effect of magnesium on the germination percentage of stored seed in 1997-98

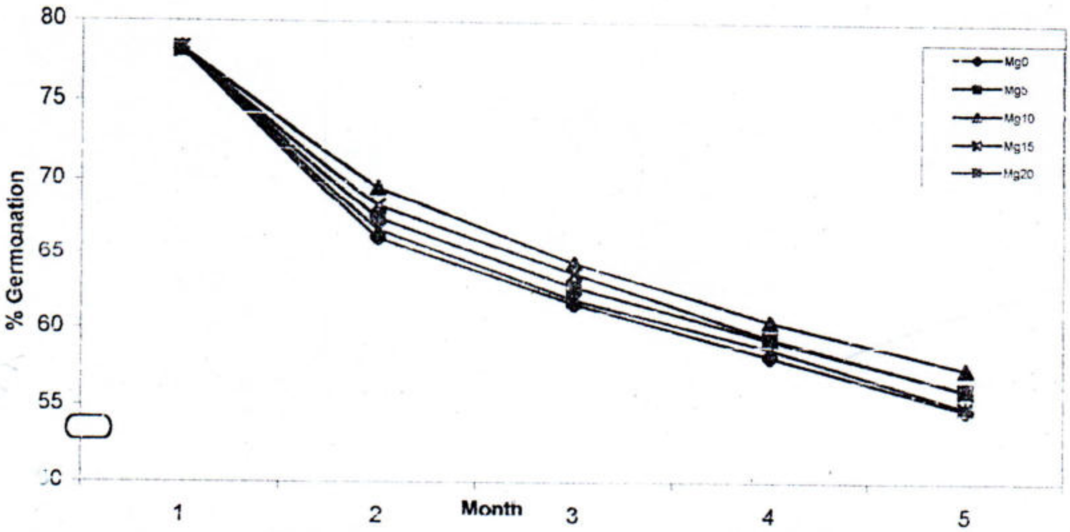


Fig 4.3.2.1.2 Effect of magnesium on the germination percentage of stored seed in 1998-99

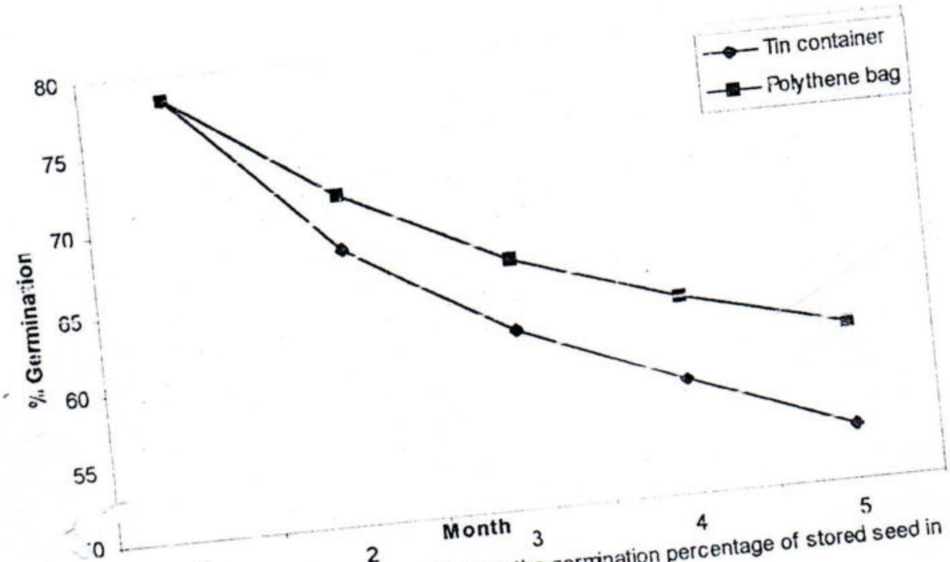


Fig 4.3.1.3Effect of storage container on the germination percentage of stored seed in 1997-98

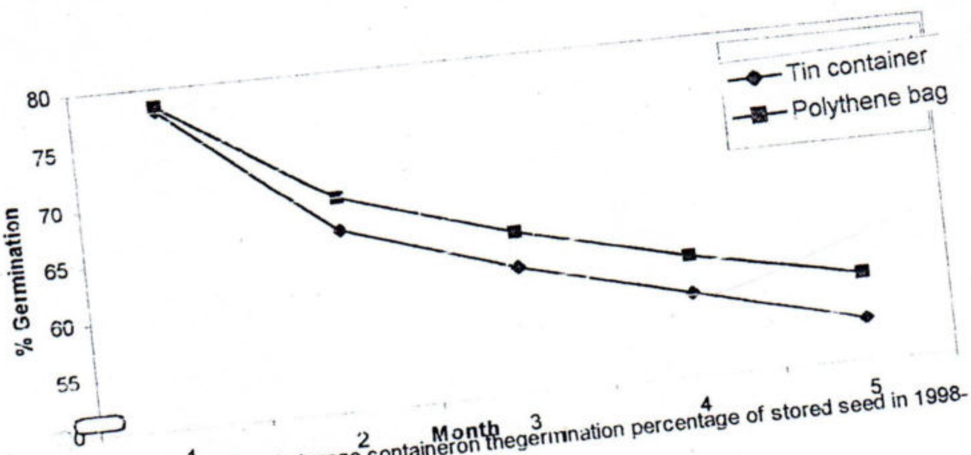


Fig 4.3.1.4 Effect of storage containeron thegermination percentage of stored seed in 1998-99

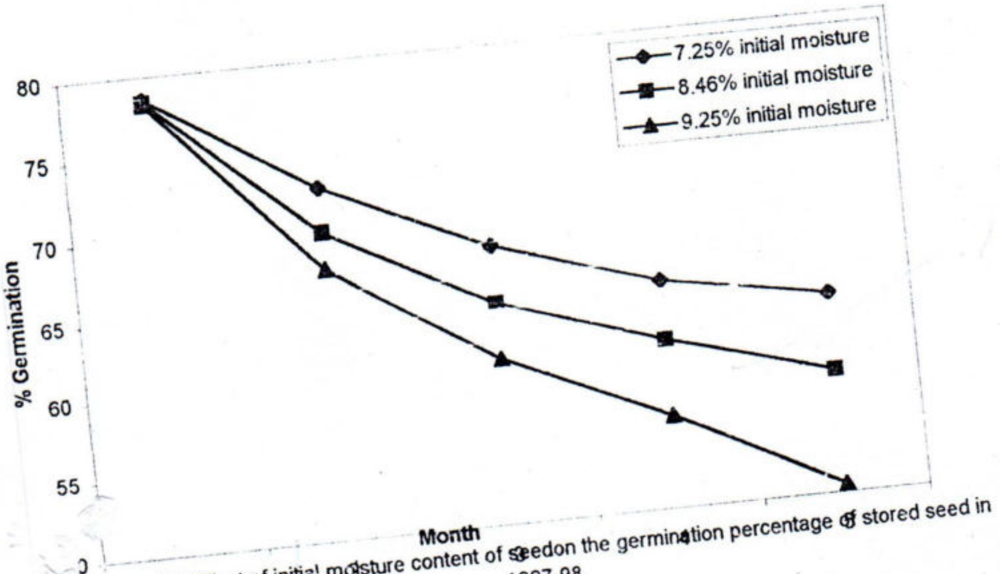


Fig 4.3.1.5 Effect of initial moisture content of seed on the germination percentage of stored seed in 1997-98

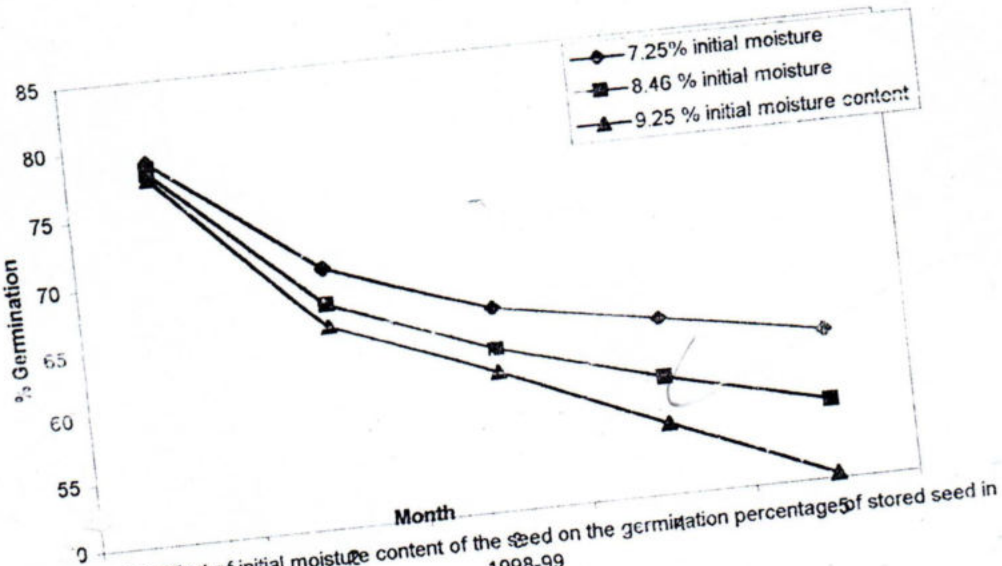


Fig 4.3.1.6 Effect of initial moisture content of the seed on the germination percentage of stored seed in 1998-99

The result revealed that inoculation had an effect on the germination percentage of the seed at early stage of storage period but with advance of time inoculation fails to affect the germination percentage of seed Krishnappa *et.al.*1998 obtained similar results.

4.3.2.5 Interaction of magnesium, *Bradyrhizobium* fertilization and storage container of the germination percentage of stored seed

The interaction of magnesium, inoculation and storage container on the germination percentage of stored seed was not significant in 1997-98 and 1998-99.

4.3.2.6 Interaction of magnesium and initial moisture content of seed on the germination percentage of stored seed

The interaction of magnesium and initial moisture content of the seed was significant at 4-month interval in 1998-99 (Table-4.3.2.2).

Table 4.3.2.2 Interaction of magnesium and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
Mg×M level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Mg_0 \times Ml_1$	78.56	70.77	66.15	62.99	61.36	78.82	68.76	64.82	63.01	60.33
$Mg_0 \times Ml_2$	78.32	68.02	62.48	59.30	56.92	78.09	65.77	60.93	57.63	54.85
$Mg_0 \times Ml_3$	78.32	66.14	58.65	54.87	49.09	77.97	63.72	59.12	54.01	49.28
$Mg_5 \times Ml_1$	78.43	72.17	67.82	64.52	62.75	78.71	70.17	65.51	63.91	61.69
$Mg_5 \times Ml_2$	78.43	69.87	64.26	60.36	57.72	78.22	66.94	62.27	58.80	55.88
$Mg_5 \times Ml_3$	78.32	67.68	60.18	55.80	50.73	77.75	65.32	60.57	55.24	50.68
$Mg_{10} \times Ml_1$	78.82	74.14	69.49	66.31	63.63	79.08	72.29	67.19	64.85	62.67
$Mg_{10} \times Ml_2$	78.56	71.72	65.48	61.86	58.93	78.12	69.20	63.75	59.58	57.34
$Mg_{10} \times Ml_3$	78.45	68.85	62.17	56.68	51.77	77.63	67.03	62.28	57.16	52.33
$Mg_{15} \times Ml_1$	78.43	72.53	68.05	65.02	63.10	78.95	70.24	66.07	63.36	61.34
$Mg_{15} \times Ml_2$	78.20	69.63	64.65	61.22	57.87	78.09	68.23	63.38	59.41	56.42
$Mg_{15} \times Ml_3$	78.85	66.85	60.92	55.86	50.77	77.53	66.49	61.60	55.45	50.39
$Mg_{20} \times Ml_1$	78.56	71.66	66.94	63.65	62.47	78.87	68.64	65.02	62.34	60.50
$Mg_{20} \times Ml_2$	78.45	68.27	63.46	60.37	57.23	78.23	66.57	61.47	58.97	55.30
$Mg_{20} \times Ml_3$	78.52	66.68	60.19	55.62	50.14	77.75	65.08	59.28	54.85	49.02
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.819	NS

The seed with 7.25% initial moisture content and with optimum doses of magnesium retained the highest percentage of germination. Seeds with 8.25% initial moisture content with different doses of magnesium retained similar percentage of germination with seeds with 7.25% initial moisture content but without magnesium. It can be concluded from the result that magnesium had the potentiality to increase the germination retaining potentiality of stored seed and the effect of initial moisture content of the seed was more dominant than the magnesium doses used in producing the seeds.

