# VARIABILITY IN SEED QUALITY AND STORABILITY OF COWPEA (*Vigna* spp.) VARIETIES

By

**ASWATHI C.**

**(2013-11-140)**

**THESIS**

**Submitted in partial fulfilment of the requirements for the degree of**

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**COLLEGE OF HORTICULTURE**
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**2015**

## DECLARATION

I, hereby declare that the thesis entitled **"Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

Certified that the thesis entitled **"Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties"** is a record of research work done independently by **Ms. Aswathi C.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of **Ms. Aswathi C.,** a candidate for the degree of **Master of Science in Agriculture** with major field in **Seed Science and Technology,** agree that the thesis entitled **"Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties"** may be submitted by **Ms. Aswathi C.,** in partial fulfilment of the requirement for the degree.

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# *Introduction*

# 1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most ancient crops cultivated by humans and has been grown as a food crop since Neolithic age (Chevalier, 1964). There are different views supporting Africa, Asia and South America as its origin. It is believed that cowpea was introduced from Africa to India approximately 2,000 to 3,500 years ago. It is mainly cultivated in India and Africa. Rajasthan, Andhra Pradesh, Gujarat, Karnataka, Kerala and Tamil Nadu are the major cowpea growing states in India.

Cowpea belongs to the family Fabaceae. It is a typical warm season crop adapted to the tropics. The crop is used in a variety of ways. Tender pods are used as vegetable and the dry beans as pulse. Due to its nutritive value and soil improving properties, it is also used as fodder, green manure and cover crop. Being a legume crop, cowpea fits well in inter-cropping systems. In Kerala, it is grown as a floor crop in coconut gardens, as an inter-crop in tapioca, fringe crop in rice fields and in garden lands. The crop is an integral part of sustainable agriculture.

Based on growth habit and utilisation of the produce, the cowpea varieties are grouped as trailing or vegetable type (*V. unguiculata* ssp. *sesquipedalis*, yard long bean), bush type (vegetable type as well as pulse type) and semi-trailing type (usually vegetable type). In Kerala, several varieties of cowpea that have been bred specifically to use as vegetable, pulse, fodder and green manure are popular.

Cowpea stands next to bitter gourd among vegetable crops grown in Kerala on a commercial scale (6714 ha) (GOK, 2015). Farmers are eager to grow improved varieties and use quality seeds. Cowpea is propagated through seeds. Seed is the basic input in agriculture. It is not necessary that the seeds should be used immediately after its production. In most cases, it becomes essential to store seeds and it is essential to maintain seed quality till the day of sowing. During storage, a number of physiological and biochemical changes occur in seeds, termed as 'ageing'. The rate at which the process of seed ageing takes place

depends on the protection mechanisms and seeds' ability to resist degradative changes. These are specific for each plant species.

There are numerous factors which affect the seed longevity starting from seed maturation to seed storage and it is difficult to control most of these factors. The longevity of seeds in storage is influenced by four major factors; i) genetics, ii) initial quality of the seed, iii) moisture content of seed or ambient relative humidity and iv) temperature of storage environment (Gupta *et al.*, 1976). It is well known that, low temperature and optimum moisture content help to maintain the longevity of orthodox seeds. However, storing the seeds under modified atmosphere having cooler and drier conditions is not a practical solution especially for the poor farmers as they have provision to store seeds only under ambient conditions. Hence, it would be worthwhile to identify genotypes which maintain high viability during storage under ambient conditions over a longer period.

The varieties may vary greatly in their potential for retaining germinability and vigour of the seed under ambient storage conditions. There may be inherent differences in varieties with respect to reactions during storage. Germination, vigour and physico-chemical changes may vary between varieties during storage. The information regarding such inter-relationship would be helpful in assessing the varieties with regard to their deterioration behaviour.

A number of improved varieties of cowpea suited for commercial cultivation have been released by the Kerala Agricultural University (KAU) and other Institutes. Not much information is available on variations with respect to seed quality parameters and senescence pattern of these cowpea varieties. Identification of varieties having inherent superior seed quality would be helpful to farmers and seed industry.

In this context the present investigation entitled "Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties" was conducted with the following objectives:

1. To assess the variations in seed quality parameters of different cowpea varieties.
2. To study the seed senescence pattern of cowpea varieties.
3. To compare the seed longevity of different cowpea varieties.

# Review of Literature

# 2. REVIEW OF LITERATURE

Seed is a living entity and is bound to lose its life due to extrinsic and intrinsic factors (Roberts, 1972). Storage potential of seed is mainly a genetic factor but is influenced by environment (Roberts, 1972; Wittington, 1978), cultivar differences (Chauhan *et al.*, 1984; Singh and Gill, 1994) and period of storage (Reddy, 1985).

Some deterioration in quality of seeds is an inexorable, inevitable and irreversible process during storage and is mainly dependent on physical, physiological and chemical composition of seed (Delouche, 1973).

Many researchers opined that seed deterioration is a progressive deleterious process which has far reaching consequences (Ellis and Roberts, 1981).

Chandrasenan (1996) observed decline in germination per cent, root length, shoot length, seedling vigour index and seedling dry weight as the storage period increased.

During storage, a number of physiological and physic-chemical changes occur, termed ageing (Sisman, 2005). The rate at which the process of seed ageing takes place depends on the ability of seed to resist degradation changes and protection mechanisms, which are specific for each plant species (Sisman and Delibas, 2004; Mohammadi *et al.*, 2011).

Genetic or inherent factors of seed and storage conditions and duration of storage influence the quality of seeds. A lot of information is available on such aspects. The literatures available are classified under (i) varietal influence on seed quality and (ii) factors influencing seed senescence and longevity and the same are summarised below:

## 2.1 Varietal influence on seed quality

Genetic makeup of the plant influences the quality of the seeds they produce. Some kind of seeds are inherently long lived, others are short lived, while others have an intermediate life span owing to their differences on genetic makeup (Delouche, 1973).

Bláha *et al.* (2005) reported that crop productivity is related to seed quality parameters (germination and vigour) which are mainly influenced by the genotype of a variety.

### 2.1.1 Studies conducted in Cereals

Investigations of six rice (*Oryza* spp.) varieties stored under identical conditions showed no significant difference in the period of viability (Roberts, 1963).

Kurdikeri (1991) reported that maize hybrids differed in their storability under ambient conditions of Bangalore. Among the hybrids Ganga Safed-2 maintained viability upto thirteen months followed by Deccan 103 (upto 11 months) while, MMH-6 retained viability only upto five months.

### 2.1.2 Studies conducted in pulses

Studies conducted by Verma and Gupta (1975) concluded that varietal differences do exist in the loss of viability of soybean seeds. The percentage germination decreased with prolonged storage in seeds of all soybean varieties. However, maximum reduction in germination percentage was observed in variety Hood and minimum in T-1.

Gupta *et al.* (1976) stored the seeds of twenty five soybean varieties and screened them for loss of viability during storage. Among the varieties Punjab-1, JS-2, JS-152 and Monetta maintained more than 70 per cent germination even after one year of storage.

Studies conducted in pigeonpea and chickpea revealed that large-seeded varieties produced larger and more vigorous seedlings, which had an advantage in crop establishment under adverse conditions (Narayanan *et al.*, 1981).

Soybean genotypes differed significantly in germinability at all stages of the storage period under ambient conditions; however a germination per cent of over 80 was maintained by eleven genotypes for six months and by four genotypes for eight months (Arulnandhy, 1983).

Burgass *et al.* (1984) reported variation in seed viability of soybean varieties stored for a period of four years and five months. At the end of storage period, germination varied from 74 per cent for Biloxi variety to zero percent for Heverlendt variety.

Vanangamudi (1988), while storing soybean seeds for 16 months observed varietal differences in seed longevity. Seeds of cultivars, Hill, Co-l, Nirnsoy 7, DS 74-37 and PB-1 had better storage potential whereas Bragg was a poor storer. He also observed that small seeds retained their viability longer than the large seeds.

Singh and Gill (1994) observed that the cultivar PK-472 of soybean had a short storability while the cultivar SL-107, SL-144 and SL-129 stored better even after sixteen months of storage in cloth bags at ambient condition.

According to Kumar *et al.* (1997), germination and seedling vigour decreased in all the varieties of peas with increased duration of storage.

Kharb *et al.* (1998) reported that the soybean genotypes F-49, MO-40, PK-262 and Durga deteriorated at faster rates and considered them as poor storers where as Kalithur, JS-8021, JS-8759, JS-8918, Punjab-1, KB-92, NRC-2, MACS-335 and Pusa-20 as good storers as these genotypes maintained the germination percentage above the minimum seed certification standards (70%) after nine months of storage.

Under ambient storage conditions, vigour and viability of twelve genotypes of rice bean declined gradually during three to three and a half years of storage (Singh *et al.*, 1998).

Khare and Satpute (1999) reported that germination seedling and plant vigour were significantly influenced by seed size but not the days to maturity. Small and medium seeded genotypes had better germination and mobilization efficiency than the bold seeded genotypes, with higher vigour index in pigeonpea.

In chickpea, the seed quality decreased with increase in storage period. However, significantly higher germination, speed of germination, root length, shoot length, vigour index, seedling dry weight and the lowest moisture content and EC were recorded in BG-256 compared to Annigeri-1, ICCV-10 and ICCV-2 (Kumbar, 1999).

Germination and field emergence were significantly low in large Kabuli seed group of chickpea as compared to small and medium seed groups. Kabuli large seed group was also inferior in root, shoot length and vigour index, and also showed rapid deterioration in viability when stored at ambient conditions (Yadav and Sharma, 1999).

Patil (2000) reported that the performance of chickpea variety Annegeri-1 was better compared to JCCV-2. Annegeri-1 recorded higher germination (68.75%) with more shoot length, root length, vigour index and seedling dry weight at the end of fourteen months of storage period.

In pigeonpea genotypes, hundred seed weight and seedling vigour index differed significantly among seed grades of all the varieties. Large seeds expressed high seedling vigour index than the small size seeds in all the varieties (Verma *et al.*, 2005).

Henshaw (2008), from a study involving twenty-eight varieties of cowpea seeds of Nigeria and USA origins reported significant variation in physical

characteristics of seed. Seed size dimensions namely; seed length, width and thickness had range values of 6-10 mm, 4-7 mm and 3-5 mm respectively.

Kadam *et al.* (2011) studied the variability in seed longevity and associated traits in soybean germplasm. Majority of the accessions (83.07%) which registered less than 30 per cent germination, were classified as poor storers; 14.70 per cent accessions which showed germination between 30 per cent to 70 per cent; were classified as medium storers; and the rest of the accessions (2.23%) which exhibited more than 70 per cent germination, were classified as good storers. They also noticed that seed longevity showed strong association with seed coat colour. The storability was found to be negatively correlated with seed size indicating that genotypes having smaller seeds were good storer.

Olasoji *et al.* (2011) reported a wide genetic variation among the African Yam Bean accessions in seed quality traits such as hundred seed weight, germination percentage as well as bulk conductivity readings on accelerated ageing.

Studies were conducted to evaluate the seed quality of different soybean varieties under long term storage by Sheidaei *et al.* (2014) from Iran reported that the cv. Williams had significantly more germination per cent compared to L17. And he also observed that the germination per cent significantly decreased by increasing the storage duration.