4.3.2.7 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the germination percentage of stored seed

The interaction of inoculation and initial moisture content of the seed did not produce significant effect on the germination percentage of the store seed in 1997-98 and 1998-99.

4.3.2.8 Interaction of magnesium, *Bradyrhizobium* fertilization and initial moisture content of seed on the germination percentage of the stored seed

The interaction of magnesium, inoculation and initial moisture content of the seed was not significant in 1997-98 and 1998-99.

4.3.2.8 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of storage container and initial moisture content of the seed was significant from 2-month interval to 5-month in 1997-98 and 1998-99 (Table-4..3.2.3). In 1997-98 the highest percentage of germination at 2- month interval was retained by the seeds with 7.25 % initial moisture content of the seed and stored in polythene bags. The lowest percentage was retained by the seed with 9.25% initial moisture content of seed and stored in tin container. In 1998-99 the highest percentage of germination was retained by the same treatment and which the seeds stored in polythene bags followed. At an interval of 3,4 and 5 months the results obtained showed identical trend whereas in the same year 8.46 % initial moisture content of the seed in polythene bags showed better performance in germination percentage. In seeds with 7.25 % initial moisture content and stored in tin container retained higher percentage of germination. The findings revealed that storage container played a vital role than the initial seed moisture content. Paungthong and Ladman (1985) obtained similar results.

Table 4.3.2.3 Interaction of storage container and initial moisture content of seed on the germination percentage of stored seed

Interaction	1997-98					1998-99				
St.cont.×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	78.59	70.77	65.19	61.12	59.14	78.66	68.12	64.51	62.07	59.90
$Sc_1 \times Ml_2$	78.39	67.79	61.73	57.45	54.08	78.03	65.95	60.93	57.43	53.93
$Sc_1 \times Ml_3$	78.30	65.39	58.49	54.14	47.47	77.66	64.53	58.65	53.47	47.62
$Sc_2 \times Ml_1$	78.54	73.74	70.19	67.88	66.18	79.11	71.91	66.94	64.91	62.71
$Sc_2 \times Ml_2$	78.39	71.21	66.41	63.79	61.40	78.26	68.74	63.79	60.32	57.98
$Sc_2 \times Ml_3$	78.20	69.09	62.36	57.40	53.53	77.79	66.52	62.49	57.21	53.06
LSD (0.05)	NS	0.888	0.594	0.587	0.461	NS	0.445	0.698	0.518	0.675

4.3.2.9 Interaction of magnesium, storage container and initial moisture content of seed on the germination percentage of the stored seed

Table 4.3.2.4 Interaction of magnesium, storage container and initial moisture content of seed on the germination percentage of the stored seed

Interaction	1997-98					1998-99				
Mg×St.con×M. level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Mg_0 \times Sc_1 \times Ml_1$	78.69	69.14	63.32	59.44	57.71	78.43	67.05	64.01	62.12	58.89
$Mg_0 \times Sc_1 \times Ml_2$	78.43	66.27	60.21	56.25	53.31	77.97	65.00	60.66	56.36	53.11
$Mg_0 \times Sc_1 \times Ml_3$	78.43	64.02	56.98	53.21	45.17	77.74	63.42	58.47	53.21	45.84
$Mg_0 \times Sc_2 \times Ml_1$	78.43	72.39	68.99	66.54	65.00	79.21	70.46	65.63	63.90	61.77
$Mg_0 \times Sc_2 \times Ml_2$	78.20	69.76	64.76	62.35	60.53	78.20	66.53	61.21	58.89	56.58
$Mg_0 \times Sc_2 \times Ml_3$	78.20	68.31	60.32	56.56	53.01	78.20	64.02	59.77	54.82	52.71
$Mg_5 \times Sc_1 \times Ml_1$	78.43	70.93	65.03	60.76	59.23	78.46	68.14	64.75	63.06	60.20
$Mg_5 \times Sc_1 \times Ml_2$	78.43	67.87	61.45	57.19	54.00	77.97	66.27	61.70	57.62	54.00
$Mg_5 \times Sc_1 \times Ml_3$	78.20	65.51	58.35	54.41	47.95	77.76	65.00	59.24	53.71	47.76
$Mg_5 \times Sc_2 \times Ml_1$	78.43	73.42	70.62	68.28	66.27	78.95	72.20	66.28	64.76	63.17
$Mg_5 \times Sc_2 \times Ml_2$	78.43	71.87	67.07	63.54	61.43	78.46	67.60	62.84	59.98	57.75
$Mg_5 \times Sc_2 \times Ml_3$	78.43	69.85	62.01	57.19	53.51	77.74	65.64	61.90	56.77	53.61
$Mg_{10} \times Sc_1 \times Ml_1$	78.69	72.37	66.95	62.60	59.67	79.21	70.31	65.38	63.55	61.21
$Mg_{10} \times Sc_1 \times Ml_2$	78.43	70.02	62.94	58.47	54.93	78.00	67.46	61.55	57.84	55.12
$Mg_{10} \times Sc_1 \times Ml_3$	78.46	66.93	60.32	55.12	48.81	77.76	65.50	59.66	54.21	49.20
$Mg_{10} \times Sc_2 \times Ml_1$	78.95	75.91	72.03	70.01	67.59	78.95	74.27	69.00	66.15	64.13
$Mg_{10} \times Sc_2 \times Ml_2$	78.69	73.42	68.02	65.25	62.94	78.23	70.93	65.95	61.33	59.55
$Mg_{10} \times Sc_2 \times Ml_3$	78.43	70.76	64.03	58.25	54.72	77.51	68.57	64.91	60.10	55.46
$Mg_{15} \times Sc_1 \times Ml_1$	78.43	71.24	65.78	62.02	59.66	78.69	68.45	64.39	61.21	60.09
$Mg_{15} \times Sc_1 \times Ml_2$	78.20	68.00	62.25	58.16	54.31	77.74	66.02	61.10	57.84	53.81
$Mg_{15} \times Sc_1 \times Ml_3$	78.20	65.50	58.78	54.12	48.14	77.53	64.62	59.12	53.61	47.85
$Mg_{15} \times Sc_2 \times Ml_1$	78.43	73.82	70.32	68.00	66.53	79.21	72.02	67.76	65.50	62.59
$Mg_{15} \times Sc_2 \times Ml_2$	78.20	71.25	67.06	64.27	61.43	78.43	70.48	65.65	60.98	59.04
$Mg_{15} \times Sc_2 \times Ml_3$	78.51	68.19	63.07	57.61	53.41	77.53	68.36	64.09	57.30	52.93
$Mg_{20} \times Sc_1 \times Ml_1$	78.69	70.16	64.88	60.76	59.44	78.49	66.66	64.02	60.42	59.11
$Mg_{20} \times Sc_1 \times Ml_2$	78.46	66.80	61.79	57.20	53.82	78.46	65.00	59.65	57.51	53.61
$Mg_{20} \times Sc_1 \times Ml_3$	78.20	65.00	58.03	53.82	47.28	77.53	64.14	56.77	52.61	47.47
$Mg_{20} \times Sc_2 \times Ml_1$	78.43	73.16	69.00	66.54	65.50	79.24	70.61	66.02	64.26	61.89
$Mg_{20} \times Sc_2 \times Ml_2$	78.43	69.73	65.13	63.54	60.64	78.00	68.14	63.30	60.42	56.98
$Mg_{20} \times Sc_2 \times Ml_3$	78.43	68.35	62.36	57.41	53.01	77.97	66.02	61.79	57.08	50.58
LSD (0.05)	NS	NS	NS	NS	NS	NS	0.996	NS	1.158	NS

The interaction of magnesium, storage container and initial moisture content of the seed was not significant (Table-4.3.9). Though the seeds with Mg 10kg/ha with 7.25% initial moisture content of seed and stored in polythene bag retained the higher percentage of germination. The lowest percentage of germination was retained by the treatment 15 kg Mg /ha with 9.25% initial moisture content and stored in polythene bags. At later interval the interaction of the three treatments showed significant effect on the germination percentage of stored seed. Seeds with or without inoculation and with 7.25% initial moisture content and stored in polythene bags retained superior percentage of germination over others. The lowest percentage of germination was retained by the treatments uninoculated seed with 9.25% initial content and stored in tin container in both the years.

4.3.2.10 Interaction of magnesium, storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of inoculation, storage container and initial moisture content of seed was not significant in 1997-98 and 1998-99.

4.3.2.11 Interaction of *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of inoculation, storage container and initial moisture content of seed was not significant in 1997-98 and 1998-99. Seeds with or without inoculation but with 7.25% of initial moisture content of seed and stored in polythene bags retained superior percentage of germination over other treatments and the lowest percentage of germination was retained by the treatment of uninoculated seed with 9.25% initial moisture and stored in tin container. The result indicated that inoculation had very little to zero effect on the germination retaining capacity of stored seed.

4.3.2.12 Interaction of magnesium, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the germination percentage of stored seed

The interaction of all the four treatments was not insignificant. The higher percentage of germination was obtained in the treatment combination of Mg 10kg/ha with inoculation and 7.25 % of initial moisture content of seed and stored in polythene bags, which produced similar result by the treatment Mg10 kg/ha without inoculation and 7.25% of initial moisture content of seed and stored in polythene bags. The lowest percentage of germination was obtained with the treatment of 0 kg Mg/ha without inoculation and with 9.25% initial moisture content of seed and stored in tin container

4.3.3.1 Effect of magnesium level, *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on seed vigour index of stored seed

At the early stage of storage the speed of germination showed by different level of magnesium was significant. The highest speed of germination was showed by the treatment Mg 10kg/ha and the control plot showed the lowest seed of germination. Both in 1997-98 and 1998-99 retained identical results(4.3.3.1). At the interval of 2-month the seeds with Mg 10 kg/ha and Mg 15kg/ha retained significantly higher speed of germination. The lowest speed of germination was trained by the control treatments. The treatments Mg 5 kg/ha and Mg 200 kg/ha retained significantly poorer but identical speed of germination. These results continued up to 5 months interval. The result showed that magnesium improved the vigour index of groundnut by improving the potentially of seed life.

The inoculation of seed with *Bradyrhizobium* did not affect the speed of germination of stored seed in early stage of storage. In the later stage of storage inoculation affected the speed of germination at an interval of 4-month in 1997-98. Inoculated seed retained superior speed of germination of stored seed. In 1998-99 the speed of germination was not affected by the inoculation treatment.

Table 4.3.3.1 Effect of magnesium level, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the vigour index of stored seed

Treatment	1997-98					1998-99				
	1 mon	2 mon	3 mon	4 mon	5 mon	1 mon	2 mon	3 mon	4 mon	5 mon
Mg level										
Mg_0	22.36	18.29	16.78	15.66	14.81	22.34	18.11	16.50	15.39	13.85
Mg_5	22.45	18.45	17.46	16.23	15.10	22.50	18.25	17.29	16.18	14.26
Mg_{10}	22.67	18.66	17.68	16.51	15.37	22.73	18.40	17.45	16.36	14.38
Mg_{15}	22.52	18.64	17.69	16.48	15.29	22.53	18.60	17.57	16.46	14.55
Mg_{20}	22.44	18.36	17.49	16.26	15.07	22.44	18.35	17.41	16.32	14.41
LSD (0.05)	0.005	0.121	0.092	0.169	0.179	0.005	0.063	0.123	0.131	0.209
Inoculatio										
I_0	22.49	18.45	17.39	16.17	14.96	22.50	18.30	17.21	16.12	14.25
I_{50}	22.49	18.51	17.45	16.28	15.04	22.51	18.38	17.28	16.17	14.33
LSD (0.05)	NS	NS	NS	0.583	NS	NS	0.256	0.256	NS	NS
St. cont.										
Sc_1	22.48	17.94	16.75	15.33	14.00	22.49	17.62	16.70	15.57	13.51
Sc_2	22.50	19.02	18.09	17.12	16.00	22.53	19.07	17.79	16.71	15.07
LSD(0.05)	0.016	0.367	0.107	0.583	0.767	0.016	0.256	0.423	0.454	0.775
M. level										
Ml_1	22.51	21.03	19.93	19.01	17.81	22.52	21.00	19.70	18.49	16.92
Ml_2	22.50	19.70	18.62	17.39	15.98	22.51	19.59	18.46	17.62	14.82
Ml_3	22.45	14.71	13.71	12.28	11.23	22.48	14.43	13.57	12.32	11.13
LSD (0.05)	0.004	0.033	0.071	0.131	0.139	0.004	0.049	0.034	0.102	0.162

The effect of storage container on the speed of germination was significant from the early stage of storage in 1997-98 and 1998-99 (Table 4..3.3.1). The seeds stored in polythene bags showed significant superiority over tin container in both the years.

The effect of initial moisture content of the seed was significant from the early stage of storage. From the interval of 2 months the highest speed of germination was restored by the treatment 7.25% initial moisture content of seed and the lowest speed was obtained by the treatment 9.25% initial moisture content. The results continued up to 5 months of interval indicating that initial moisture content of seed played very important in the storage behavior and speed of germination of stored seed.

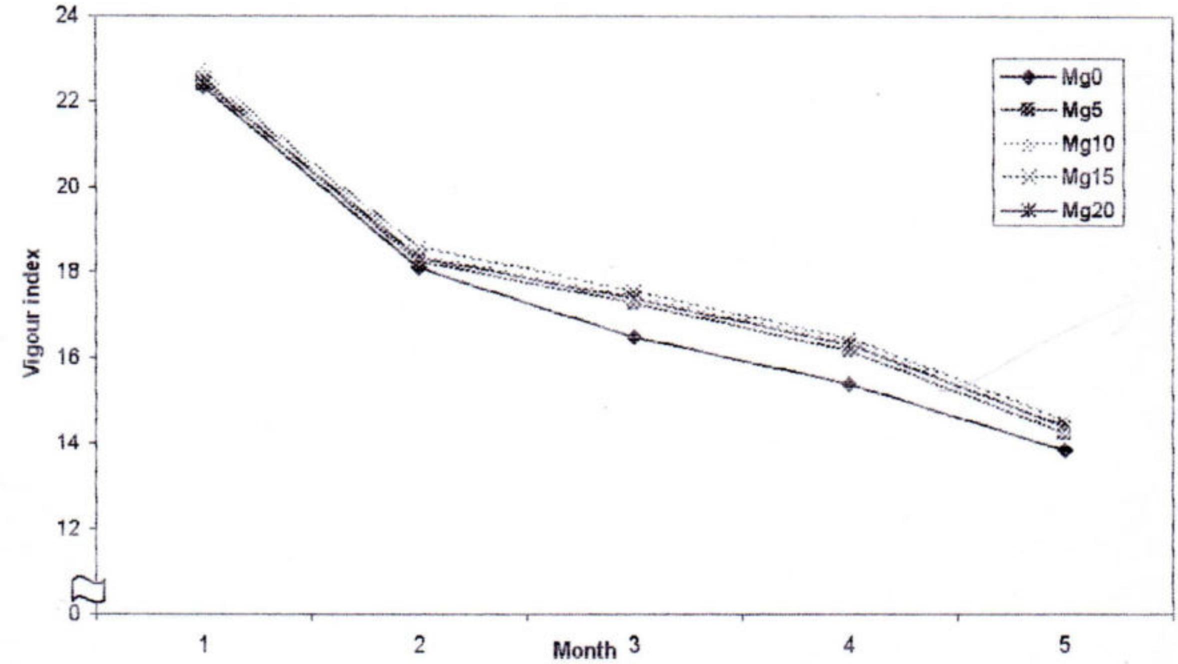


Fig 4.3.3.1.1 Effect of magnesium on the vigour index of stored seed in 1997-98

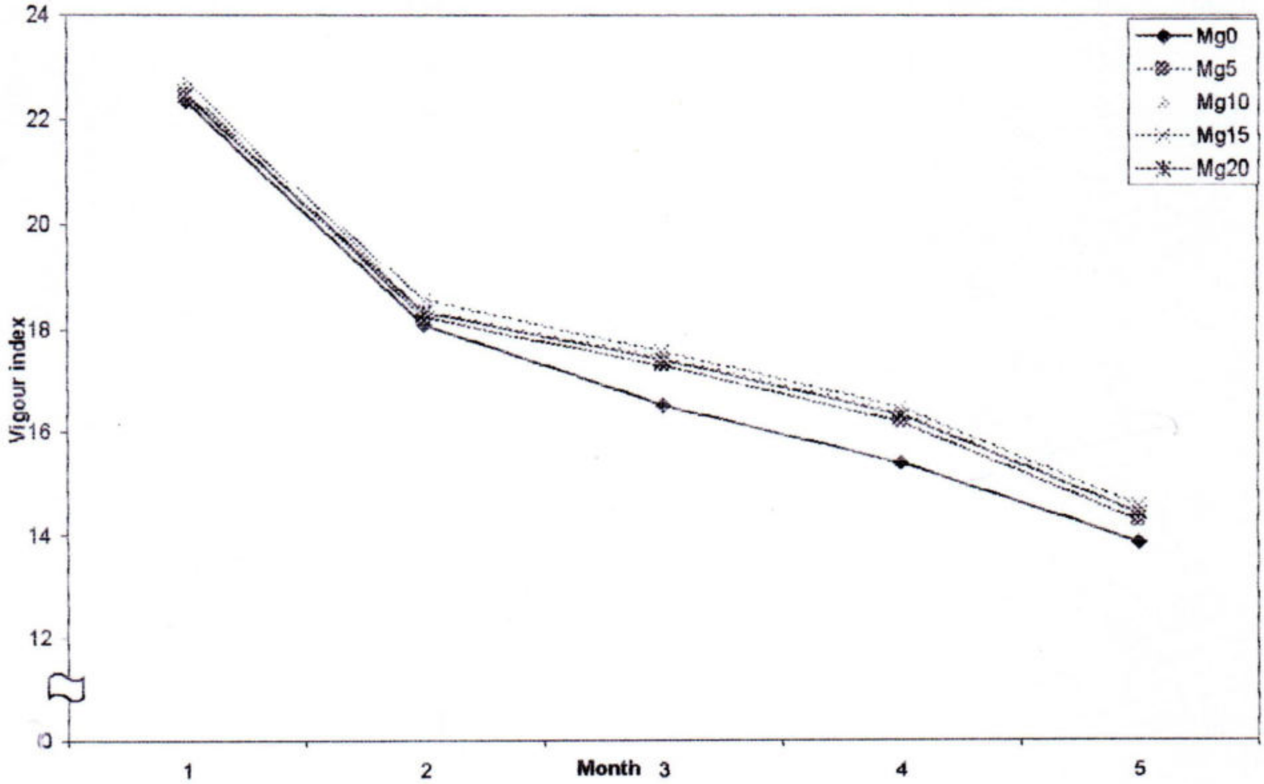


Fig 4.3.3.1.2 Effect of magnesium on the vigour index of stored seed in 1998-99

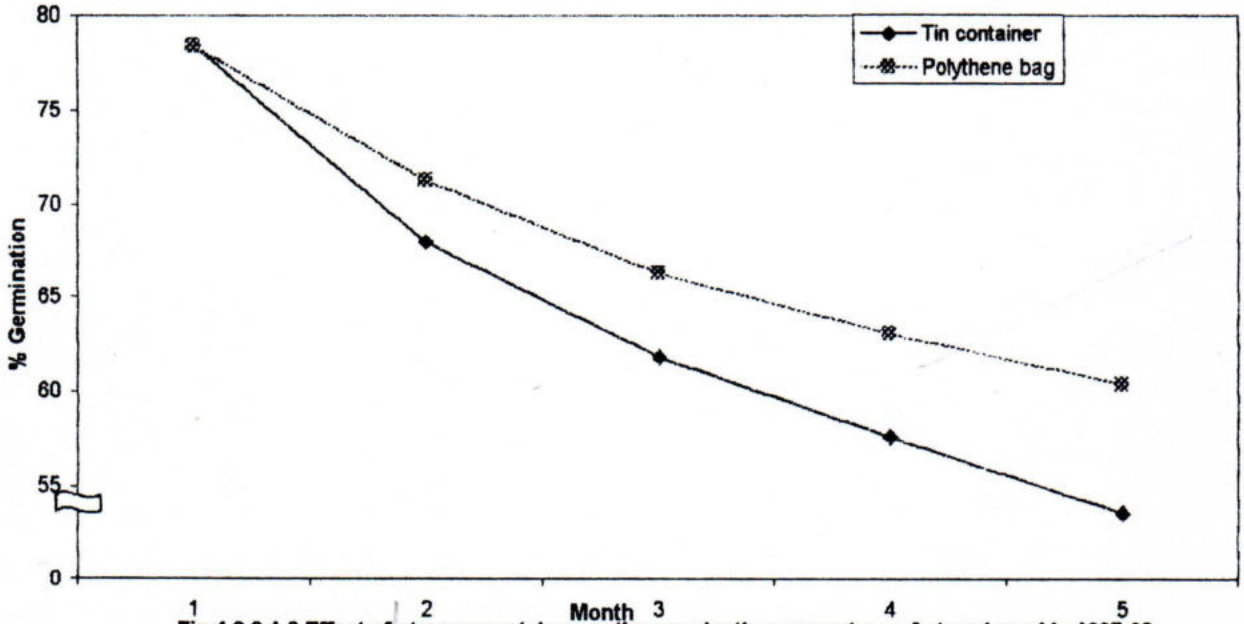


Fig 4.3.3.1.3 Effect of storage container on the germination percentage of stored seed in 1997-98

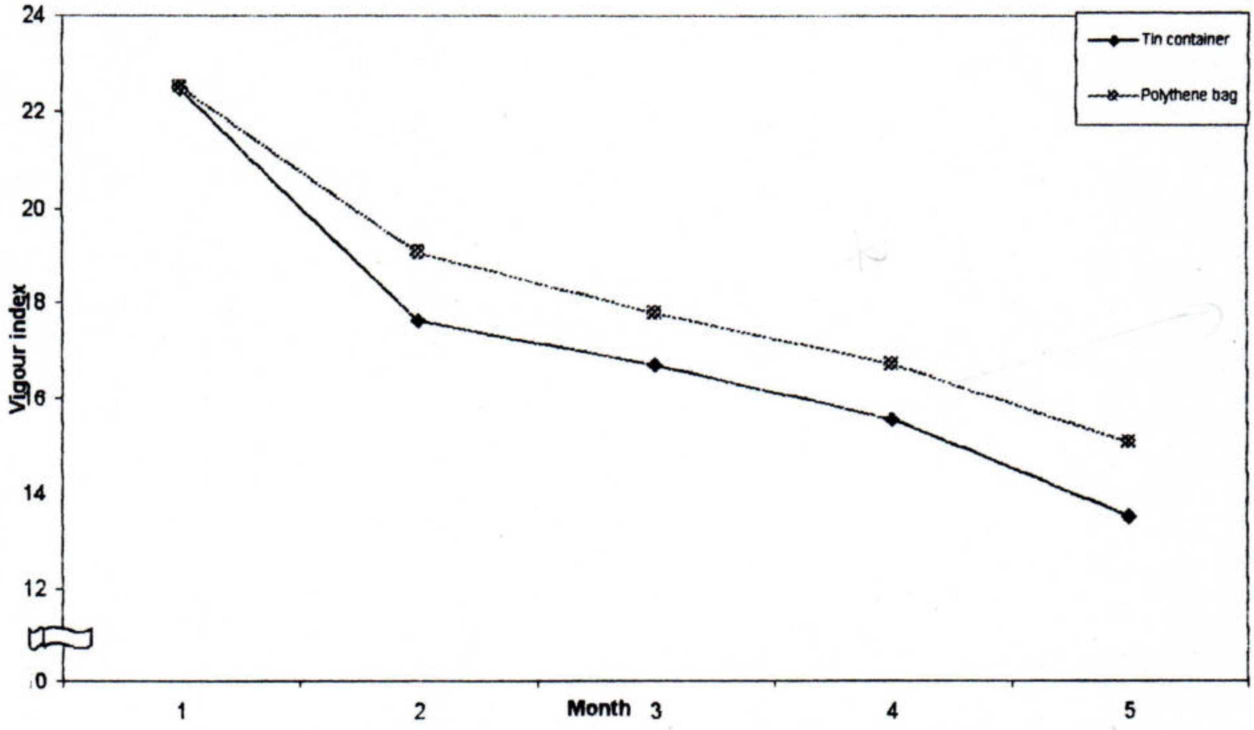


Fig 4.3.3.1.4 Effect of storage container on the vigour index of stored seed in 1998-99