Studies conducted in Adilabad district of Telangana by Saxena *et al.* (2015) in two soybean varieties PK-262 and PK-472 revealed that PK-472 variety showed maximum deterioration in seed constituents during storage and also thirty one fungal species belonging to thirteen different genera were isolated from PK-262 and thirty nine fungal species belonging to eighteen genera were isolated from PK- 472.

**2.1.3 Studies conducted in Oilseeds**

Tewari and Gupta (1981) reported that seeds of sunflower variety Perodavik followed by those of Sunrise Selection, had greater viability and vigour than VNI IMK at the end of eight months storage in ambient conditions as well as in cold storage.

Somers *et al.* (1983) reported wide range of genetic variability for seed viability and seedling vigour index among various genotypes of sunflower over different storage period.

Maedaj *et al.* (1986) subjected the eleven cultivars of sunflower having 96.9 to 92.6 per cent initial germination for accelerated ageing at 40°C temperature and 100 per cent RH for 120 hours. The samples having higher initial germination showed the greatest difference in germination between the cultivars after 72 hours of ageing. While the cultivars with initial germination percentage greater than 50 per cent showed maximum difference in germination after 48 hours of ageing.

Bhaskar (1988) from Bangalore reported that sunflower cultivar RHA-274 maintained satisfactory germination upto thirteen months of storage with increased field emergence, root length, shoot length, with decreased free fatty acid content while, Morden, KBSH-1 and CMS-234A maintained satisfactory germination upto twelve months of storage and 6D-1 maintained upto eleven months.

Ramaiah (1994) from Bangalore also observed significant variation in germination of sunflower varieties KBSH-1 (68.55%) followed by BSH-1 and APSH-11 and it was lowest in CMS 234A (64.50%) at the end of eighteen months storage.

Sultana (1994) observed that, when twenty cultivated genotypes of groundnut (*Arachis hypogaea* L.) were stored under ambient conditions of

Kharagpur for fifteen months, there was considerable loss of seed viability ranging from 33 to 100 per cent depending on the genotype. The genotype ICG 10035 lost complete viability, while ICG 4906 showed minimum damage with a loss of 33 per cent seed viability.

Tungeswara (1996) from Dharwad reported that KBSH-1 hybrid sunflower maintained satisfactory germination up to eight months of storage, while RHA-60-1 maintained germination only for six months of storage with lower field emergence per cent, shoot length, root length, seedling dry weight with increased electrical conductivity and fungi infection.

In groundnut, erect varieties showed quick increase in germinability upto ninety one per cent after two months of storage and decreased to twelve per cent after eight months of storage; whereas in the semi-spreading group, germinability increased to 97 per cent after three months of storage then gradually decreased to 16 per cent after eight months of storage (Swain *et al.*, 2001).

Kurdikeri *et al.* (2003) observed significant varietal differences for germination in groundnut. Among six genotypes of groundnut stored in cloth bag under ambient conditions of Dharwad, Cvs. DH-330, JL-24, TMV-2 and ICGS-76 maintained satisfactory germination (70%) as per seed the minimum seed certification standards upto fifteen months while, Mardur local and DH-40 maintained germination upto eleven and nine months, respectively.

Mrutyunjaya (2003) observed increased level of total dehydrogenase activity in three cultivars of sunflower with three vigour levels namely, high (0.91 to 0.93), medium (0.74 to 0.88) and low (0.69 to 0.81) vigour seeds of KBSH-1, high (0.92 to 0.94), medium (0.71 to 0.82) and low (0.68 to 0.81) vigour seeds of CMS-234A, and high (0.90 to 0.92), medium (0.72 to 0.87) and low (0.62 to 0.78 absorbance values) vigour seeds of RHA6D-1.

Sunflower hybrids differed significantly in storage potential and seed germination (74.69%), speed of germination, field emergence, shoot length, root

length, seedling dry weight, vigour index and oil content were maximum with low EC and fungal activity in KBSH-1 compared to RFSH-1 at end of storage period (Divya-Shree, 2006).

Nataraj (2008) opined that all seed quality parameters declined with the advancement of storage period in sunflower hybrids. Initially higher germination was recorded in the KBSH-53 (90.33%) as compared to KBSH-55 (88.66%) and low germination in KBSH-55 (28.77%) and KBSH- 53 (28.33%) at the end of the storage period.

Studies conducted by Ransingh *et al.* (2011) revealed that among the groundnut varieties SB XI was found to be better storer than TAG-24 and TG-26, maintaining germination above the minimum seed certification standard (70%) up to 240 days whereas, it was low for TAG-24 and TG-26 (180 days).

Nataraj *et al.* (2011) noticed that advancement of storage period increases permeability of membrane and leads to loss of electrolytes and its variations between varieties. They observed that lower electrical conductivity of leachate (194.53 dS/m) and higher dehydrogenase activity (1.258) in KBSH-53 sunflower hybrid than KBSH-55 (196.56 dS/m, 1.250 respectively) at the end of storage period.

Balakrishna *et al.* (2012), while studying the effect of seed storability in sunflower varieties and hybrids, concluded that, better seed quality parameters were recorded in KBSH-41 followed by KBSH-44, while it was the lowest in KBSH-1, MSFH-17 and Morden at the end of fourteenth month of storage.

### 2.1.4 Studies conducted in fibre crops

Based on average per cent germination, Chhabra and Verma (1993) reported that out of two varieties of cotton tested, the variety G-27 could store for longer period of twenty four months than H-777 which maintained viability upto eighteen months.

### 2.1.5 Studies conducted in Vegetables

Bass (1970) observed cultivar differences in longevity under specified storage in lettuce seeds.

It is reported that, seeds of tomato cultivar XXIVA lost viability in one year while cultivar Moldavian lost its viability only after ten years under the same storage conditions (Zhuchenko *et al.*, 1979).

Doijode (1987) evaluated different tomato cultivars for the seed longevity under ambient conditions (16-35°C, RH 25-90%) at Bangalore. The genotypes Punjab Kesari and Sel-II showed high seed longevity whereas ACC- 99, Arka Vikas, A-2 and Pusa Ruby exhibited low longevity.

In onion, genotypes Arka Pragati, Poona Red, Chikkaballapur Local, Crystal Box and Nasik Red showed relatively high storability on ageing (Doijode, 1990).

The pattern of seed quality deterioration of twenty genotypes of tomato was studied under six periods of accelerated ageing at 100 per cent RH and 40°C by Deka *et al.* (1993). The results indicated significant differences in response to deterioration of quality due to genotypes and periods of ageing. Among the genotypes, ten were classified as tolerant, eight as moderately tolerant and two as susceptible to senescence in storage.

Doijode (1993) from his studies at Bangalore revealed that the seed storability and seedling vigour were related to storage period in bell pepper cvs. Arka Mohini and Arka Gaurav. Seed germinability and vigour significantly differed with the period of storage in both cultivars and the decreased seed germinability was associated with decrease in seedling vigour.

Danej and Dumbre (1996) from Maharashtra reported that the difference due to genotypes of tomato on germination and vigour index was significant. Cultivar Dhanashree recorded the highest germination (92.60%) and vigour index

(1639) compared to Bhagyashree and Pusa Early Dwarf which recorded 88.1 and 89.8 per cent germination and 1500 and 1466 vigour index respectively.

Hunje (2002) reported that in chilli, Byadagi Kaddi showed significantly higher seed quality parameters during storage period compared to Dyavanur local.

Among three varieties of onion, variety N-53 was found to be better storer than N-2-4-1 and B-780, in maintaining germination above minimum seed certification standards (70%) up to 270 days (Mate and Shelar, 2011).

Information available on varietal influences on seed storage are summarised in the table 2.1. It is concluded that genetic makeup of accessions or varieties has a profound influence on seed storability and quality.

**Table 2.1 Varietal influence on seed quality-summary**

| Crop | Varieties which retained | | Type of Storage condition | Author |
|---|---|---|---|---|
| | Maximum quality | Minimum quality | | |
| Maize | Ganga Safed-2, Deccan- 103 | MMH-6 | Ambient | Kurdikeri (1991) |
| Soybean | Hill, Co-l, Nirnsoy 7, DS 74-37 and PB-1 | Bragg | Ambient | Vanangamudi (1988) |
| | SL-107, SL-144 and SL-129 | PK- 472 | Ambient | Singh and Gill (1994) |
| | Kalithur, JS-8021, JS-8759, JS-8918, Punjab-1, KB-92, NRC-2, MACS-335 and Pusa-20 | F-49, MO-40, PK-262 and Durga | Ambient | Kharb *et al.* (1998) |
| | cv. Williams | L17 | Ambient | Sheidaei *et al.* (2014) |
| | PK-262 | PK-472 | Ambient | Saxena *et al.* (2015) |
| Chickpea | BG-256 | Annigeri-1, ICCV-10 and ICCV-2. | Ambient | Kumbar (1999) |
| | Annegeri-1 | JCCV-2 | Ambient | Patil (2000) |
| Sunflower | Perodavik and Sunrise selection | VNI IMK | Ambient and cold | Tewari and Gupta (1981) |
| | RHA-274, Morden, KBSH-1 and CMS-234A | 6D-1 | Ambient | Bhaskar (1988) |
| | KBSH-1, BSH-1 and APSH-11 | CMS 234A | Ambient | Ramaiah (1994) |
| | KBSH-1 | RHA-60-1 | Ambient | Tungeswara (1996) |
| | KBSH-1 | RFSH-1 | Ambient | Divya-Shree (2006) |
| | KBSH-53 | KBSH-55 | Ambient | Nataraj *et al.* (2011) |
| | KBSH-41 and KBSH-44 | KBSH-1, MSFH-17 and Morden | Ambient | Balakrishna *et al.* (2012) |
| Groundnut | ICG 4906 | ICG 10035 | Ambient | Sultana (1994) |
| | DH-330, JL-24, TMV-2 and ICGS-76 | Mardur local and DH-40 | Ambient | Kurdikeri *et al.* (2003) |
| | SB XI | TAG-24 and TG-26 | Ambient | Ransingh *et al.* (2011) |
| Cotton | G-27 | H-777 | Ambient | Chhabra and Verma (1993) |

| | | | | |
|---|---|---|---|---|
| Tomato | Moldavian | XXIVA | Ambient | Zhuchenko *et al.* (1979) |
| | Punjab Kesari and Sel-II | ACC- 99, Arka Vikas, A-2 and Pusa Ruby | Ambient | Doijode (1987) |
| | Dhanashree | Bhagyashree and Pusa Early Dwarf | Ambient | Danej and Dumbre (1996) |
| Chilli | Byadagi Kaddi | Dyavanur local | Ambient | Hunje (2002) |
| Onion | N-53 | N-2-4-1 and B-780 | Ambient | Mate and Shelar (2011) |

## 2.2 Factors influencing seed senescence and longevity

During storage of seeds, a number of physiological and biochemical changes take place, which lead to gradual decline in seed quality parameters.

The longevity of sunflower seed in storage is influenced by four major factors *viz.* (i) inheritance of the species, (ii) quality of seed at the time when it enters into storage, (iii) temperature of the storage environment and (iv) the moisture content of the seed or ambient relative humidity (Harrington, 1972 and Delouche *et al.,* 1973).