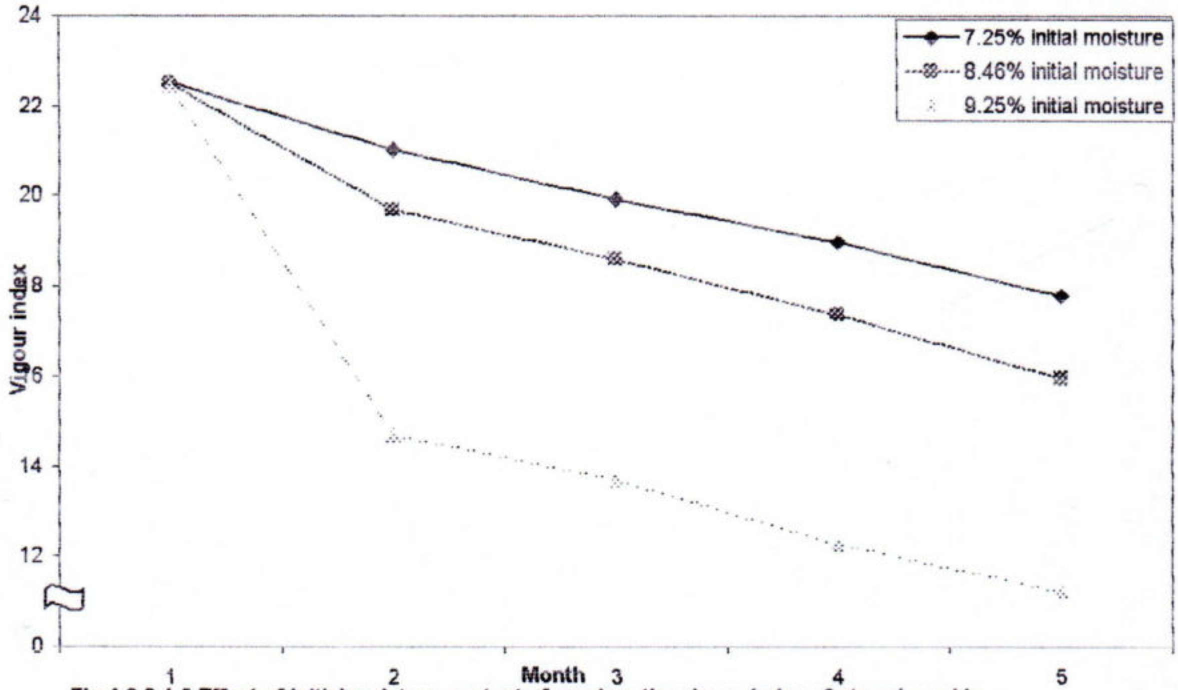
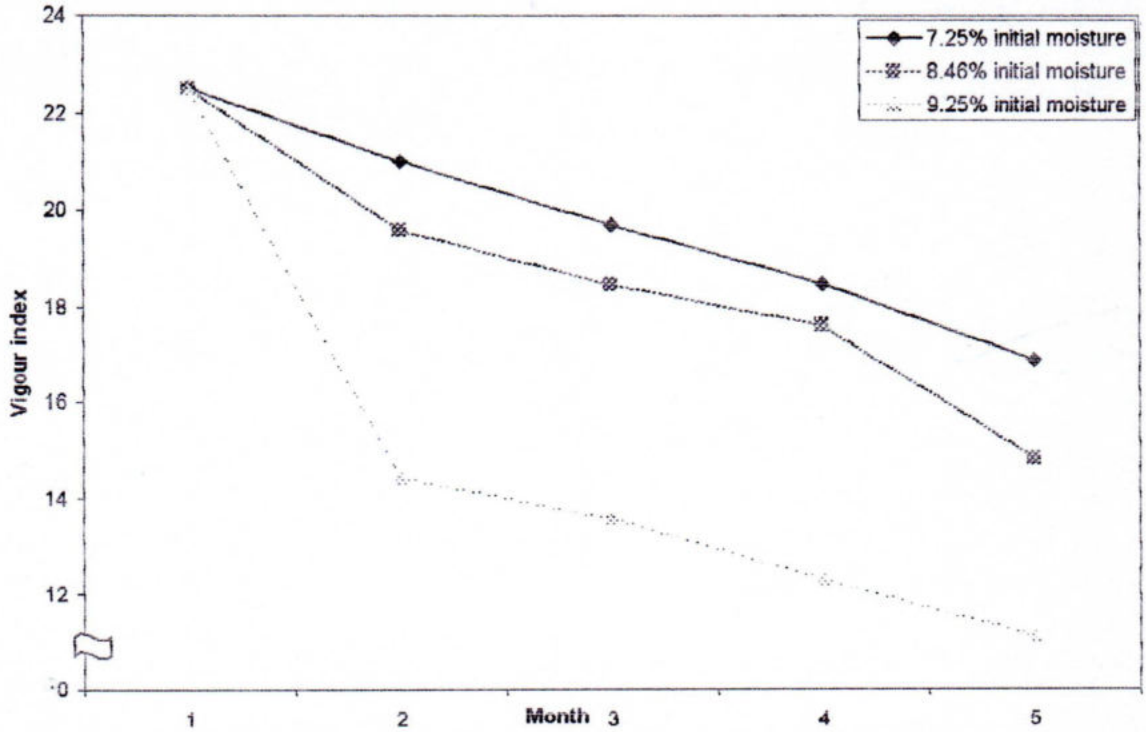


Fig 4.3.3.1.5 Effect of initial moisture content of seed on the vigour index of stored seed in 1997-98



4.3.3.1.6 Effect of initial moisture content of seed on the vigour index of stored seed in 1998-99

4.3.3.2 Interaction of magnesium and *Bradyrhizobium* fertilization of the vigour index of stored seed

The interaction of magnesium and inoculation was not significant in 1997-98 and 1998-99. It was evident from the table that inoculation did better than the uninoculated one. The vigour index increased with the increasing magnesium level up to optimum level and then it declines.

4.3.3.3 Interaction of magnesium and storage container on the vigour index stored seed

Magnesium and storage container interacted significantly from the early stage of storage (Table-4..3..3..2). In 1997-98 from the interval of 2-month the seed with higher level of magnesium and stored in polythene bags retained the higher speed of germination and the seeds with higher level of magnesium stored in tin container retained identical speed of germination. From the interval of 3-month the speed of germination of seed grouped into three. The highest germination speed was retained by higher level of magnesium stored in polythene bags and the seeds with lower or zero level of magnesium retained lowest group and the mid group was with the seeds with higher magnesium and stored in tin container or seeds with lower level of magnesium and stored in polythene bags. The result indicated that storage container dictated more on the vigour index than the magnesium doses.

Table 4.3.3.2 Interaction of magnesium and storage container on the vigour index stored seed

Interaction	1997-98					1998-99				
Mg×St.cont.	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Mg_0 \times Sc_1$	22.33	17.73	16.14	14.94	13.39	22.31	17.39	15.53	14.79	13.08
$Mg_0 \times Sc_2$	22.39	18.84	17.42	16.37	14.96	22.37	18.84	17.07	15.99	14.62
$Mg_5 \times Sc_1$	22.44	17.97	16.72	15.23	13.97	22.46	17.53	16.76	15.66	13.48
$Mg_5 \times Sc_2$	22.46	18.93	18.20	17.22	16.23	22.54	18.97	17.83	16.70	15.04
$Mg_{10} \times Sc_1$	22.64	18.23	16.96	15.58	14.32	22.68	17.70	16.92	15.83	13.57
$Mg_{10} \times Sc_2$	22.70	19.09	18.39	17.43	16.42	22.77	19.11	17.99	16.89	15.19
$Mg_{15} \times Sc_1$	22.53	18.02	17.06	15.57	14.28	22.54	17.88	17.02	15.86	13.77
$Mg_{15} \times Sc_2$	22.51	19.26	18.32	17.40	16.31	22.52	19.32	18.12	17.06	15.33
$Mg_{20} \times Sc_1$	22.44	17.77	16.88	15.33	14.06	22.44	17.58	16.89	15.74	13.63
$Mg_{20} \times Sc_2$	22.44	18.96	18.10	17.18	16.09	22.43	19.11	17.93	16.89	15.18
LSD (0.05)	0.006	0.171	NS	0.239	0.254	0.006	NS	NS	NS	NS

4.3.3.4 Interaction of *Bradyrhizobium* fertilization and storage container on the vigor index of stored seed

Inoculation and storage container fail to interact significantly from the early stage of storage on the vigor index of stored seed. At later interval of months the seeds stored in polythene bag with or without inoculation retained higher speed of germination over the seeds in tin container.

4.3.3.5 Interaction of magnesium, *Bradyrhizobium* fertilization and storage container on the vigour index of stored seed

The interaction of magnesium, inoculation and storage container was not significant in 1997-98 and 1998-99. Seeds with higher level of magnesium and stored in polythene bags retained higher speed of germination. The seeds with or without magnesium and stored in tin container retained lowest speed of germination.

4.3.3.6 Interaction of magnesium and initial moisture content of seed on the vigour index of stored seed

The interaction of magnesium and initial moisture content of the seed was significant in 1997-98 and 1998-99 (Table 4..3..3..3). From the early interval the seeds of higher level of magnesium and lower initial moisture content (7.25% and 8.46%) retained identical speed of germination while the seed with lower level of magnesium or zero magnesium with higher (9.25%) of percentage of initial moisture content retained lower speed of germination. In the first year with the advance of time in storage the effect of magnesium showed distinct superiority in the entire 5-month interval. In 1998-99 the effect of magnesium gradually lost its dominance in the interaction process and the speed of germination became grouped with percentage of initial moisture content of seed. The result revealed that the effect of magnesium on the vigour index lost its superiority in storage with the advance of time.

Table 4.3.3.3 Interaction of magnesium and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
Mg×M level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Mg_0 \times Ml_1$	22.37	20.83	18.94	18.16	16.44	22.35	20.82	18.63	17.62	16.16
$Mg_0 \times Ml_2$	22.38	19.52	17.99	16.97	15.32	22.34	19.33	17.60	16.54	14.49
$Mg_0 \times Ml_3$	22.35	14.52	13.42	11.85	10.76	22.32	14.20	13.27	12.02	10.90
$Mg_5 \times Ml_1$	22.47	21.02	20.05	19.14	18.11	22.52	20.92	19.77	18.52	16.98
$Mg_5 \times Ml_2$	22.46	19.67	18.69	17.34	16.02	22.52	19.49	18.54	17.73	14.69
$Mg_5 \times Ml_3$	22.42	14.68	13.63	12.19	11.17	22.47	14.33	13.56	12.29	11.12
$Mg_{10} \times Ml_1$	22.71	21.21	20.33	19.41	18.38	22.75	21.06	19.95	18.74	17.06
$Mg_{10} \times Ml_2$	22.71	19.89	18.88	17.72	16.34	22.73	19.67	18.71	17.90	14.89
$Mg_{10} \times Ml_3$	22.60	14.88	13.82	12.40	11.39	22.69	14.48	13.70	12.44	11.18
$Mg_{15} \times Ml_1$	22.55	21.15	20.25	19.25	18.17	22.54	21.23	20.16	18.91	17.22
$Mg_{15} \times Ml_2$	22.53	19.83	18.83	17.59	16.21	22.55	19.87	18.86	18.06	15.17
$Mg_{15} \times Ml_3$	22.48	14.93	13.98	12.61	11.50	22.51	14.69	13.69	12.42	11.26
$Mg_{20} \times Ml_1$	22.47	20.95	20.08	19.08	17.92	22.47	20.99	20.01	18.65	17.17
$Mg_{20} \times Ml_2$	22.45	19.58	18.70	17.33	16.00	22.43	19.61	18.61	17.88	14.88
$Mg_{20} \times Ml_3$	22.41	14.56	13.69	12.35	11.31	22.41	14.44	13.62	12.42	11.17
LSD (0.05)	0.008	0.209	0.160	0.293	0.311	0.008	0.108	NS	0.227	NS

4.3.3.7 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed

The interaction of inoculation and initial seed moisture content was not significant from the early stage of storage (Table-4..3..3.4). The seeds with lower initial moisture content (7.25% and 8.46%) retained higher speed of germination while the seeds with or without inoculation with higher (9.25%) initial moisture content of seed retained the poorest speed of germination. The effect of inoculation did not show any substantial increase in the speed of germination of the stored seed.

Table 4.3.3.4 Interaction of *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
I×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$I_0 \times Ml_1$	22.51	21.00	19.90	18.96	17.77	22.52	20.97	19.66	18.47	16.86
$I_0 \times Ml_2$	22.51	19.69	18.61	17.35	15.93	22.51	19.56	18.42	17.59	14.77
$I_0 \times Ml_3$	22.44	14.67	13.67	12.21	11.18	22.48	14.39	13.55	12.29	11.12
$I_{50} \times Ml_1$	22.51	21.06	19.96	19.05	17.84	22.53	21.04	19.75	18.51	16.97
$I_{50} \times Ml_2$	22.50	19.71	18.62	17.43	16.03	22.52	19.63	18.51	17.66	14.88
$I_{50} \times Ml_3$	22.46	14.76	13.75	12.35	11.27	22.48	14.47	13.59	12.34	11.13
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.3.3.8 Interaction of magnesium, *Bradyrhizobium* fertilization and initial moisture content of seed on the vigour index of stored seed

The interaction of magnesium, inoculation and initial moisture content of the seed was not significant in 1997-98 and 1998-99. The seeds with higher magnesium level and lower initial moisture content retained similar speed of germination with the seeds with little or zero magnesium level with or without inoculation.

4.3.3.9 Interaction of storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of storage container and initial moisture content of the seed was significant in 1997-98 and 1998-99 (Table 4..3..3..5). At an interval of 2-month in 1997-98 the seeds with 7.25% stored in polythene bags retained the highest speed of germination. The seeds with 8.46% initial moisture content of seed stored either in polythene bags or in tin container retained identical speed of germination. In 1998-99 the speed of germination of different initial moisture level and storage container interacted very distinctly and each interaction treatment retained significantly different speed of germination. The result indicate that the effect of storage container affected the speed of germination at early stage of storage while the initial moisture content of seed affected the speed at germination though out the whole storage period. The results are in full agreement with Suchanya *et.al* and Kritsanapong (1988)

Table 4.3.3.5 Interaction of storage container and moisture level on seed vigour index over storage period

Interaction	1997-98					1998-99				
St.cont. ×M.level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Sc_1 \times Ml_1$	22.51	20.67	19.35	18.00	16.86	22.50	20.47	19.19	18.25	16.53
$Sc_1 \times Ml_2$	22.49	18.95	18.18	16.62	15.30	22.50	18.72	18.19	17.23	14.25
$Sc_1 \times Ml_3$	22.43	14.22	12.73	11.38	9.85	22.46	13.66	12.73	11.24	9.74
$Sc_2 \times Ml_1$	22.52	21.40	20.51	20.02	18.75	22.55	21.54	20.21	18.72	17.31
$Sc_2 \times Ml_2$	22.52	20.45	19.05	18.16	16.66	22.53	20.47	18.74	18.02	15.40
$Sc_2 \times Ml_3$	22.47	15.21	14.69	13.18	12.60	22.50	15.20	14.41	13.39	12.51
LSD (0.05)	0.005	0.132	0.101	0.185	0.197	0.005	0.068	0.134	0.144	0.229

4.3.10 Interaction of magnesium, storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of magnesium, storage container and initial moisture content of the seed on the speed of germination of stored seed was not significant in 1997-98 and 1998-99. The seeds with different level of magnesium, lower level of initial moisture content (7.25% and 8.46%) and stored in polythene bag retained better speed germination while seeds with different levels of magnesium with highest level of initial moisture content 9.25% and stored in polythene bags or tin container retained lower speed of germination (Table-4..3..3.6).

Table4.3.3.6 Interaction of magnesium, storage container and initial moisture content of seed on the vigour index of stored seed

Interaction	1997-98					1998-99				
S×St.con×M. level	1mon	2mon	3mon	4mon	5mon	1mon	2mon	3mon	4mon	5mon
$Mg_0 \times Sc_1 \times Ml_1$	22.33	20.42	18.45	17.63	16.05	22.32	20.25	18.28	17.25	15.70
$Mg_0 \times Sc_1 \times Ml_2$	22.35	18.75	17.53	16.27	14.75	22.32	18.48	17.12	16.20	14.03
$Mg_0 \times Sc_1 \times Ml_3$	22.32	14.03	12.45	10.93	9.38	22.28	13.43	12.40	10.92	9.50
$Mg_0 \times Sc_2 \times Ml_1$	22.40	21.25	19.43	18.68	16.83	22.38	21.38	18.97	17.98	16.62
$Mg_0 \times Sc_2 \times Ml_2$	22.40	20.28	18.45	17.67	15.90	22.37	20.17	18.08	16.88	14.95
$Mg_0 \times Sc_2 \times Ml_3$	22.38	15.00	14.38	12.77	12.13	22.37	14.97	14.15	13.12	12.30
$Mg_5 \times Sc_1 \times Ml_1$	22.45	20.68	19.33	18.00	16.85	22.48	20.37	19.22	18.32	16.55
$Mg_5 \times Sc_1 \times Ml_2$	22.43	18.97	18.13	16.42	15.27	22.48	18.65	18.30	17.35	14.08
$Mg_5 \times Sc_1 \times Ml_3$	22.43	14.27	12.68	11.28	9.78	22.42	13.57	12.75	11.30	9.82
$Mg_5 \times Sc_2 \times Ml_1$	22.48	21.35	20.77	20.28	19.37	22.55	21.47	20.33	18.72	17.42
$Mg_5 \times Sc_2 \times Ml_2$	22.48	20.37	19.25	18.27	16.78	22.55	20.33	18.78	18.10	15.30
$Mg_5 \times Sc_2 \times Ml_3$	22.42	15.08	14.58	13.10	12.55	22.52	15.10	14.37	13.28	12.42
$Mg_{10} \times Sc_1 \times Ml_1$	22.70	20.93	19.72	18.27	17.30	22.70	20.53	19.38	18.53	16.63
$Mg_{10} \times Sc_1 \times Ml_2$	22.68	19.27	18.35	16.93	15.60	22.70	18.82	18.50	17.52	14.30
$Mg_{10} \times Sc_1 \times Ml_3$	22.55	14.48	12.82	11.55	10.07	22.65	13.75	12.87	11.43	9.77
$Mg_{10} \times Sc_2 \times Ml_1$	22.72	21.48	20.93	20.55	19.47	22.80	21.58	20.52	18.95	17.48
$Mg_{10} \times Sc_2 \times Ml_2$	22.73	20.52	19.42	18.50	17.08	22.77	20.53	18.92	18.28	15.48
$Mg_{10} \times Sc_2 \times Ml_3$	22.65	15.28	14.83	13.25	12.72	22.73	15.20	14.53	13.45	12.60
$Mg_{15} \times Sc_1 \times Ml_1$	22.57	20.72	19.73	18.13	17.18	22.55	20.73	19.60	18.68	16.83
$Mg_{15} \times Sc_1 \times Ml_2$	22.53	19.03	18.47	16.90	15.53	22.55	18.98	18.63	17.63	14.62
$Mg_{15} \times Sc_1 \times Ml_3$	22.48	14.30	12.97	11.67	10.12	22.53	13.92	12.83	11.27	9.85
$Mg_{15} \times Sc_2 \times Ml_1$	22.53	21.58	20.77	20.37	19.17	22.53	21.73	20.72	19.13	17.60
$Mg_{15} \times Sc_2 \times Ml_2$	22.53	20.63	19.18	18.28	16.88	22.55	20.75	19.08	18.48	15.72
$Mg_{15} \times Sc_2 \times Ml_3$	22.47	15.55	15.00	13.55	12.88	2248.	15.47	14.55	13.57	12.67
$Mg_{20} \times Sc_1 \times Ml_1$	22.48	20.58	19.50	17.95	16.93	22.47	20.47	19.48	18.48	16.92
$Mg_{20} \times Sc_1 \times Ml_2$	22.45	18.73	18.43	16.60	15.35	22.43	18.65	18.40	17.43	14.22
$Mg_{20} \times Sc_1 \times Ml_3$	22.38	14.00	12.72	11.45	9.90	22.42	13.63	12.78	11.30	9.77
$Mg_{20} \times Sc_2 \times Ml_1$	22.45	21.32	20.67	20.22	18.90	22.47	21.52	20.53	18.82	17.43
$Mg_{20} \times Sc_2 \times Ml_2$	22.45	20.43	18.97	18.07	16.65	22.43	20.57	18.82	18.33	15.55
$Mg_{20} \times Sc_2 \times Ml_3$	22.43	15.12	14.67	13.25	12.72	22.40	15.25	14.45	13.53	12.57
LSD (0.05%)	0.011	0.296	NS	0.226	NS	0.011	NS	0.300	NS	NS

4.3.3.11 Interaction of *Bradyrhizobium* fertilization, storage container and initial moisture content of seed on the vigour index of stored seed

The interaction of inoculation, storage container and initial moisture content of the seed was not significant in 1997-98 and 1998-99 (Table-4..3..2.2). The seeds with lower initial moisture content of seed (7.25% and 8.46%) and stored in polythene or tin container with or without inoculation retained similar speed of germination. The seeds with higher (9.25%) initial moisture content of seed, irrespective of storage container retained lower speed of germination.

4.3.3.12 Interaction of magnesium, *Bradyrhizobium* fertilization, storage container and initial moisture content of the seed on the vigour index of stored seed

The interaction of magnesium, inoculation, storage container and initial moisture content was not significant in 1997-98 and 1998-99. The seeds containing different levels of magnesium, with lower level of initial moisture content of seed and stored in polythene or tin retained similar speed of germination. Inoculation fail to affect the interaction process though it had an increasing trend to boost up speed of germination of stored seed.

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the field and laboratory of Oil Seed Division, Bangladesh Agricultural Research Institute Joydebpur, Gazipur during the period of November 1997 to December 1999 to see the effect of fertilizer elements sulphur, calcium, magnesium and *Bradyrhizobium* inoculation on the yield and quality of groundnut seed and the interaction of these fertilized seed with initial moisture content of seed and storage container. The study included the activities of i) Production of seed at different level of all the three fertilizer elements and inoculum. ii) Drying of the seeds to three level of initial moisture content iii) Storing the seeds in two type of storage container iv) Laboratory performance i.e. the percentage of germination and speed of germination (vigour index) of the stored seed.