During prolonged storage conditions of high humidity and high temperatures, increase in seed-hardness was noticed in cowpea (black-eyed peas), as in other leguminous seeds (Sefa-Dedeh *et al.,* 1979; Swanson *et al.,* 1985).

Seed quality is an essential component in crop production as vigour and yield are strongly influenced by initial seed quality (Manga and Yadav, 1996; Ramanadane and Thirumeni, 2001; Gastel *et al.*, 2002).

High quality seed will produce vigorous seedlings under a wide range of environmental conditions (Murungu *et al.*, 2006).

### 2.2.1 Seed moisture

Ghosh and Basak (1958) reported that jute seeds could be stored for more than nineteen months without impairing its germination, provided the moisture content of seed is brought down to minimum 7.2 per cent through drying in sun and then storing them in air tight containers.

The moisture content of seed is utmost important factor in the determination of seed longevity during storage (Barton, 1961).

High seed moisture has a great influence on seed deterioration (Gregg, 1982). So, seed must be dried to a safe moisture level immediately after harvest

and it should be maintained until planting. Seed deterioration can increase with the increase of seed moisture (Justice and Bass, 1978).

Balamurugan *et al.* (1989) studied storability in sunflower seeds dried to eight per cent and stored in cloth bag under ambient condition for twenty months. The germination per cent, root length, seedling dry matter and vigour index remained high up to ten months and thereafter decreased with increase in storage period. The deterioration of the stored seed is a natural phenomenon and the seeds tend to lose viability even under ideal storage conditions. Aged seeds show decreased vigour and produce weak seedlings that are unable to survive once introduced into a habitat.

Narayanaswamy (2003) reported that groundnut seeds at 8.00 to 9.53 per cent moisture content could be stored for eight months without losing its germination under ambient conditions at Bangalore.

Keshavulu and Krishnasamy (2005) reported that soybean seed stored with initial moisture content of nine per cent, recorded highest (84%) germination, root length, shoot length, speed of germination, vigour index and field emergence.

### 2.2.2 Germination and vigour

Heydecker (1972) stated that decline in rate of emergence was attributed to loss of seed vigour during ageing. He further opined that initial slow growth rate of the embryo tend to continue during ontogenetic development into seedling stage resulting in slow and low rate of emergence.

According to Delouche (1974) seed germination and seedling vigour declined with increasing storage period.

Perry (1976) reported that seedling vigour was interrelated to rate of germination, rate of uniformity, rate of seedling growth, plant performance and yield.

Gowda (1981) reported significant reduction in loss of viability and vigour of sunflower seeds during storage under room conditions.

In groundnut, Singh and Khatra (1984) noticed that seedling vigour index decreased with increased period of ageing.

Ramamoorthy *et al.* (1989) observed decline in seedling vigour index (2960 to 2020) with increased ageing period from nine to fourteen days in maize. In sorghum, a similar trend was reported by Sundareswaran and Krishnasamy (1994).

Pandian *et al.* (1994) noticed decrease in germination in rice genotypes with increase in ageing period.

Narwal *et al.* (1998) observed that seed viability and vigour of okra under ambient conditions of storage could be retained up to six months at Hissar. The seed viability and germination reached its peak after six months of storage and then it started declining gradually.

The germination studies conducted by Manoharan (1999) during ten months of storage period revealed that chilli seeds lost viability completely from the ninth month of storage onwards in ambient conditions.

Decrease in germination of maize, soybean and sunflower seeds was observed by Simic *et al.* (2007) after four years of storage.

Shakuntala (2009) reported that germination of sunflower seeds declined progressively with increase in the period of storage.

A decline in germination observed after twelve months of storage in carrot, cucumber, onion and tomato by Alsadon *et al.* (2011).

Tabatabaei (2013) observed that the highest germination percentage, germination index, normal seedling per cent of barley seeds were achieved in

control conditions (0 day of storage) and increasing storage duration resulted higher reduction in germination characteristics.

### 2.2.3 Seedling length

Metzer (1966) observed significant and positive correlation between germination and seedling length in soybean.

In soybean, increased ageing caused decline in seedling length (Grabe and Metzer, 1969).

Studies conducted by Ching and Schoolcraft (1968) and Villiers (1972) proved that reduction in seedling length due to ageing was a result of disintegration of cellular membranes. These consequently impaired the growth of the seedlings by leaching of solutes and inter cellular disorganization.

Agarwal (1974) observed the reduction in germination per cent was accompanied by a reduction in shoot length and root length of maize seeds at both room temperature and cold temperature after a period of eleven months while Manjunath (1993) observed that, groundnut seeds with high initial germination exhibited higher root length (12.41 cm) and shoot length (8.16 cm).

### 2.2.4 Seed microflora

Christensen and Kauffmann (1969) reported that, even under limited moisture conditions where fungi and other microorganisms cannot grow, storage fungi adversely affect the seed by bringing down the seed viability, seedling vigour and also affect the chemical composition of seeds.

Krishnamurthy and Raveesha (1996) identified thirty eight species of fungi associated with storage of soybean seeds. Among them, *Aspergillus, Pencillium, Rhizopus* and *Nigricans* were most commonly occurring storage fungi which reduce seed germination and seedling vigour and cause a variety of symptoms on seedling.

### 2.2.5 Influence of Electrical Conductivity (EC) on storage

Pollock and Roos (1972) formulated a method of evaluating relative vigour of seed lot by measuring the amount of material leached from the seed soaked in water, the lower the vigour the greater the amount of leaching.

According to Srivastava and Gill (1975), increase in electrical conductivity of leachates indicated an increase in seed deterioration.

Sen and Pal (1979) reported increased leaching of electrolytes in seed leachate with increase in storage period in sunflower.

Loss of electrolyte into imbibing medium increased with ageing was observed in very old rice seeds (Ghosh *et al.*, 1980).

The leachate exudates as measured by electrical conductivity were associated with loss of vigour and viability. Increased leaching of solutes was related to low metabolic activity of seed (Abdul-Baki and Anderson, 1972 and Powell and Mathews, 1986).

Negative correlation between electrical conductivity (EC) with germination and field emergence was reported by Urbaniak (1984). He also concluded that EC is not the accurate estimate of seed quality in French bean.

In French bean seeds, Pandey (1989) reported that membrane integrity loss as manifested by electrolyte and solute leakage increased steadily with increase in duration of ageing.

Doijode (1985) reported that the losses of seed sugars, amino acids and leachate conductivity were directly proportional to ageing period and inversely proportional to seed germination of onion.

Nautiyal *et al.* (1988) observed that loss of viability in groundnut was associated with increase in EC, potassium and sugar contents of seed leachates.

Similarly, Dey and Mukherjee (1988) and Deshpande (1988) also reported that electrolyte leakage increased with storage. Likewise membrane degradation during seed deterioration as judged by increased seed leachate and electrical conductivity were reported by Agrawal (1980) and Dighe *et al.* (1995) in sunflower.

Krishnaswamy and Ramarajapalaniappan (1989) reported that in tomato and brinjal there was a significant association of electrical conductivity of seed leachate and field emergence of seeds. Soaking brinjal seeds for two hours and tomato seeds for four hours was found to be optimum for measuring seed leachate electrical conductivity.

Vyas *et al.* (1990) reported that in soybean seeds, a decrease in germination per cent was accompanied by an increase in leaching of electrolytes and that electrical conductivity of seed leachate is a good indicator of seed storability and germinability.

Deswal and Sheoran (1993) reported that permeability of membrane increases with increase in storage period and leads to loss of electrolytes, sugars, amino acids and phenols.

Manjunath (1993) noticed increased EC (307.50 to 1027.75 mmhos/cm) of seed leachate with decrease in vigour levels in groundnut.

Kalpana and Rao (1995) reported that in pigeon pea seeds, progressive loss in seed viability and vigour, reduced water uptake, increased leakage of solutes and decline in respiratory activity were accompanied with ageing of seeds. These changes associated with ageing were interpreted as resultants of membrane deterioration.

Perez and Arguello (1995) reported that changes in membrane integrity associated with seed deterioration occurred first in the embryonic axes and can best be monitored by conductivity tests.

Lin and Ferrari (1996) observed greater electrolyte conductivity in aged seeds and a significant correlation between vigour, germination and electrolyte conductivity for all the cultivars under study.

Biradar (1996) noticed increased electrical conductivity of seed leachate as the days of ageing increased in sunflower.

Faster decline in seed germination and seedling vigour was associated with greater leakage and higher production of volatile aldehydes in soybean (Shanmugavel *et al.*, 1996). Similar observation was also made by Nautiyal *et al.* (1997) in groundnut during ageing.

The electrical conductivity of seed leachate increased with period of storage of chilli seeds revealing the loss of membrane integrity resulting in leakage of cell contents outside the cell membrane (Manoharan, 1999).

Sandyarani (2002) reported that cotton seeds recorded higher electrical conductivity due to ageing, in both fresh and aged seeds.

Electrical conductivity of stored seeds showed a progressive increase with increase in storage period, the average initial EC value was 0.51 and the final value was 0.66 at the end of ten months of storage as reported by Basavaraj *et al.* (2008) in onion.

Saha and Sultana (2008) reported that seed germination and field emergence percentage decreased but electrical conductivity of seed leachate increased with increasing seed age in the soybean varieties. Irrespective of varieties, plants grown from twenty months aged seed accumulated more dry matter per plant but crop growth rate (CGR) were lower than the other ageing treatments at twelve, eight and six months.

## 2.3 Cold storage

The work of Maurya (1971) in which soybean seeds were stored under both ambient conditions and cold storage for sixteen months revealed that the seeds stored in ambient conditions lost complete viability in nine months.

Singh and Setia (1974) reported that germination of soybean seeds kept in the cold storage was much higher than these seeds kept at room temperature. Seed kept under room temperature lost viability completely twelve months after storage.

Verma and Gupta (1975) observed a loss in viability of soybean seeds due to storage in room under ambient conditions than cold storage.

Nagaveni (2005) observed that the onion seeds stored under cold storage condition recorded higher germination, rate of germination, seedling dry weight, vigour index, field emergence, moisture content and lower electrical conductivity (74.1%, 17.86, 15.18 mg, 1038, 59.90%, 9.10% and 0.545 dSm-1 respectively) compared to the seeds stored under ambient condition (50.5%, 11.96, 14.23 mg, 641, 38.10%, 8.43%, 0.558 dSm-1, respectively) at the end of twelve months of storage.

A summary of the literature available on factors influencing seed senescence furnished in table 2.2.

The review of literature clearly shows variations in seed quality and storability among varieties and there are many factors which influence seed senescence and longevity. But such studies are lacking in cowpea varieties under hot humid tropical conditions of Kerala and hence, this study was taken up.

Details of the investigations and methodology adopted are furnished in the following chapter.