Experiment 4.1.1.1 Effect of sulphur and *Bradyrhizobium* fertilization on the growth and yield was conducted in the field of Oil Seed Division of BARI from November 1997 to 1998 and was repeated in 1998 to 1999. There were 5(five) treatments of sulphur and 2(two) treatment of *Bradyrhizobium* fertilization. The sulphur treatments were 0,20,40,60 and 80kg S/ha and the inoculation treatments were 0 and 50g I /kg of seed. Design of the experiment was Randomized complete block design. The data was analyzed through a statistical computer programme M-StatC following the principles of complete randomized block designs. The number of replication was 3 and plot size was 4m × 2.5m.

Land preparation, fertilizer application and intercultural operation was followed as per recommendation of BARI. The crops were harvested in the mid May in both the years. Pod yield and yield attributing components were recorded to assess the effect of fertilizer elements on the yield and yield attributes of groundnut. The seeds from each plot were put in net bags and the seeds were sun dried from morning to noon. The seeds were apportioned into three and each portion was dried until attained the required initial moisture content by the seed. The moisture content of the seed was measured by over dry method.

Experiment 4.2.1.1 Effect of calcium and *Bradyrhizobium* fertilization on the growth and yield were conducted in the same way as described for Experiment 4.1. Calcium oxide was chosen to find out the effect of calcium. There were 5(five) treatments of calcium and 2(two) treatment of ***Bradyrhizobium*** fertilization. The calcium treatments were 0,50,100,150 and 200kg Ca/ha and the inoculation treatments were 0 and 50g I /kg of seed. The design of the experiment, cultural and intercultural operations and fertilizer and water management was also followed as done in the experiment 4.1.1.1. Harvesting and drying of seed was also done following the experiment 4.1. 1.1. Other activity of the experiment was also same to the experiment 1.

Experiment 4.3.1.1 Effect of magnesium and *Bradyrhizbium* fertilization on the growth and yield was conducted in the field of Oil Seed Division, BARI in the similar way, as done in experiment 4.1.1.1 and 4.1.2.1. Magnesium chloride was choosen to supply the crop magnesium only. There were 5 doses of magnesium 0, 5, 10, 15, and 20kg Mg/ha and two levels of ***Bradyrhizobium*** fertilization 0 and 50 g I/kg of seed. Cultural, intercultural operations, fertilizer and water management was done as par recommendation of BARI. Harvesting of seeds and drying of seeds was done as in experiment 4.1.1.1 and 4.2.1.1

Experiment 4.1.2.1 and 4.1.3.1. Groundnut seed quality as affected by Sulphur, ***Bradyrhizobium*** fertilization, initial moisture content of the seed and seed container at storage was conducted at the laboratory of Oil Seed Division, BARI. Joydebpur, Gazipur from August 1998 to December 1998 and was repeated in 1999. The experiment consisted of three level of initial moisture content of seed viz. 7.25%, 8.46% and 9.25% obtained through sun drying. After harvesting sun drying of the seed was done keeping net bags in the puccca floor to obtain the desired moisture content of seed. Two types of container, tin container and polythene bag of .25 mm thickness were used. Seeds were harvested when the seed of first flushing were fully matured and the seed coats were pinkish in colour. During the drying time at night times the harvested crops were colleted from the floor and kept under a shaded threshing floor so that rainfall cannot affect the dried seeds. The crops were then threshed plot wise, cleaned and apportioned into three lots and drying treatments were imposed for different period of time for different seed lots. Each seed lot was divided into two apportions and stored in two type of container. The storage experiment was set on 5th August and continued for 5 months. The experiment was replicated thrice and seeds produced from experiment 4.1were used in this storage experiment, a completely randomized design was adapted and analysis of data was done in M-statc programme. Seed sample were collected following standard method at monthly interval. Seed quality was assessed considering the percentage of germination and speed of germination or vigour index.

Experiment 4.2.2.1 and 4.2.3.1 Effect of Calcium, ***Bradyrhizobium*** fertilization initial moisture content of the seed and storage container on the germination percentage and vigour index was conducted at the laboratory of Oil Seed Division, BARI. Joydebpur, Gazipur. . All the activities was done as like as experiment 4.1.2.1 and 4.1. 3.1

Experiment 4.3.2.1 and 4.3.3.1 Effect of magnesium and *Bradyrhizobium* fertilization, initial moisture content of seed and storage container at storage was conducted at the laboratory of Oil Seed Division, BARI. Joydebpur, Gazipur. All the activities was done as like as experiment4.1.2.1 and 4.1.3.1

Results received in the experiment 4.1.1.1 showed that sulphur affected the yield and yield attributes significantly. Yield of pod and 100 seed weight affected positively and significantly in 1997-98 and 1998-99 on the other hand inoculation increased the yield of pod in both the years. 100 seed weight was increased significantly in 1st year. The level of sulphur application affected shelling percentage and harvest index of the crop and ***Bradyrhizobium*** fertilization also significantly affected shelling percentage and harvest index of the crop. Number of matured pod per plant; plant height and number branches per plant was also increased significantly with the level of sulphur. ***Bradyrhizobium*** fertilization also pushed up the yield attributes but was not significant. Among the doses of sulphur 60kg S/ha showed the best performance in all respect and doses above 60kg S/ha showed negative results. From the above results it can be concluded that the effects of sulphur on yield and yield attribute of groundnut was better up to 60 kg s/ha and then it declines.

Results of germination and speed of germination test in experiment 4.1.2.1 and 4.1.3.1 revealed that among the four treatment sulphur, storage container and initial moisture content of the seed effected significantly on the germination retention capacity of seed in 1997-98 and 1998-99 while inoculation fails to show significant effect on percentage of germination. Seeds with 60kg S/ha retained the highest percentage of germination while stored in polythene bags and can retain the germination percentage of stored seed up to standard level for 5 months while seeds stored in tin container maintain the germination percentage of seed for only 4 months of storage. Initial moisture contents of the seed play a vital role in retaining the germination percentage of stored seed. Seeds with initial moisture content of 7.25% retained the germination percentage up to standard level for 5 months while seeds with 8.46% initial moisture content of seed could maintain the germination percentage up to standard level more than 4 months and seeds with 9.25% initial moisture content of seed fail to maintain the germination percentage of seed stored seed up to standard level of ISTA for more than 3 months.

Results of the experiment 4.2.2.1 reveal that calcium applied as calcium oxide affected significantly the yield and yield attributes of groundnut. Pod yield was affected significantly with the application of different level of calcium. The highest pod yield was obtained in the treatment of 150 kg Ca/ha while least yield was obtained in control. The yield increased up to the level of 150 kg Ca/ha and then it declines. The interaction of calcium and inoculation was not significant on yield and 100 seed weight. Yield attributes also responded accordingly with the yield. Plant heights, number of branches/plant, mature pods/plant, 100 seed weight, shelling percentage and harvest index seed was affected significantly with the level of calcium. Inoculation did not affect the yield and yield attributes in most case but inoculation had a positive effete on all the yield and yield attributes.

Results of experiment 4.2.2.1and 4.2.3.1 showed that calcium had a significant effect of the germination percentage and speed of germination of stored seed. Inoculation in most of the interval did not produce significant effect on the percentage and speed of germination of stored seed. The interaction of calcium and ***Bradyrhizobium*** fertilization was also not significant on the percentage of germination and speed of germination. The effect of storage container was significant and they played a very vital role in the germination percentage and vigour index of stored groundnut seed. Interaction of calcium and storage container in many intervals was significant but interaction of inoculation and storage container was not significant. The initial moisture content of the seed affected significantly both the percentage and speed of germination of stored seed. It also produced significant effect by interaction with the storage container. The seeds with 7.25% and 8.46% of initial moisture content could retain the germination percentage and speed of germination up to 5 month of interval while seeds with 9.25% fail to maintain the standard level of percentage and speed of germination up to 5 months. The seeds stored in polythene bag maintained the germination percentage and speed up to standard level for 5 months while seeds stored in tin container lost the standard percentage and speed with in 3 months of storage.

Results of field experiment 4.3.1.1 showed that magnesium could improve the yield and yield attributes of groundnut. Though the increase in yield was poorer to the former two-fertilizer element but the effect was significant on the yield. The yield attributes was also affected significantly by the different doses of magnesium. Plant height and number of branches per plant was not affected significantly by the magnesium level and other yield attributes like number of mature pod/plant, shelling percentage, harvest index and 100 seed weight was significantly affected by level of magnesium. Magnesium fails to check the late setting of fruits. The level of magnesium also varied the number of immature pod per plant significantly. The level of magnesium also affected the seed quality, in respect of percent oil and percent protein.

Results of experiment4.3.2.1 and 4.3.3.1 revealed that magnesium affected significantly both the percentage of the germination and speed of germination of stored seed. Though the effect of storage container and initial moisture content of the seed was more dominant yet magnesium maintained a separate position in the interaction process. The seed with 10 kg mg/ha retained the highest percentage and speed of germination and these seeds maintained their percentage and speed of germination up to standard level for 5 months of storage. Inoculation like with other fertilizing elements did not produce significant effect on the percentage and speed of germination of stored seed. Storage container and initial moisture content of seed individually affected both the quality significantly. The interaction of magnesium with storage container was not significant on the percentage of germination and speed of germination but the interaction of magnesium and initial moisture content of seed was significant on the vigour index. The effect of storage container was significant and they played a very vital role in the longevity and vigour index of stored groundnut seed. Interaction of magnesium and storage container in many intervals was significant. The seeds with 7.25% of initial moisture content could retain the germination percentage and speed of germination up to 5 month of interval while seeds with 9.25% fail to maintain the standard level of germination percentage and speed up to 5 months. The seeds stored in polythene bag maintained the germination percentage and speed of germination up to standard level up to 5 months while seeds stored in tin container lost the standard percentage and speed with in 3 months of storage.

CHAPTER VI

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A.1.1 Mean monthly weather data for the year 1997-98

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%) at 9am	Relative Humidity (%) at 2pm
July	28.81	26.31	520.8	84.83	77.65
August	32.21	26.22	345.8	84.58	72.32
September	31.52	25.50	509.0	89.26	81.50
October	31.73	22.33	13.8	80.51	61.35
November	30.02	19.07	0.0	80.23	55.37
December	24.22	14.11	221.8	85.87	65.09
January	22.03	12.50	32.4	83.77	65.93
February	27.62	15.74	2.0	76.03	46.53
March	29.86	17.83	69.8	70.35	49.41
April	32.32	22.50	192.8	78.77	60.27
May	32.67	24.94	291.20	80.00	65.71
June	33.74	27.66	98.70	83.16	71.93

A.1.2 Mean monthly weather data for the year 1998-99

Month	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%) at 9am	Relative Humidity (%) at 2pm
July	31.54	20.70	122.9	87.55	78.64
August	31.74	26.60	382.32	86.25	78.51
September	32.71	26.32	287.60	81.97	72.30
October	32.89	25.51	52.40	76.00	65.61
November	30.05	20.57	113.8	78.93	62.83
December	27.05	15.05	0.0	78.70	54.90
January	26.04	12.63	0.0	78.74	51.06
February	29.65	15.69	0.0	72.53	43.32
March	33.88	19.91	0.0	67.06	40.73
April	35.20	25.13	8.6	74.53	54.37
May	32.42	24.81	325.00	81.19	68.48
June	32.49	26.34	338.20	84.03	74.37

A.2.1 Treatment combination of the experiment 4.1.3.1

1 1. 0 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Tin

2 2. 0 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Polypropylene

3 3. 0 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed +Tin

4 4. 0 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene

5 5. 0 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +Tin

6 6. 0 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene

7 7. 0 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed +Tin

8 8. 0 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed + Polypropylene

9 9. 0 kg S/ha + 50 g I/kg of seed+8.46%initial moisture content of seed +Tin

10 10. 0 kg S/ha +50 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene

11 11. 0kgS/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Tin

12 12. 0 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene

13 13. 20 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Tin

14 14. 20 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Polypropylene

15 15. 20 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed +Tin

16. 20 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene

17. 20 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +Tin

18. 20 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene

19. 20 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed +Tin

20. 20 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed + Polypropylene

21. 20 kg S/ha + 50 g I/kg of seed+8.46%initial moisture content of seed +Tin

22. 20 kg S/ha +50 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene

23. 20kg S/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Tin

24. 20 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene

25. 40 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Tin

26. 40 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Polypropylene

27. 40 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed +Tin

28. 40 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene

29. 40 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +Tin

30. 40 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +

Polypropylene

A.2.2 Treatment combination of the experiment 4.1.3.1

31. 40 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed +Tin
32. 40 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed + Polypropylene
33. 40 kg S/ha + 50 g I/kg of seed+8.46%initial moisture content of seed +Tin
34. 40 kg S/ha +50 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene
35. 40kg S/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Tin
36. 40kg S/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene
37. 60 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Tin
38. 60 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Polypropylene
39. 60 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed +Tin
40. 60 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene
41. 60 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +Tin
42. 60 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene
43. 60 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed +Tin
44. 60 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed + Polypropylene
45. 60 kg S/ha + 50 g I/kg of seed+8.46%initial moisture content of seed +Tin
46. 60 kg S/ha +50 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene
47. 60kg S/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Tin
48. 60 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene
49 80 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Tin
50 80 kg S/ha + 0 g I/kg of seed+7.25%initial moisture content of seed +Polypropylene
51. 80 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed +Tin
52. 80 kg S/ha + 0 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene
53. 80 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed +Tin
54. 80 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene
55. 80 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed +Tin
56. 80 kg S/ha + 50 g I/kg of seed+7.25%initial moisture content of seed + Polypropylene
57. 80 kg S/ha + 50 g I/kg of seed+8.46%initial moisture content of seed +Tin
58. 80 kg S/ha +50 g I/kg of seed+8.46%initial moisture content of seed + Polypropylene
59. 80kg S/ha +50 g I/kg of seed+9.25%initial moisture content of seed + Tin
60. 80 kg S/ha + 0 g I/kg of seed+9.25%initial moisture content of seed + Polypropylene

Appendix A 3.1 Analysis of variance (ANOVA) of effect of sulphur and *Bradyrhizobium* fertilization on growth and yield of groundnut in 1997-98 and 1998-99

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98									
		Plant height (cm)	No. of branch/plant	No. Mature pod/pl	No. Immature pod/plant	% Shelling	Harvest index	Weight of 100 seeds (g)	Pod yield kg/ha	% Oil content	% Protein content
1.Replication	2	10.05	0.171	0.595	1.715	4.09	3.78	4.87**	0.009	2.25	0.084
2.Sulphur	4	16.82	4.562**	34.52**	12.04	142.18*	156.70**	17.40**	0.48**	15.12**	37.82**
3.Inoculatio	1	0.065	0.675**	2.028	18.88	24.35**	25.43**	5.38**	0.03**	3.92**	8.53**
4.Fert × Ino	4	26.30	1.523**	0.685	11.73	4.91	37.34**	6.43**	0.001	1.43	1.10
5.Error	18	52.96	1783	10.20	32.61	16.60	38.70	6.65	0.032	8.98	3.38
		Mean sum of square in 1998-99									
1.Replication	2	35.12	0.55*	1.433	4.21**	1.13	5.17*	0.124	0.000	0.95	0.35
2.Sulphur	4	61.55	2.03**	34.58**	8.77**	89.94**	39.38**	69.032	0.157**	11.50**	63.25**
3.Inoculatio	1	16.58	0.71**	5.21*	1.59**	13.39**	1.81	6.52	0.011**	1.92*	9.97**
4.Fert x Ino	4	36.00	0.09	3.93	2.30**	0.363	3.95	0.94	0.003	1.82	0.53
5.Error	18	290.52	1.245	17.72	2.27	13.036	12.67	4.62	0.01	4.52	7.36

* Significant at 5% and ** significant at 1 % level

Appendix A 3.2 Analysis of variance of effect of calcium and *Bradyrhizobium* fertilization on growth and yield of groundnut in 1997-98 and 1998-99

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98									
		Plant height (cm)	No. of branch/plant	No. Mature pod/pl	No. Immature pod/plant	% Shelling	Harvest index	Weight of 100 seeds (g)	Pod yield kg/ha	% Oil content	% Protein content
1.Replication	2	6.67	0.074	2.77	0.08	11.38**	0.404	5.71*	0.003	0.34	1.05
2.calcium	4	112.8**	3.048**	93.66**	3.64	90.95**	193.2**	65.91**	0.30**	8.18**	16.22**
3.Inoculatio	1	0.47	0.147	11.29*	1.83	6.03*	2.90	2.13	0.017**	0.32	0.34
4.Fert × Ino	4	90.93**	0.41	5.14	1.96	1.01	2.45	4.78	0.005	1.77	1.02
5.Error	18	63.19	1.75	28.24	9.36	20.86	22.83	10.62	0.039	3.94	5.11
		Mean sum of square in 1998-99									
1.Replication	2	9.38	1.63**	1.01*	0.32	0.333	2.79	0.81	0.001	0.056	3.65
2.calcium	4	285.3**	7.82**	31.77**	3.46	52.07**	169.3**	163.3**	0.17**	11.23**	33.51**
3.Inoculatio	1	27.26	2.03**	6.72**	1.87	1.43	9.44**	2.56	0.01**	0.35	0.19
4.Fert × Ino	4	58.76	0.425	0.97	3.42	0.37	6.96	1.54	0.001	0.57	8.17
5.Error	18	130.46	2.047	2.23	12.17	11.72	23.54	29.46	0.006	1.23	17.02

* Significant at 5% and ** significant at 1 % level

Appendix A 3.3 Analysis of variance (ANOVA) of effect of magnesium and ***Bradyrhizobium*** fertilization on growth and yield of groundnut in 1997-98 and 1998-99

Sources of variation	Degrees of freedom	Plant height (cm)	No. of branch/plant	No. Mature pod/pl	No. Immature pod/plant	% Shelling	Harvest index	Weight of 100 seeds (g)	Pod yield kg/ha	% Oil content	% Protein content
		Mean sum of square in 1997-98									
1.Replication	2	0.54	4.07**	0.55	3.50*	1.32	8.69**	4.14	0.02	4.69**	1.56*
2.calcium	4	5.32	7.10**	71.30**	7.68**	46.64	12.78**	43.28**	0.067**	31.17**	25.41**
3.Inoculatio	1	2.11	0.59*	6.44**	0.705	7.61**	0.72	2.35	0.008*	0.33	1.82**
4.Fert × Ino	4	27.47	0.23	1.05	2.99	3.25**	5.47	2.06	0.004	1.22	1.86
5.Error	18	75.41	2.17	3.04	8.31	6.24	12.55	31.69	0.035	4.55	3.33
		Mean sum of square in 1998-99									
1.Replication	2	46.05	0.139	1.539*	0.20	5.44	25.59*	12.63**	0.007	2.63*	2.93*
2.calcium	4	91.50	2.261	34.81**	2.26	54.55**	33.82**	60.51**	0.147**	18.35**	21.52**
3.Inoculatio	1	22.19	0.768	14.21**	0.65	14.71**	0.148	0.79	0.022**	1.24*	13.97**
4.Fert × Ino	4	76.09	0.805	2.93*	1.98	4.85	8.24	4.04	0.003	2.52	1.54
5.Error	18	152.70	4.021	3.74	12.31	19.79	15.49	17.64	0.057	5.30	7.43

*Significant at 5% and ** significant at 1 % level

Appendix A 3.4 Analysis of variance of sulphur, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage of stored seed in1997-98 and 1998-99.

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98				
		1 month	2 month	3 month	4 month	5 month
Sulphur(A)	4	4.584	376.02**	189.34**	190.29**	201.68**
Inoculation(B)	1	0.104	18.32	6.33**	4.64*	2.69*
A×B	4	1.712	0.751	1.622	1.216	1.775
St con (C)	1	26.78*	111.69**	420.22**	1007.34**	1585.20**
A×C	4	1.329	3.119	1.652	7.290	2.079
B×C	1	0.014	0.110	0.063	1.787	0.260
A×B×C	4	0.827	0.368	0.161	1.209	1.671
In.M. con (D)	2	44.57*	990.31**	663.992**	2144.32**	3521.06**
A×D	8	1.682	11.40*	14.710**	8.241	5.022
B×D	2	0.002	1.090	0.552	1.341	0.404
A×B×D	8	3.101	4.840	1.448	3.925	2.052
C×D	2	0.824	0.888**	45.159**	261.311**	37.03**
A×C×D	8	1.856	17.477	2.538	6.157	7.405
B×C×D	2	0.091	0.637	0.186	0.392	0.009
A×B×C×D	8	2.254	4.782	1.710	1.609	4.726
Error	120	95.587	83.390	65.548	113.802	70.421
		Mean sum of square in 1998-99				
Sulphur(A)	4	6.63*	162.83**	227.10**	115.87**	101.49**
Inoculation(B)	1	0.100	0.198	10.737	6.456	4.598
A×B	4	0.593	37.504	9.700	6.182	7.332
St. container (C)	1	0.282	674.74**	652.78**	598.90**	1054.45**
A×C	4	3.942	23.076	35.68	12.998	5.915
B×C	1	1.974	1.218	0.095	0.118	0.319
A×B×C	4	3.432	3.233	0.722	7.886	6.663
In. M. con (D)	2	43.68*	1002.25**	1334.11**	1445.79**	3296.07**
A×D	3	4.256	27.095	13.627	5.937	28.010
B×D	2	0.048	1.515	9.964	2.320	0.679
A×B×D	3	3.817*	11.387	4.786	11.047	13.242
C×D	2	4.020	91.47**	94.56**	79.57**	62.17**
A×C×D	3	6.367	38.489	9.012	14.388	110.19**
B×C×D	2	0.011	1.009	3.306	1.498	0.357
A×B×C×D	3	1.904	6.819	3..47	5.894	5.190
Error	120	80.839	622.997	508.694	298.303	525.116

* Significant at 5% and ** significant at 1 % level Analysis was based on transformed scale to Arcsine

Appendix A 3.5 Analysis of variance of sulphur, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the vigour index of stored seed in1997-98 and 1998-99..

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98				
		1 month	2 month	3 month	4 month	5 month
Sulphur(A)	4	0.28	20.14**	14.43**	7.88**	11.89**
Inoculation(B)	1	0.04	0.03	0.207	0.05	0.04
A×B	4	0.19	2.61	0.18	0.10	0.13
St. container (C)	1	0.17	61.72**	155.12**	247.57**	434.93**
A×C	4	0.20	7.67**	1.33	0.09	0.095
B×C	1	0.07	1.06*	0.05	0.02	0.008
A×B×C	4	0.20	2.78*	1.21	0.09	0.015
In.M. con (D)	2	0.19	112.28**	393.32**	778.97**	573.52**
A×D	8	0.38	2.75	8.01**	0.498	0.058
B×D	2	0.09	0.097	0.269	0.025	0.001
A×B×D	8	0.46	1.18	0.274	0.068	0.009
C×D	2	0.06	3.00**	23.46**	90.16**	28.19**
A×C×D	8	0.4	1.36	3.67	0.43	0.165**
B×C×D	2	0.13	0.056	0.64	0.009	0.006
A×B×C×D	8	0.39	0.515	0.861	0.08	0.008
Error	120	6.177	34.35	30.11	8.97	0.055
		Mean sum of square in1998-99				
Sulphur(A)	4	20.014	2.799**	38.56**	31.233	40.68**
Inoculation(B)	1	5.270	0.156	0.76**	0.660	0.29*
A×B	4	20.070	0.170	0.216	0.101	0.021
St. container (C)	1	5.270	60.90**	105.34**	55.667	205.44**
A×C	4	20.423	0.340	6.20**	1.906	3.425
B×C	1	4.934	0.040	0.013	0.060	0.013
A×B×C	4	19.734	0.024	0.373	0.128	0.013
In.M. con (D)	2	10.372	159.45**	1475.14**	1570.308	1843.49**
A×D	8	40.473	1.61**	4.24**	6.440	9.11**
B×D	2	10.034	0.005	0.481	0.009	0.002
A×B×D	8	40.139	0.186	0.620	0.081	0.030
C×D	2	10.034	0.142	5.86**	2.607	15.41**
A×C×D	8	39.803	0.89*	3.89**	2.948	4.78*
BxCxD	2	9.967	0.091	0.377	0.067	0.009
A×B×C×D	8	39.875	0.082	0.608	0.129	0.011
Error	120	600.37	6.147	10.827	20.193	13.653

* Significant at 5% and ** significant at 1 % level*Analysis was based on transformed scale to Arcsine

Appendix A 3
stored seed n

Sources of variation
Magnesium(A
Inoculation(3)
A×B
St. container ((
A×C
B×C
A×B×C
In.M. conter t (
A×D
B×D
A×B×D
C×D
A×C×D
B×C×D
A×B×C×D
Error
Magnesium A)
Inoculation(3)
A×B
St. container ((
A×C
B×C
A×B×C
In.M. conter t (D
A×D
B×D
A×B×D
C×D
A×C×D
B×C×D
A×B×C×D
Error

* Significant it 5%

Appendix A 3.6 Analysis of variance of calcium, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage of stored seed in1997-98 and 1998-99.