**Table 2.2 Factors influencing seed senescence and longevity- summary**

| | Parameters | Observations related to ageing of seeds | Author |
|---|---|---|---|
| **I. General reports** | Seed germination and vigour | Decreased | Delouche (1974) |
| | Seed microflora | Adversely affect the seed by bringing down the seed viability, seedling vigour and also affect the chemical composition of seeds. | Christensen and Kauffmann (1969) |
| | Permeability of seed membrane | Increases with increase in storage period and leads to loss of electrolytes, sugars, amino acids and phenols | Deswal and Sheoran (1993) |
| | Electrical conductivity | Greater electrolyte conductivity in aged seeds and a significant correlation between vigour and germination | Lin and Ferrari (1996) |
| **II. Crops** Jute | Seed moisture – 7.2 per cent | Seeds could be stored for more than nineteen months without impairing its germination in air tight container | Ghosh and Basak (1958) |
| Sunflower | Seed moisture – 8 per cent | The per cent germination, root length, seedling dry matter and vigour index remained high upto ten months and thereafter decreased | Balamurugan *et al.* (1989) |
| Groundnut | Seed moisture- 8.00 to 9.53 per cent | No reduction in germination for eight months under ambient conditions. | Narayanaswamy (2003) |
| Soybean | Initial moisture content – nine per cent | Recorded highest (84%) germination, root length, shoot length, speed of germination, vigour index and field emergence. | Keshavulu and Krishanasamy (2005) |
| Groundnut | Seedling vigour index | Decreased | Singh and Khatra (1984) |
| Maize | | Decreased | Ramamoorthy *et al.* (1989) |
| Sorghum | | Decreased | Sundareswaran and Krishnasamy (1994). |
| Okra | Viability and vigour | Reached its peak after six months of storage and then it started declining gradually. | Narwal *et al.* (1998) |
| Rice | | Decreased | Pandian *et al.* (1994) |

| | | | |
|---|---|---|---|
| Maize, Soybean and Sunflower | Germination | Decrease in germination after four years of storage | Simic *et al.* (2007) |
| Sunflower | | Declined progressively | Shakuntala (2009) |
| Carrot, Cucumber, Onion and Tomato | | Declined after twelve months of storage | Alsadon *et al.* (2011) |
| Barley | | The highest germination characteristics were achieved in control conditions (0 day of storage) and increasing storage duration resulted higher reduction in germination characteristics. | Tabatabaei (2013) |
| Soybean | Seedling length | Decreased | Grabe and Metzer (1969) |
| Maize | Germination per cent, shoot and root length | Reduced in both room temperature and cold temperature after a period of eleven months. | Agarwal (1974) |
| Soybean | Seed microflora | Reduce seed germination and seedling vigour and cause a variety of symptoms on seedling | Krishnamurthy and Raveesha (1996) |
| Sunflower | Seed leachate | Increased | Sen and Pal (1979) |
| Rice | | Increased | Ghosh *et al.* (1980) |
| French bean | | Increased | Pandey (1989) |
| Onion | | Directly proportional to ageing period and inversely proportional to seed germination | Doijode (1985) |
| Soybean | | Decrease in germination per cent with increase in seed leachate. | Vyas *et al.* (1990) |
| Groundnut | | Increase in seed leachate with decrease in vigour level | Manjunath (1993) |
| Cotton | | Higher electrical conductivity due to ageing | Sandyarani (2002) |
| Soybean | Temperature | Germination was much higher in cold storage than seeds kept at room temperature | Singh and Setia (1974) |
| Soybean | Temperature | A loss in viability of seeds due to storage in room under ambient conditions than cold storage | Verma and Gupta (1975) |
| Onion | Temperature | The seeds stored under cold storage condition recorded higher germination and lower electrical conductivity. | Nagaveni (2005) |

# Materials and Methods

# 3. MATERIALS AND METHODS

The present investigation was carried out in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara during the year 2013-2015 with the objective of studying the 'variability in seed quality and storability of cowpea (*Vigna* spp.) varieties'.

The site is located at 10° 31' N latitude, 76° 13' E longitude at an altitude of 22.25 m above mean sea level. The area experiences a typical warm humid tropical climate and receives an average rainfall of 2663 mm per year.

## 3.1 Varieties

Ten varieties that included Sreya, Hridya and Bhagyalakshmi of bushy type, Anaswara, Kairali, Kanakamony and Kashi Kanchan of semi-trailing type and Lola, Vellayani Jyothika and Vyjayanthi of trailing type were selected for the study. The seeds were collected from Department of Olericulture, College of Horticulture, Vellanikkara, Onattukara Regional Agricultural Research Station, Kayamkulam and Department of Olericulture, College of Agriculture, Vellayani.

## 3.2 Experimental site

The varieties were grown in the experimental field of the Department of Plant Breeding and Genetics during February-June, 2014 and seeds required for the study collected. The main characters of the varieties are furnished in table 3.1. (Plate 1 and Plate 2).

The storage studies were conducted in the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University, Vellanikkara (July 2014 to May 2015).

**Table 3.1 Details of varieties**

| Code | Variety | Growth habit | Flower colour | Pod colour | Mean pod length (cm) | Mean number of seeds per pod | Seed colour | Mean seed length (mm) | Mean seed breadth (mm) | 100 Seed weight (g) | Seed moisture (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V1 | Lola | Trailing | Light violet | Light green | 46.90 | 15 | Black | 11.50 | 5.17 | 16.33 | 8.30 |
| V2 | Vellayani Jyothika | Trailing | White | Light green | 48.00 | 16 | Dark brown with cream | 12.00 | 4.35 | 22.36 | 8.10 |
| V3 | Vyjayanthi | Trailing | Light violet | Wine red | 45.70 | 17 | Brown | 10.00 | 4.71 | 15.62 | 7.80 |
| **Mean** | | | | | **46.87** | **16** | | **11.17** | **4.74** | **18.10** | |
| V4 | Anaswara | Semi trailing | Light violet | Light green | 21.10 | 14 | Cream | 9.14 | 5.05 | 18.45 | 8.10 |
| V5 | Kairali | Semi trailing | Light violet | Violet | 18.70 | 13 | Reddish brown | 7.69 | 4.07 | 14.89 | 8.20 |
| V6 | Kanakamony | Semi trailing | Light blue | Green | 17.35 | 15 | Dark red | 5.86 | 4.53 | 12.19 | 8.10 |
| V7 | Kashi Kanchan | Semi trailing | Light violet | Green | 19.90 | 14 | Brick red | 6.31 | 3.66 | 10.88 | 7.90 |
| **Mean** | | | | | **19.26** | **14** | | **7.25** | **4.33** | **14.10** | |
| V8 | Sreya | Bushy | Violet | Violet | 17.70 | 15 | Cream | 6.08 | 3.53 | 14.07 | 8.20 |
| V9 | Hridya | Bushy | Light rose | Dark green | 10.00 | 12 | Cream | 3.53 | 1.96 | 4.87 | 8.00 |
| V10 | Bhagyalakshmi | Bushy | Light violet | Light green | 16.10 | 12 | Light brown with cream | 5.93 | 3.90 | 9.99 | 8.20 |
| **Mean** | | | | | **14.60** | **13** | | **5.18** | **3.13** | **9.64** | |

**Plate 1. Seed multiplication plot of cowpea varieties – initial and vegetative stages**


**Plate 2. Seed characters of cowpea varieties**

### 3.3 Design of experiment

The design of experiment adopted for laboratory studies was a Completely Randomized Design (CRD) with three replications.

### 3.4 Seed multiplication

Seeds of ten varieties were sown in the department field and were grown under uniform management during February 2014 to June 2014, and seeds required for the study were collected from these varieties.

### 3.5 Seed packing and storage

The uniformly processed seeds (composite sample of first five harvests) were packed as 50g lots/replication/month in 700 G polythene bags and stored at ambient conditions. The atmospheric conditions during the storage period (monthly mean) are furnished in Annexure- I.

In order to evaluate the performance of seeds under cold storage, a similar set of seeds were also stored in an air conditioned room (20°C±2°C).

### 3.6 Experimental details

The germination and quality parameters of seeds at the time of storage was tested and recorded. Thereafter, samples of seeds stored were tested at monthly intervals for a period of ten months. The following observations were recorded:

#### 3.6.1 Seed colour

Seed colour of ten varieties were observed and noted as per the Royal Horticultural Society colour charts.

#### 3.6.2 Seed length (mm)

By using a vernier caliper the seed length of each variety was determined and the mean expressed in millimetre.

### 3.6.3 Seed breadth (mm)

The seed breadth of each variety was measured using a vernier caliper and the mean expressed in millimetre.

### 3.6.4 100 seed weight (g)

Determination of 100 seed weight was done as per the International Rules for Seed Testing (ISTA, 1985) and the mean expressed in grams.

### 3.6.5 Seed moisture (%)

The seed moisture constant before storage was determined by gravimetric method and expressed in per cent.

### 3.6.6 Germination (%)

In each variety, germination was assessed at monthly intervals adopting the sand method advocated by ISTA (1985). Four hundred seeds from each variety were sown in trays containing sterilized sand (4 replications with 100 seeds per replication) (Plate 3). Daily observation on germination was recorded up to eighth day. The mean number of normal seedlings produced to the total number of seeds sown was expressed as germination per cent.

### 3.6.7 Days to first germination

The number of days taken from sowing up to first germination in each variety was recorded.

### 3.6.8 Days to fifty per cent germination

The number of days taken from sowing to fifty per cent germination in each variety was recorded.


**Plate 3. Seed germination test by sand method**

### 3.6.9 Speed of germination

Germination for each day was counted and recorded up to the final count. The speed of germination was calculated employing the following formula suggested by Maguire (1962).

$$\text{Speed of germination} = X_1/Y_1 + X_2\text{-}X_1/Y_2 + \ldots\ldots + X_n\text{-}X_{n\text{-}1}/Y_n$$

Where $X_n$ = per cent germination on $n^{th}$ day

$Y_n$ = number of days from sowing to $n^{th}$ count

### 3.6.10 Seedling shoot length (cm)

In each variety, five normal seedlings were selected at random from each replication on eighth day. The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and the mean expressed in centimetre.

### 3.6.11 Seedling root length (cm)

The root length of the normal seedlings selected for shoot length was recorded and the mean expressed in centimetre.

### 3.6.12 Seedling dry weight (g)

Ten normal seedlings were selected from each replication from each variety and air dried first for six hours and then in hot air oven maintained at 60°C for 48 h and were cooled in a desiccator for 45 minutes; then the dry weight of seedlings was recorded and the mean expressed in grams

### 3.6.13 Vigour indices

Two measures of vigour indices (Vigour index I and Vigour index II) were recorded. The Vigour index (VI) was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed in number.

Vigour index- I = Germination (%) X Seedling length (cm)

Vigour index- II = Germination (%) X Seedling dry weight (g)

### 3.6.14 Electrical conductivity of seed leachate ($dSm^{-1}$)

In each variety, five grams of seeds per replication were surface sterilized using 0.1 per cent mercuric chloride solution and rinsed with water thoroughly. These seeds were soaked in 25 ml distilled water in a beaker and kept in an incubator maintained at 25±10°C temperature. After 24 h of soaking, the solution was decanted and the volume made up to 25 ml using distilled water. The electrical conductivity was recorded using the digital conductivity meter (Model - Eutech- CON 510) and expressed in decisiemens per metre ($dSm^{-1}$) (ISTA, 1999).

### 3.6.15 Dehydrogenase activity

Aqueous solution of 2, 3, 5- triphenyl tetrazolium chloride (T.T.C- 0.25 per cent of pH 7.0) was prepared in 1000 ml of Sorenson's phosphate buffer. The buffer was prepared by mixing 400 ml of aqueous solution of A (9.078g $KH_2PO_4$ in 1 litre distilled water) with 600 ml of aqueous solution B (11.376g $Na_2HPO_4$ in 1 litre distilled water).

Seeds were preconditioned by soaking in water for 24 hours. The embryos of ten seeds from each replication were removed carefully and placed over a filter paper in petridish. T.T.C. was added to immerse the embryos and kept in darkness for twelve hours. The excess T.T.C. solution was decanted and embryos thoroughly washed with distilled water. The colour was eluted from the stained embryos by steeping in 2 ml of 2-methoxy ethanol (methyl cellosolve) for 1 hour before decanting the solution. The intensity of red colour of the decanted solution was read in spectrophotometer (Model- 4001/4 Thermospectonic, Thermo Electro Corporation, USA) at 470 nm (Lakon, 1942).

### 3.6.16 Seed microflora (%)

Storage fungi present on seeds were detected using blotter method as prescribed by ISTA (1985). Ten seeds were placed equidistantly on three layered moistened blotter taken in sterilized petriplates. Each treatment was replicated four times. They were incubated at 20°C for seven days with an alternate cycle of twelve hours near ultra violet range and for remaining twelve hours in dark. On eighth day, the plates were examined under stereo binocular microscope for the presence of seed borne fungi. The number of infected seeds were counted and expressed in per cent.

### 3.7 Statistical analysis

The following statistical tools were employed in the study:

- Statistical analysis of monthly germination and lab test data in CRD using MSTAT-C package
- Correlation and path analysis by using SPAR 1 software
- Stability analysis by using Eberhart and Russel model (1966) in SPAR 1 software
- $D^2$ analysis (Mahalanobis, 1930) using SPAR 1 software

Details of observations recorded and results are furnished in the following chapter.

# Results

# 4. RESULTS

The results obtained and their statistical analyses are presented below:

## 4.1 Germination

### 4.1.a Under ambient conditions of storage

Mean germination per cent of seeds of cowpea varieties, along with results of statistical analysis are furnished in table 4.1.a.

**Variability among genotypes**

Considering the overall performance of seeds during storage, it was found that the varieties did not vary significantly for seed germination at initial stage, after one and three months of storage. However, they differed significantly in second and from fourth month of storage. The overall monthly mean germination of varieties decreased gradually from 96.50 per cent (initial) to 49.17 per cent (10MAS) during storage.

The initial germination per cent of seeds varied from 92.50 per cent (Vyjayanthi) to 100 per cent (Kanakamony). Germination after ten months of storage ranged from 30.83 per cent (Vellayani Jyothika) to 61.67 per cent (Kashi Kanchan).

On examining the varietal variations, it was observed that, in second month after storage (2MAS), the varieties Kanakamony and Anaswara showed the highest germination and Kanakamony (98.33%), Anaswara (98.33%), Kashi Kanchan (97.50%), Vellayani Jyothika (95.83%), Lola (95.00%), Hridya (95.00%) and Vyjayanthi (92.50%) were on par with each other. Similarly, Sreya (89.17%), Bhagyalakshmi (89.17%) and Kairali (83.33%) were on par with each other. The lowest germination was recorded in Kairali (83.33%). After ten months of storage, the highest germination was recorded in Kashi Kanchan (61.67%). It

was on par with Kanakamony (57.50%). Vellayani Jyothika (30.83%) recorded the lowest estimate and varied significantly from others.

Considering the overall performance of varieties, Kashi Kanchan (81.82%) and Kanakamony (80.23%) of group II registered the highest germination while Vellayani Jyothika (69.70%) recorded the lowest germination.

**Variability based on growth habit**

Analysis of group means indicate that the three groups differed significantly in germination at initial stage and thereafter from the fourth month after storage. Varieties belonging to trailing type had the lowest mean germination during the first two months (94.72% and 95.55%), and thereafter from eight months after storage. Bush type recorded the lowest germination from two to seven months after storage.

The germination per cent varied from 95.55 per cent (1MAS) to 44.44 per cent (10MAS) in group I, 97.92 per cent (initial) to 54.38 per cent (10MAS) in group II and 96.39 per cent (initial) to 46.95 per cent (10MAS) in group III.

Comparing the group means initially before storage, semi-trailing (97.92%) and bush type (96.39%) varieties were on par. Similarly, trailing (94.72%) and bush (96.39%) varieties were on par with each other. The highest germination was in semi trailing and the lowest was in trailing. After ten months of storage, the group means of trailing (44.44%), semi trailing (54.38%) and bush (46.95%) varieties varied significantly with each other. The highest was in semi trailing and the lowest was in trailing varieties.

Considering varietal means under trailing types (Group I) germination did not show significant variation among varieties up to six months after storage; and thereafter it varied significantly. At seven months after storage, varieties Lola (57.50%), Vellayani Jyothika (52.50%) and Vyjayanthi (67.50%) of trailing type

varied significantly. After ten months of storage, Lola (50.83%) and Vyjayanthi (51.67%) were on par and Vellayani Jyothika (30.83%) varied significantly.

In the case of semi trailing type (Group II), the varieties varied significantly except at three, four, five, seven and nine months after storage. Before storage, Kanakamony (100.00%), Anaswara (99.17%) and Kashi Kanchan (97.50%) were on par with each other, while, Kashi Kanchan (97.50%) and Kairali (95.00%) were on par. After ten months of storage, the four varieties varied significantly from each other.

Monthly germination among varieties under bush type (Group III) significantly varied only at five months after storage. At five months of storage, Bhagyalakshmi (84.17%) varied significantly from others recording the highest germination followed by Hridya (77.50%) and Sreya (73.33%) which were on par with each other.

The overall monthly mean germination of varieties decreased gradually from 96.50 per cent (initial) to 49.17 per cent (10MAS) during storage.

**Table 4.1.a Mean germination (%) of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 95.83 | 97.50 | 95.00 | 85.00 | 83.33 | 78.33 | 66.67 | 57.50 | 57.50 | 56.67 | 50.83 | 74.92 |
| | 2.Vellayani Jyothika | 95.83 | 95.83 | 95.83 | 90.00 | 90.00 | 86.67 | 64.17 | 52.50 | 33.33 | 31.67 | 30.83 | 69.70 |
| | 3.Vyjayanthi | 92.50 | 93.33 | 92.50 | 87.50 | 82.50 | 80.83 | 71.67 | 67.50 | 64.17 | 52.50 | 51.67 | 76.06 |
| Overall mean (Group I) | | 94.72 | 95.55 | 94.44 | 87.50 | 85.28 | 81.94 | 67.50 | 59.17 | 51.67 | 46.95 | 44.44 | |
| SE (±) | | 2.31 | 1.60 | 2.10 | 2.89 | 2.26 | 2.04 | 2.04 | 1.44 | 3.08 | 1.60 | 2.20 | |
| **CD** | | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **4.99** | **10.67** | **5.54** | **7.62** | |
| Group II (Semi trailing) | 4.Anaswara | 99.17 | 99.17 | 98.33 | 87.50 | 85.83 | 84.17 | 65.83 | 63.33 | 62.50 | 55.00 | 53.33 | 77.65 |
| | 5.Kairali | 95.00 | 92.50 | 83.33 | 85.00 | 80.00 | 79.17 | 68.33 | 65.83 | 53.33 | 50.83 | 45.00 | 72.58 |
| | 6.Kanakamony | 100.00† | 100.00† | 98.33 | 90.00 | 85.83 | 86.67 | 75.83 | 66.67 | 65.83 | 55.83 | 57.50 | 80.23 |
| | 7.Kashi Kanchan | 97.50 | 95.00 | 97.50 | 95.00 | 86.67 | 85.83 | 82.50 | 68.33 | 68.33 | 61.67 | 61.67 | 81.82 |
| Overall mean (Group II) | | 97.92 | 96.67 | 94.37 | 89.38 | 84.58 | 83.96 | 73.12 | 66.04 | 62.50 | 55.83 | 54.38 | |
| SE (±) | | 0.83 | 1.10 | 1.91 | 2.50 | 1.77 | 1.82 | 2.39 | 2.20 | 2.50 | 2.70 | 0.93 | |
| **CD** | | **2.71** | **3.59** | **6.24** | **NS** | **NS** | **NS** | **7.81** | **NS** | **8.17** | **NS** | **3.04** | |
| Group III (Bush) | 8.Sreya | 95.83 | 95.83 | 89.17 | 82.50 | 78.33 | 73.33 | 60.83 | 55.00 | 55.83 | 55.00 | 49.17 | 71.89 |
| | 9.Hridya | 95.83 | 95.00 | 95.00 | 90.00 | 81.67 | 77.50 | 60.83 | 54.17 | 52.50 | 50.00 | 45.00 | 72.50 |
| | 10.Bhagyalakshmi | 97.50 | 97.50 | 89.17 | 85.00 | 82.50 | 84.17 | 62.50 | 61.67 | 55.83 | 49.17 | 46.67 | 73.79 |
| Overall mean (Group III) | | 96.39 | 96.11 | 91.11 | 85.83 | 80.83 | 78.33 | 61.39 | 56.95 | 54.72 | 51.39 | 46.95 | |
| SE (±) | | 1.08 | 1.27 | 2.97 | 2.64 | 1.98 | 1.60 | 1.36 | 2.31 | 1.08 | 1.92 | 1.36 | |
| **CD** | | **NS** | **NS** | **NS** | **NS** | **NS** | **5.54** | **NS** | **NS** | **NS** | **NS** | **NS** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.82 | 0.72 | 1.28 | 1.46 | 1.09 | 1.00 | 1.11 | 1.12 | 1.31 | 1.20 | 0.84 | |
| **CD (for group means)** | | **2.54** | **NS** | **NS** | **NS** | **3.22** | **2.96** | **3.28** | **3.30** | **3.86** | **3.54** | **2.49** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 96.50 | 96.17 | 93.42 | 87.75 | 83.67 | 81.67 | 67.92 | 61.25 | 56.92 | 51.83 | 49.17 | |
| SE (±) | | 1.57 | 1.39 | 2.33 | 2.66 | 1.99 | 1.83 | 2.02 | 2.04 | 2.39 | 2.19 | 1.54 | |
| **CD (for variety means)** | | **NS** | **NS** | **6.89** | **NS** | **5.88** | **5.41** | **5.97** | **6.03** | **7.06** | **6.47** | **4.55** | |

† Not included in statistical analysis as all the replication values were same.

MAS: Months after storage

### 4.1.b Germination under cold storage

Mean germination per cent of seeds of cowpea varieties stored in cold storage recorded at five and ten months after storage were compared with those stored for corresponding period in ambient conditions. The results of statistical analysis are furnished in table 4.1.b.

**Variability among genotypes**

The initial germination per cent of seeds in cold storage varied from 92.50 per cent (Vyjayanthi) to 100 per cent (Kanakamony). Germination after ten months varied between 40.83 per cent (Vellayani Jyothika) and 64.17 per cent (Sreya). Considering the overall performance of seeds during storage, the varieties did not vary significantly for the seed germination at five and ten months of cold storage.

On examining the varietal variations after five months of storage, variety Kanakamony showed the highest germination (90.83%) which was on par with Kashi Kanchan (88.33%). The lowest germination was recorded in Sreya (76.67%). Sreya and Kairali (80.00%) were on par. After ten months of storage the highest germination was recorded by Sreya. Performance of Sreya (64.17%), Kashi Kanchan (63.33%) and Lola (60.83) were on par with each other. The lowest germination was observed in Vellayani Jyothika (40.83%) which distinctly differed from others.