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98				
		1 month	2 month	3 month	4 month	5 month
Calcium(A)	4	0.488	225.22**	112.15**	137.66**	344.778**
Inoculation(B)	1	0.014	2.37	4.35	4.96*	1.028
A×B	4	0.054	2.37	3.04	8.28	6.96
S.container (C)	1	0.014	893.46**	1020.81**	1045.70**	914.19**
A×C	4	0.054	23.5**	35.12**	54.95**	82.38**
B×C	1	0.014	2.96	0.073	0.069	0.093
A×B×C	4	0.054	5.04	1.21	17.94*	2.97
In.M. cot (D)	2	0.244*	877.68**	1245.99**	2639.04**	30.99.61**
A×D	8	0.98	9.023	14.91	7.34	20.17*
B×D	2	0.027	5.55	0.031	5.71	0.327
A×B×D	8	0.11	12.18	4.17	6.95	11.70
C×D	2	0.027	1.24	94.13**	10.63*	20.44**
A×C×D	8	0.11	14.76	11.37	72.42**	27.66**
B×C×D	2	0.027	1.99	0.19	0.121	0.018
A×B×C×D	8	0.11	4.84	4.36	9.712	5.25
Error	120	4.88	139.63	148.81	159.58	151.48
		Mean sum of square in 1998-99				
Calcium(A)	4	1.766**	148.34*	390.28**	348.12**	283.65**
Inoculation(B)	1	0.008	0.126	3.42	14.17	18.92**
A×B	4	0.272	19.61	13.14	26.55	1.26
St. container (C)	1	0.339*	3242.75**	1849.86**	1304.67**	14.08.30**
A×C	4	1.356**	87.55	727.55	15.82	37.64*
B×C	1	0.014	5.62	0.026	2.57	077.831
A×B×C	4	0.054	29.55	11.04	63.29	10.71
In.M. content (D)	2	0.678**	452.61**	3531.52**	2764.98**	3650.85**
A×D	8	1.51**	53.64	50.42	40.15	42.49
B×D	2	0.16	11.19	0.903	2.58	5.27
A×B×D	8	0.40	52.12	27.08	37.77	2.77
C×D	2	0.35	340.77**	188.20**	20.75	17.52
A×C×D	8	1.41**	64.72	32.77	38.83	32.50
B×C×D	2	0.027	14.37	2.21	4.65	1.40
A×B×C×D	8	0.11	47.07	14.39	63.10	6.05
Error	120	7.43	1524.9	1120.7	1092.6	386.77

Significant at 5% and ** significant at 1% level* Analysis was based on transformed scale to Arcsine

Appendix A 3.7 Analysis of variance of calcium, ***Bradyrhizobium*** fertilization, initial moisture content of seed and storage container on the vigour index of stored seed in1997-98 and 1998-99.

Sources of variation	Degrees of freedom	Mean sum of square in 1997-98				
		1 month	2 month	3 month	4 month	5 month
Calcium(A)	4	0.01**	13.25**	24.01**	19.13**	28.22**
Inoculation(B)	1	0.00	0.26**	0.41	0.18	0.15
A×B	4	0.001	0.09	0.35	0.09	0.06
St.container(C)	1	0.004**	62.19**	74.28**	48.97**	262.57**
A×C	4	0.01**	1.37**	1.18	0.78	2.28**
B×C	1	0.000	0.006	0.000	0.005	0.01
A×B×C	4	0.001	0.044	0.054	0.08	0.02
In.M. con (D)	2	0.007**	233.31**	14.90.37**	1479.86**	1761.23**
A×D	8	0.021**	1.39**	1.36	1.20	0.25
B×D	2	0.000	0.023	0.09	0.04	0.005
A×B×D	8	0.001	0.054	0.15	0.06	0.03
C×D	2	0.007**	8.79**	1.32	13.78**	56.04**
A×C×D	8	0.021**	0.359	0.78	0.31	0.80
B×C×D	2	0.000	0.152	0.033	0.013	0.002
A×B×C×D	8	0.001	0.353	0.21	0.11	0.037
Error	120	0.013	5.513	15.56	6.56	6.95
		Mean sum of square in 1998-99				
Calcium(A)	4	0.356	11.86**	12.47**	31.46**	37.07**
Inoculation(B)	1	0.000	0.20	0.83**	0.66**	0.01
A×B	4	0.00	0.60	.040	0.036	0.14
St cont (C)	1	0.089	1.57**	101.85**	159.24**	216.04**
A×C	4	0.356	2.46**	0.36	0.18	0.37
B×C	1	0.00	0.002	0.20	0.024	0.07
A×B×C	4	0.000	0.63	0.38	0.039	0.25
In.M. content (D)	2	0.178	59.12**	997.62**	1657.09**	1911.36**
A×D	3	0.711	0.95	3.09**	2.97**	12.17**
B×D	2	0.000	0.33	0.24	0.061	0.24
A×B×D	3	0.00	0.78	1.15	0.17	0.49
C×D	2	0.178	1.17**	4.18**	8.22**	25.81**
A×C×D	3	0.711	1.24	1.47	0.76	1.99
B×C×D	2	0.000	0.42	0.25	0.04	0.26
A×B×C×D	3	0.000	0.91	0.89	0.11	0.40
Error	120	5.333	13.71	15.55	13.71	16.28

* Significant at 5% and ** significant at 1 % level *Analysis was based on transformed scale to Arcsine

Appendix A 3.8 Analysis of variance of magnesium, *Bradyrhizobium* fertilization, initial moisture content of seed and storage container on the germination percentage of stored seed in 1997-98 and 1998-99.

Sources of variation	Degree of freedom	Mean sum of square in 1997-98				
		1 month	2 month	3 month	4 month	5 month
Magnesium (A)	4	3.682	220.83**	213.10**	32.56**	104.62**
Inoculation (B)	1	0.601	12.71*	11.38**	2.91	2.20
A×B	4	0.723	2.42	5.23	0.26	5.37
St. container (C)	1	0.113	508.98**	917.37**	1338.98**	2048.38**
A×C	4	1.184	5.04	4.95	0.52	10.41
B×C	1	0.152	0.021	0.64	0.25	0.14
A×B×C	4	0.569	1.51	1.06	0.29	0.96
In.M. content (D)	2	2.922	755.82**	1548.83**	1147.09**	4489.02**
A×D	3	0.937	11.95	4.79	1.65	4.49
B×D	2	0.276	0.814	0.114	0.92	1.62
A×B×D	3	1.374	4.19	1.63	0.35	2.33
C×D	2	0.072	4.05	10.27*	54.50**	13.07**
A×C×D	3	1.523	4.90	11.15	1.02	9.86
B×C×D	2	0.489	0.76	0.31	0.26	0.31
A×B×C×D	3	1.127	3.58	1.25	0.31	1.56
Error	120	28.491	361.71	161.81	1.32	97.48
		Mean sum of square in 1998-99				
Magnesium (A)	4	0.285	258.748**	197.131**	108.547**	163.116**
Inoculation (B)	1	0.284	11.636**	12.254**	12.219**	11.544**
A×B	4	3.197*	1.461	6.319	1.039	2.864
St. container (C)	1	3.354*	366.515**	416.946**	448.533**	756.361**
A×C	4	1.824	29.747**	80.278**	30.218**	12.128
B×C	1	9.533**	2.866*	4.064	0.660	0.533
A×B×C	4	0.763	2.202	7.064	2.583	5.173
In.M. content (D)	2	41.307**	612.295**	821.419**	2003.717*	3607.18
A×D	3	2.202	16.786**	9.063	26.708	8.974
B×D	2	0.634	0.636	0.898	0.200	0.117
A×B×D	3	3.159	2.498	2.006	4.399	4.902
C×D	2	0.852	24.535**	15.626*	7.710**	51.620
A×C×D	3	3.763	16.416**	11.621	19.475*	20.950
B×C×D	2	0.079	0.431	1.959	1.220	0.439
A×B×C×D	3	3.266	2.180	2.095	4.286	4.696
Error	120	95.358	91.135	223.577	123.20	208.99

* Significant at 5% and ** significant at 1% level* Analysis was based on transformed scale to Arcsine

Appendix A 3.9 Analysis of variance of magnesium, ***Bradyrhizobium*** fertilization, initial moisture content of seed and storage container on the vigour index of stored seed in1997-98 and 1998-99.

Sources of variation	Degrees of freedom	Mean sum of square				
		1 month	2 month	3 month	4 month	5 month
Magnesium (A)	4	0.008**	16.37**	19.77**	16.89**	33.17**
Inoculation(B)	1	0.00	0.085	0.12	0.48*	0.30
A×B	4	0.001	0.367	0.12	0.34	0.26
St. container (C)	1	0.002**	1.70**	80.13**	143.83**	179.60**
A×C	4	0.004**	7.43**	0.49	1.59	2.48
B×C	1	0.001	0.035	0.05	0.08	0.10
A×B×C	4	0.001	0.084	0.03	0.10	0.19
In.M. content (D)	2	0.003**	146.44**	1290.01**	1480.03**	1384.74**
A×D	8	0.004*	3.31**	3.88**	2.51**	7.39**
B×D	2	0.001	0.019	0.04	0.04	0.01
A×B×D	8	0.003	0.25	0.21	0.16	0.16
C×D	2	0.004**	0.14	9.65**	1.81**	14.78**
A×C×D	8	0.008**	1.03*	0.64	2.46*	2.95
B×C×D	2	0.000	0.03	0.05	0.06	0.07
A×B×C×D	8	0.003	0.23	0.12	0.015	0.10
Error	120	0.033	7.17	9.75	15.65	26.97
		Mean sum of square in 1998-99				
Magnesium (A)	4	0.008**	4.68**	26.40**	26.81**	10.16**
Inoculation(B)	1	0.001**	0.25**	0.24	0.12	0.27
A×B	4	0.002*	0.021	0.05	0.023	0.14
St. container (C)	1	0.005**	94.90**	52.81**	57.91**	110.61**
A×C	4	0.008**	0.07	0.04	0.20	0.035
B×C	1	0.001**	0.001	0.00	0.016	0.047
A×B×C	4	0.002*	0.004	0.001	0.024	0.077
In.M. content (D)	2	0.004**	1437.91**	1262.74**	1339.20**	1032.70**
A×D	8	0.009	0.067	5.27	5.20**	2.84**
B×D	2	0.001**	0.002	0.029	0.007	0.081
A×B×D	8	0.001	0.042	0.13	0.126	0.35
C×D	2	0.004	3.70**	9.78*	23.84**	33.53**
A×C×D	8	0.009**	0.11	1.10	0.41	0.67
B×C×D	2	0.001**	0.003	0.004	0.012	0.05
A×B×C×D	8	0.001**	0.03	0.021	0.11	0.29
Error	120	0.027	2.98	8.[illegible]73	9.23	24.12

- Significant at 5% and ** significant at 1 % level* Analysis was based on transformed scale to Arcsine