Considering the overall performance of varieties, Kashi Kanchan (83.05%) and Kanakamony (82.78%) of group II had the highest germination and Vellayani Jyothika (74.16%) had the lowest germination during cold storage.

**Variability based on growth habit**

Analysis of group means indicate that the three groups differed significantly during initial stage, five and ten months after storage. Varieties belonging to trailing type had the lowest mean germination initially before storage

and ten months after storage (94.72% and 52.50%). The highest mean germination was recorded by semi trailing type varieties initially before storage, five and ten months after storage.

The germination per cent varied from 94.72 per cent (initial) to 52.50 per cent (10MAS) in group I, 97.92 per cent (initial) to 58.12 per cent (10MAS) in group II and 96.39 per cent (initial) to 55.56 per cent (10MAS) in group III.

Comparing the group means initially before storage, semi trailing (97.92%) and bush type (96.39%) varieties were on par. Similarly, trailing (94.72%) and bush (96.39%) varieties were on par with each other. The highest germination was in semi trailing and the lowest was in trailing. After five months of storage, the group means of semi trailing (86.12%), trailing (83.05%) and bush (79.45%) varieties varied significantly with each other. The highest was in semi trailing and the lowest was in bush varieties. After ten months of storage, the highest germination was recorded by semi trailing varieties (58.12%), which were found to be on par with bush type (55.56%). Trailing type varied significantly from others and recorded the lowest germination (52.50%).

Varieties under trailing types (Group I), varied significantly with respect to germination ten months after storage only. Ten months after storage, Lola recorded the highest germination (60.83%) and was found on par with Vyjayanthi (55.83%). The lowest was recorded in Vellayani Jyothika (40.83%).

In the case of semi trailing type varieties (Group II), germination varied significantly from initial to ten months after storage. Within semi trailing type, before storage, Kanakamony (100.00%), Anaswara (99.17%) and Kashi Kanchan (97.50%) were on par. After ten months of storage, Kashi Kanchan (63.33%), Anaswara (58.33%) and Kanakamony (57.50%) were on par with each other. Kairali (53.33%) was found to be on par with Anaswara and Kanakamony.

Monthly germination among varieties under bush type (Group III) significantly varied only in tenth month after storage. Hridya (50.00%) and

Bhagyalakshmi (52.50%) were on par and Sreya recorded the highest germination (64.17%) and varied significantly from others.

The overall monthly mean germination of varieties decreased gradually from 96.50 per cent (initial) to 55.67 per cent (10MAS) under cold storage.

**Table 4.1.b Mean germination (%) of cowpea varieties influenced by cold storage**

| | Variety | Initial | 5MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 95.83 | 80.83 | 60.83 | 79.16 |
| | 2.Vellayani Jyothika | 95.83 | 85.83 | 40.83 | 74.16 |
| | 3.Vyjayanthi | 92.50 | 82.50 | 55.83 | 76.94 |
| Overall mean (Group I) | | 94.72 | 83.05 | 52.50 | |
| SE (±) | | 2.31 | 1.80 | 2.04 | |
| **CD** | | **NS** | **NS** | **7.07** | |
| Group II (Semi trailing) | 4.Anaswara | 99.17 | 85.33 | 58.33 | 80.94 |
| | 5.Kairali | 95.00 | 80.00 | 53.33 | 76.11 |
| | 6.Kanakamony | 100.00† | 90.83 | 57.50 | 82.78 |
| | 7.Kashi Kanchan | 97.50 | 88.33 | 63.33 | 83.05 |
| Overall mean (Group II) | | 97.92 | 86.12 | 58.12 | |
| SE (±) | | 0.83 | 0.72 | 1.91 | |
| **CD** | | **2.71** | **2.35** | **6.24** | |
| Group III (Bush) | 8.Sreya | 95.83 | 76.67 | 64.17 | 78.89 |
| | 9.Hridya | 95.83 | 79.17 | 50.00 | 75.00 |
| | 10.Bhagyalakshmi | 97.50 | 82.50 | 52.50 | 77.50 |
| Overall mean (Group III) | | 96.39 | 79.45 | 55.56 | |
| SE (±) | | 1.08 | 1.60 | 0.96 | |
| **CD** | | **NS** | **NS** | **3.33** | |
| SE (±) | | 0.82 | 0.76 | 0.95 | |
| **CD (for group means)** | | **2.54** | **2.26** | **2.80** | |
| Monthly overall mean | | 96.50 | 83.25 | 55.67 | |
| SE (±) | | 1.57 | 1.39 | 1.73 | |
| **CD (for variety means)** | | **NS** | **4.11** | **5.11** | |

† Not included in statistical analysis as all the replication values were same.

MAS: Months after storage

## 4.2 Days to first germination

### 4.2.a Under ambient conditions of storage

Mean days to first germination of seeds of cowpea varieties under ambient storage conditions are furnished in table 4.2.a.

The results indicated that the days taken by all the ten cowpea varieties to first germination was three during all stages of testing. Storage did not affect days to first germination.

| Variety | Table 4.2.a Mean days to first germination of cowpea varieties influenced by period of storage** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS |
| 1.Lola | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2.Vellayani Jyothika | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 3.Vyjayanthi | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4.Anaswara | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 5.Kairali | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 6.Kanakamony | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 7.Kashi Kanchan | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 8.Sreya | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 9.Hridya | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 10.Bhagyalakshmi | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

** Statistical analysis was not done since all the values were same.

MAS: Months after storage

### 4.2.b Days to first germination under cold storage

Mean days to first germination of seeds of cowpea varieties kept in cold storage were compared at five and ten months after storage, with those stored in ambient conditions. The results are furnished in table 4.2.b.

The results indicated that the days taken by all the ten cowpea varieties to first germination was three before storage and both after five and ten months of cold storage.

| Variety | Table 4.2.b Mean days to first germination of cowpea varieties influenced by cold storage** | | |
|---|---|---|---|
| | Initial | 5MAS | 10MAS |
| 1.Lola | 3 | 3 | 3 |
| 2.Vellayani Jyothika | 3 | 3 | 3 |
| 3.Vyjayanthi | 3 | 3 | 3 |
| 4.Anaswara | 3 | 3 | 3 |
| 5.Kairali | 3 | 3 | 3 |
| 6.Kanakamony | 3 | 3 | 3 |
| 7.Kashi Kanchan | 3 | 3 | 3 |
| 8.Sreya | 3 | 3 | 3 |
| 9.Hridya | 3 | 3 | 3 |
| 10.Bhagyalakshmi | 3 | 3 | 3 |

** Statistical analysis was not done since all the values were same.

MAS: Months after storage

### 4.3 Days to fifty per cent germination

### 4.3.a Under ambient conditions of storage

Mean days to fifty per cent germination of seeds of cowpea varieties under ambient storage conditions are furnished in table 4.3.a.

The results indicated that there was only slight variation in the days taken to fifty per cent germination by all the ten cowpea varieties, the estimates being three days before to 4.67 days at ten months after storage. In the case of Vellayani Jyothika, germination was below fifty per cent from eight month after storage. Almost all the varieties except bush type (Sreya, Hridya and Bhagyalakshmi) had recorded fifty per cent germination on the third day, up to seven months of storage.

| Variety | Table 4.3.a Mean days to fifty per cent germination of cowpea varieties influenced by period of storage** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS |
| 1.Lola | 3 | 3 | 3.33 | 3.67 | 4 | 4 | 4 | 4 | 3.67 | 5 | 5 |
| 2.Vellayani Jyothika | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 0 | 0 | 0 |
| 3.Vyjayanthi | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4.67 | 5 |
| 4.Anaswara | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.33 | 4.33 | 4.67 |
| 5.Kairali | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.33 | 3.33 |
| 6.Kanakamony | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4.67 | 4.67 |
| 7.Kashi Kanchan | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| 8.Sreya | 3.67 | 3.67 | 4 | 4 | 4 | 4.67 | 5 | 4.33 | 4.33 | 5 | 5 |
| 9.Hridya | 3.33 | 3 | 3.67 | 3.67 | 4 | 4.33 | 5 | 4.67 | 4 | 3 | 3.67 |
| 10.Bhagyalakshmi | 3 | 3 | 3 | 3.67 | 3.33 | 3.67 | 4 | 4 | 3.67 | 3.33 | 3.67 |

** Statistical analysis not done since the range is too small.

MAS: Months after storage

### 4.3.b Days to fifty per cent germination under cold storage

Mean days to fifty per cent germination of seeds of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results are furnished in table 4.3.b.

The results indicated that the days taken by all the ten cowpea varieties to fifty per cent germination increased particularly in case of trailing and bushy type from initial to ten months of cold storage. In the case of Vellayani Jyothika, germination fell below fifty per cent after ten months of cold storage.

| Variety | Table 4.3.b Mean days to fifty per cent germination of cowpea varieties influenced by cold storage** | | |
|---|---|---|---|
| | Initial | 5MAS | 10MAS |
| 1.Lola | 3 | 3.33 | 4 |
| 2.Vellayani Jyothika | 3 | 3 | 0 |
| 3.Vyjayanthi | 3 | 3 | 3 |
| 4.Anaswara | 3 | 3 | 3 |
| 5.Kairali | 3 | 3 | 3 |
| 6.Kanakamony | 3 | 3 | 3 |
| 7.Kashi Kanchan | 3 | 3 | 3 |
| 8.Sreya | 3.67 | 4 | 4.67 |
| 9.Hridya | 3.33 | 3.67 | 4 |
| 10.Bhagyalakshmi | 3 | 3.33 | 4 |

**Statistical analysis not done since the range is too small.

MAS: Months after storage

## 4.4 Speed of germination

### 4.4.a Under ambient conditions of storage

Mean speed of germination of seeds of cowpea varieties, along with results of statistical analysis are furnished in table 4.4.a.

### Variability among genotypes

The initial speed of germination of seeds varied from 26.75 (Sreya) to 31.38 (Kanakamony) and that after ten months of storage from 9.45 (Vellayani Jyothika) to 18.32 (Kashi Kanchan). Considering the overall performance of seeds during storage, the speed of germination of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, it was seen that, initially before storage, Kanakamony (31.38) showed the highest speed of germination and the lowest was recorded by Sreya (26.75). Kanakamony was on par with Kairali (30.59), Vellayani Jyothika (30.13), Anaswara (29.91), Kashi Kanchan (29.79) and Vyjayanthi (29.21). Vyjayanthi was found to be on par with Bhagyalakshmi

(28.86), Lola (27.92), Hridya (26.84) and Sreya (26.75). After ten months of storage, the highest speed of germination was recorded by Kashi Kanchan (18.32), which was on par with Kanakamony (17.77). The lowest was recorded by Vellayani Jyothika (9.45).

Considering the overall performance of varieties, Kashi Kanchan (25.27) and Kanakamony (24.62) of group II had the highest speed of germination and Sreya (20.30) had the lowest speed of germination.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to semi trailing type had the highest speed of germination during first two months (30.42 and 30.51). The lowest speed of germination was observed in last months of storage in seeds of trailing type (13.18).

The speed of germination varied from 29.37 (1MAS) to 13.18 (10MAS) in group I, 30.51 (1MAS) to 16.37 (10MAS) in group II and 30.17(1MAS) to 14.00 (10MAS) in group III.

Comparing the group means initially before storage, semi trailing (30.42) and trailing (29.09) were on par. The highest speed of germination was recorded in semi trailing type. Bush type varied significantly from others and recorded the lowest speed of germination (27.48). After ten months of storage, three groups differed significantly from each other. The highest was recorded by semi trailing (16.37) and the lowest was in trailing (13.18).

Considering variety means under trailing types (Group I), speed of germination did not show significant variation among varieties up to three months after storage and thereafter it varied significantly except at six months after storage. After ten months of storage, Vyjayanthi (15.56) and Lola (14.53) were on par and Vellayani Jyothika varied significantly from others.

In the case of semi trailing type, varieties varied significantly except before and at two, five and seven months after storage.

Variety means for monthly speed of germination among bush type (Group III) varied significantly except before and at two, seven, nine and ten months after storage. Bhagyalakshmi (31.57) and Hridya (31.42) were on par. Sreya (27.52) varied significantly from others. Bhagyalakshmi and Sreya recorded the highest and the lowest speed of germination respectively at first month of storage. At eight months after storage, Bhagyalakshmi (17.78) and Sreya (17.46) were on par and Hridya (16.38) varied significantly from others.

The overall monthly mean speed of germination of varieties decreased gradually from 30.06 (1MAS) to 14.70 (10MAS) during storage.

**Table 4.4.a Mean speed of germination of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 27.92 | 29.32 | 26.84 | 24.38 | 23.10 | 22.10 | 19.68 | 17.48 | 18.10 | 15.98 | 14.53 | 21.77 |
| | 2.Vellayani Jyothika | 30.13 | 29.90 | 30.49 | 28.08 | 27.68 | 27.14 | 20.89 | 16.07 | 10.62 | 9.28 | 9.45 | 21.79 |
| | 3.Vyjayanthi | 29.21 | 28.89 | 28.59 | 27.33 | 25.74 | 25.17 | 22.74 | 21.77 | 20.32 | 16.05 | 15.56 | 23.76 |
| Overall mean (Group I) | | 29.09 | 29.37 | 28.64 | 26.60 | 25.51 | 24.80 | 21.10 | 18.44 | 16.35 | 13.77 | 13.18 | |
| SE (±) | | 1.18 | 0.51 | 0.92 | 0.93 | 0.75 | 0.54 | 0.69 | 0.32 | 0.92 | 0.39 | 0.57 | |
| **CD** | | **NS** | **NS** | **NS** | **NS** | **2.60** | **1.87** | **NS** | **1.11** | **3.19** | **1.35** | **1.97** | |
| Group II (Semi trailing) | 4.Anaswara | 29.91 | 29.70 | 26.17 | 25.84 | 25.50 | 25.10 | 20.64 | 20.05 | 19.63 | 16.86 | 16.08 | 23.23 |
| | 5.Kairali | 30.59 | 29.32 | 25.53 | 25.42 | 23.39 | 23.85 | 21.23 | 20.97 | 16.78 | 14.57 | 13.32 | 22.27 |
| | 6.Kanakamony | 31.38 | 32.82 | 29.61 | 27.12 | 25.17 | 25.32 | 22.52 | 21.12 | 20.82 | 17.15 | 17.77 | 24.62 |
| | 7.Kashi Kanchan | 29.79 | 30.18 | 30.38 | 28.79 | 26.34 | 26.35 | 25.50 | 22.16 | 21.79 | 18.37 | 18.32 | 25.27 |
| Overall mean (Group II) | | 30.42 | 30.51 | 27.92 | 26.79 | 25.10 | 25.16 | 22.47 | 21.08 | 19.76 | 16.74 | 16.37 | |
| SE (±) | | 0.59 | 0.49 | 1.56 | 0.55 | 0.51 | 0.53 | 0.73 | 0.58 | 0.62 | 0.67 | 0.29 | |
| **CD** | | **NS** | **1.60** | **NS** | **1.80** | **1.67** | **NS** | **2.38** | **NS** | **2.03** | **2.19** | **0.95** | |
| Group III (Bush) | 8.Sreya | 26.75 | 27.52 | 24.67 | 22.67 | 21.07 | 19.75 | 17.17 | 16.77 | 17.46 | 15.60 | 13.85 | 20.30 |
| | 9.Hridya | 26.84 | 31.42 | 26.49 | 24.67 | 22.38 | 21.16 | 17.36 | 16.59 | 16.38 | 15.03 | 13.82 | 21.10 |
| | 10.Bhagyalakshmi | 28.86 | 31.57 | 26.37 | 24.67 | 23.96 | 23.93 | 18.94 | 18.42 | 17.78 | 14.82 | 14.34 | 22.15 |
| Overall mean (Group III) | | 27.48 | 30.17 | 25.84 | 24.00 | 22.47 | 21.61 | 17.82 | 17.26 | 17.21 | 15.15 | 14.00 | |
| SE (±) | | 0.73 | 0.39 | 0.54 | 0.26 | 0.53 | 0.31 | 0.32 | 0.53 | 0.28 | 0.55 | 0.34 | |
| **CD** | | **NS** | **1.35** | **NS** | **0.90** | **1.84** | **1.07** | **1.11** | **NS** | **0.97** | **NS** | **NS** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.46 | 0.26 | 0.63 | 0.35 | 0.33 | 0.26 | 0.34 | 0.27 | 0.36 | 0.31 | 0.22 | |
| **CD (for group means)** | | **1.37** | **0.76** | **1.85** | **1.03** | **0.97** | **0.77** | **1.01** | **0.81** | **1.06** | **0.91** | **0.66** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 29.14 | 30.06 | 27.51 | 25.90 | 24.43 | 23.99 | 20.67 | 19.14 | 17.97 | 15.37 | 14.70 | |
| SE (±) | | 0.85 | 0.47 | 1.14 | 0.64 | 0.60 | 0.47 | 0.62 | 0.50 | 0.66 | 0.56 | 0.41 | |
| **CD (for variety means)** | | **2.51** | **1.39** | **3.37** | **1.89** | **1.77** | **1.39** | **1.83** | **1.48** | **1.95** | **1.65** | **1.21** | |

MAS: Months after storage

### 4.4.b Speed of germination under cold storage

Mean speed of germination of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.4.b.

**Variability among genotypes**

The initial speed of germination of seeds varied from 26.75 (Sreya) to 31.38 (Kanakamony) and that after ten months of storage from 11.74 (Vellayani Jyothika) to 19.35 (Kashi Kanchan). Considering the overall performance of seeds during storage, the varieties varied significantly from initial to ten months after storage.

On examining the varietal variations, it was seen that, initially before storage, Kanakamony (31.38) showed the highest speed of germination and the lowest was recorded by Sreya (26.75). Kanakamony was found to be on par with Kairali (30.59), Vellayani Jyothika (30.13), Anaswara (29.91), Kashi Kanchan (29.79) and Vyjayanthi (29.21). Vyjayanthi was also on par with Bhagyalakshmi (28.86), Lola (27.92), Hridya (26.84) and Sreya (26.75). After ten months of storage, the highest speed of germination was recorded by Kashi Kanchan (19.35) which was on par with Sreya (18.57) and Lola (18.40). The lowest was recorded in Vellayani Jyothika (11.74) and it varied significantly from others.

Considering the overall performance of varieties, Kashi Kanchan (25.48) and Kanakamony (25.17) of group II had the highest speed of germination and Hridya (21.03) had the lowest speed of germination.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to semi trailing type had the

highest speed of germination during initially before storage (30.42), five (26.00) and ten months after storage (17.69).

The speed of germination varied from 29.09 (initial) to 15.70 (10MAS) in group I, 30.42 (initial) to 17.69 (10MAS) in group II and 27.48 (initial) to 16.39 (10MAS) in group III.

Comparing the group means before storage, semi trailing (30.42) and trailing (29.09) were on par. The highest was recorded in semi trailing. Bush type varied significantly from others and recorded the lowest speed of germination (27.48). After ten months of storage, semi trailing recorded the highest speed of germination (17.69) and varied significantly from others. Bush type (16.39) and trailing (15.70) were on par with each other.

Considering the group means of speed of germination, trailing types (Group I) did not show significant variations among varieties initially before storage and thereafter it varied significantly at five and ten months after storage. After ten months of storage, Lola (18.40) and Vyjayanthi (16.96) were on par and the lowest was recorded in Vellayani Jyothika (11.74) and differed significantly from others.

The semi trailing and bush type varieties (Group II and Group III) varied significantly at five and ten months after storage. After ten months of storage, in semi trailing varieties, the highest speed of germination was recorded in Kashi Kanchan (19.35) and varied significantly from others. Kanakamony (17.53), Anaswara (17.27) and Kairali (16.62) were on par with each other.

Among bush type, Sreya varied significantly from others with the highest speed of germination (18.57) and Bhagyalakshmi (15.88) and Hridya (14.72) were on par.

The overall monthly mean speed of germination of varieties decreased gradually from 29.14 (initial) to 16.70 (10MAS) under cold storage.

| Table 4.4.b Mean speed of germination of cowpea varieties influenced by cold storage | | | | | |
|---|---|---|---|---|---|
| | **Variety** | **Initial** | **5MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 27.92 | 22.98 | 18.40 | 23.10 |
| | 2.Vellayani Jyothika | 30.13 | 27.32 | 11.74 | 23.06 |
| | 3.Vyjayanthi | 29.21 | 26.07 | 16.96 | 24.08 |
| Overall mean (Group I) | | 29.09 | 25.46 | 15.70 | |
| SE (±) | | 1.18 | 0.43 | 0.56 | |
| **CD** | | **NS** | **1.49** | **1.94** | |
| Group II (Semi trailing) | 4.Anaswara | 29.91 | 26.18 | 17.27 | 24.45 |
| | 5.Kairali | 30.59 | 23.89 | 16.62 | 23.70 |
| | 6.Kanakamony | 31.38 | 26.60 | 17.53 | 25.17 |
| | 7.Kashi Kanchan | 29.79 | 27.31 | 19.35 | 25.48 |
| Overall mean (Group II) | | 30.42 | 26.00 | 17.69 | |
| SE (±) | | 0.59 | 0.37 | 0.46 | |
| **CD** | | **NS** | **1.21** | **1.50** | |
| Group III (Bush) | 8.Sreya | 26.75 | 21.27 | 18.57 | 22.20 |
| | 9.Hridya | 26.84 | 21.53 | 14.72 | 21.03 |
| | 10.Bhagyalakshmi | 28.86 | 23.54 | 15.88 | 22.76 |
| Overall mean (Group III) | | 27.48 | 22.11 | 16.39 | |
| SE (±) | | 0.73 | 0.49 | 0.42 | |
| **CD** | | **NS** | **1.70** | **1.46** | |
| SE (±) | | 0.46 | 0.23 | 0.27 | |
| **CD (for group means)** | | **1.37** | **0.69** | **0.78** | |
| Monthly overall mean | | 29.14 | 24.67 | 16.70 | |
| SE (±) | | 0.85 | 0.43 | 0.48 | |
| **CD (for variety means)** | | **2.51** | **1.27** | **1.42** | |

MAS: Months after storage

## 4.5 Seedling shoot length

### 4.5.a Under ambient conditions of storage

Mean seedling shoot length of cowpea varieties, along with results of statistical analysis are furnished in table 4.5.a.

**Variability among genotypes**

The initial seedling shoot length of seeds varied from 21.68 cm (Hridya) to 29.53 cm (Kanakamony). After ten months of storage it varied from 16.67 cm (Hridya) to 21.34 cm (Kanakamony). Considering the overall performance of seeds during storage, the seedling shoot length of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, before storage, the highest seedling shoot length was recorded by Kanakamony (29.53 cm) and the lowest in Hridya (21.68). Here, varieties Kanakamony (29.53 cm), Lola (28.00 cm) and Kashi Kanchan (27.43 cm) were on par with each other and Hridya (21.68 cm), Kairali (22.10 cm), Anaswara (22.79 cm), Vyjayanthi (23.07 cm) and Sreya (24.07 cm) were on par with each other. And that after ten months of storage, the highest was in Kanakamony (21.34 cm) and was on par with Kairali (21.16 cm). The lowest was recorded by Hridya (16.67 cm) and was on par with Anaswara (17.40 cm).

Considering the overall performance of varieties, Kanakamony (24.14) and Kairali (24.00) of group II had the highest seedling shoot length and Hridya (18.35) had the lowest seedling shoot length.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing type showed the highest seedling shoot length and the lowest was recorded by bush type varieties.

The seedling shoot length varied from 25.91 cm (1MAS) to 19.56 cm (10MAS) in group I, 25.46 cm (initial) to 19.94 cm (9MAS) in group II and 23.52 cm (initial) to 17.92 cm (10MAS) in group III.

Comparing the group means, before storage, trailing (25.66 cm) and semi trailing (25.46 cm) were on par. The highest was recorded in trailing. The lowest was recorded in bush type (23.52 cm) and it varied significantly from others. After ten months of storage, the highest seedling shoot length was recorded in semi trailing (20.01 cm) and was on par with trailing (19.56 cm). Bush type (17.92 cm) varied significantly from other two.

Considering the variety means of seedling shoot length under trailing types (Group I), it did not show significant variation among varieties except initial and three months of storage. Before storage, Lola (28.00 cm) and Vellayani Jyothika (25.90 cm) were on par and the highest was recorded by Lola. The lowest seedling shoot length was in Vyjayanthi (23.07 cm) and varied significantly from others.

In the case of semi trailing type varieties (Group II), it varied significantly from initial to ten months after storage. Initially before storage, Kanakamony (29.53 cm) and Kashi Kanchan (27.43 cm) were on par and Anaswara (22.79 cm) and Kairali (22.10 cm) were on par. After ten months of storage, Kanakamony (21.34 cm), Kairali (21.16 cm) and Kashi Kanchan (20.12 cm) were on par. The lowest was in Anaswara (17.40 cm) and varied significantly from others.

Variety means for seedling shoot length among bush type (Group III) significantly varied except initial month before storage. After ten months of storage, Sreya (19.19 cm) and Bhagyalakshmi (17.89 cm) were on par and the lowest was in Hridya (16.67 cm) which differed significantly from others.

The overall monthly mean seedling shoot length of varieties decreased gradually from 24.94 cm (initial) to 19.24 cm (10MAS) during storage.

**Table 4.5.a Mean seedling shoot length (cm) of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 28.00 | 26.80 | 25.63 | 26.96 | 23.69 | 22.45 | 21.95 | 21.67 | 20.12 | 19.87 | 19.06 | 23.29 |
| | 2.Vellayani Jyothika | 25.90 | 26.30 | 25.53 | 25.67 | 23.07 | 23.34 | 21.81 | 21.17 | 21.25 | 20.86 | 19.83 | 23.16 |
| | 3.Vyjayanthi | 23.07 | 24.63 | 23.70 | 24.94 | 23.82 | 23.20 | 22.05 | 20.56 | 20.91 | 20.79 | 19.78 | 22.50 |
| Overall mean (Group I) | | 25.66 | 25.91 | 24.95 | 25.86 | 23.53 | 23.00 | 21.94 | 21.13 | 20.76 | 20.51 | 19.56 | |
| SE (±) | | 0.67 | 1.38 | 0.57 | 0.39 | 0.29 | 0.56 | 0.64 | 0.57 | 0.39 | 0.62 | 0.24 | |
| **CD** | | **2.32** | **NS** | **NS** | **1.35** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | |
| Group II (Semi trailing) | 4.Anaswara | 22.79 | 23.23 | 21.10 | 18.82 | 18.43 | 18.29 | 18.29 | 17.62 | 17.51 | 17.47 | 17.40 | 19.18 |
| | 5.Kairali | 22.10 | 25.67 | 28.57 | 28.09 | 25.36 | 25.19 | 24.72 | 21.79 | 21.35 | 20.03 | 21.16 | 24.00 |
| | 6.Kanakamony | 29.53 | 28.07 | 23.93 | 24.55 | 24.51 | 24.31 | 23.49 | 22.65 | 22.75 | 20.38 | 21.34 | 24.14 |
| | 7.Kashi Kanchan | 27.43 | 22.60 | 21.20 | 19.83 | 19.81 | 19.83 | 22.10 | 23.09 | 23.21 | 21.88 | 20.12 | 21.92 |
| Overall mean (Group II) | | 25.46 | 24.89 | 23.70 | 22.82 | 22.03 | 21.91 | 22.15 | 21.29 | 21.21 | 19.94 | 20.01 | |
| SE (±) | | 1.24 | 0.94 | 0.42 | 0.23 | 0.47 | 0.32 | 0.46 | 0.36 | 0.41 | 0.59 | 0.49 | |
| **CD** | | **4.05** | **3.07** | **1.37** | **0.75** | **1.54** | **1.05** | **1.50** | **1.18** | **1.34** | **1.93** | **1.60** | |
| Group III (Bush) | 8.Sreya | 24.07 | 24.10 | 25.90 | 25.09 | 23.35 | 23.33 | 20.63 | 21.22 | 21.46 | 20.19 | 19.19 | 22.59 |
| | 9.Hridya | 21.68 | 20.33 | 19.63 | 18.81 | 18.26 | 17.21 | 17.31 | 17.53 | 17.39 | 16.98 | 16.67 | 18.35 |
| | 10.Bhagyalakshmi | 24.80 | 20.60 | 21.03 | 18.96 | 18.90 | 19.01 | 19.87 | 18.33 | 19.63 | 18.29 | 17.89 | 19.76 |
| Overall mean (Group III) | | 23.52 | 21.68 | 22.19 | 20.95 | 20.17 | 19.85 | 19.27 | 19.03 | 19.49 | 18.49 | 17.92 | |
| SE (±) | | 0.83 | 0.48 | 0.31 | 0.53 | 0.56 | 0.30 | 0.54 | 0.26 | 0.67 | 0.28 | 0.41 | |
| **CD** | | **NS** | **1.66** | **1.07** | **1.84** | **1.94** | **1.04** | **1.87** | **0.90** | **2.32** | **0.97** | **1.42** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.54 | 0.55 | 0.24 | 0.21 | 0.25 | 0.22 | 0.30 | 0.23 | 0.27 | 0.29 | 0.22 | |
| **CD (for group means)** | | **1.59** | **1.61** | **0.72** | **0.63** | **0.74** | **0.65** | **0.88** | **0.67** | **0.80** | **0.86** | **0.66** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 24.94 | 24.23 | 23.62 | 23.17 | 21.92 | 21.62 | 21.22 | 20.56 | 20.56 | 19.67 | 19.24 | |
| SE (±) | | 0.98 | 1.00 | 0.44 | 0.39 | 0.46 | 0.40 | 0.54 | 0.41 | 0.49 | 0.53 | 0.41 | |
| **CD (for variety means)** | | **2.90** | **2.96** | **1.30** | **1.15** | **1.36** | **1.18** | **1.60** | **1.21** | **1.45** | **1.57** | **1.21** | |

MAS: Months after storage

### 4.5.b Seedling shoot length under cold storage

Mean seedling shoot length of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.5.b.

**Variability among genotypes**

The initial seedling shoot length of seeds varied from 21.68 (Hridya) to 29.53 (Kanakamony); and that after ten months of storage from 17.03 (Hridya) to 21.45 (Kairali). Considering the overall performance of seeds during storage, the seedling shoot length of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, initially before storage, the highest seedling shoot length was recorded by Kanakamony (29.53 cm) and the lowest in Hridya (21.68). Here, varieties Kanakamony (29.53 cm), Lola (28.00 cm) and Kashi Kanchan (27.43 cm) were on par with each other and Hridya (21.68 cm), Kairali (22.10 cm), Anaswara (22.79 cm), Vyjayanthi (23.07 cm) and Sreya (24.07 cm) were on par with each other. And that after ten months of storage, the highest was in Kairali (21.45 cm) and it differed significantly from others. The lowest seedling shoot length was recorded by Hridya (17.03 cm). Hridya (17.03 cm), Anaswara (17.22 cm) and Bhagyalakshmi (18.01 cm) were on par with each other.

Considering the overall performance of varieties, Kanakamony (24.62) of group II had the highest seedling shoot length and Hridya (18.63) had the lowest seedling shoot length.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing types showed the highest seedling shoot length and the lowest was recorded by bush type varieties.

The seedling shoot length varied from 25.66 cm (initial) to 19.57 cm (10MAS) in group I, 25.46 cm (initial) to 19.32 cm (10MAS) in group II and 23.52 cm (initial) to 18.23 cm (10MAS) in group III.

Comparing the group means at initially before storage, trailing (25.66 cm) and semi trailing (25.46 cm) were on par. The highest was recorded in trailing. The lowest was recorded in bush type (23.52 cm) and it varied significantly from others. After ten months of storage, the highest seedling shoot length was recorded by trailing (19.57 cm) and was on par with semi trailing (19.32 cm). Bush type (18.23 cm) varied significantly from other two.

Considering the variety means of seedling shoot length under trailing types (Group I), did not show significant variations among varieties except initially before storage. Initially before storage, Lola (28.00 cm) and Vellayani Jyothika (25.90 cm) were on par and the highest was recorded by Lola. The lowest seedling shoot length was in Vyjayanthi (23.07 cm) and varied significantly from others.

In the case of semi trailing type varieties (Group II), it varied significantly from initial to ten months after storage. Initially before storage, Kanakamony (29.53 cm) and Kashi Kanchan (27.43 cm) were on par and Anaswara (22.79 cm) and Kairali (22.10 cm) were on par. After ten months of storage, the highest was recorded by Kairali (21.45 cm) and it varied significantly from others. After ten months of storage, Kashi Kanchan (19.59 cm) and Kanakamony (19.03 cm) were on par. The lowest was recorded by Anaswara (17.22 cm) and it varied significantly from others.

Variety means for seedling shoot length among bush type (Group III) significantly varied except initial month before storage. After ten months of storage, Sreya showed the highest seedling shoot length (19.65 cm) and varied significantly from others. Bhagyalakshmi (18.01 cm) and Hridya (17.03 cm) were on par.

The overall monthly mean seedling shoot length of varieties decreased gradually from 24.94 (initial) to 19.07 (10MAS) under cold storage.

**Table 4.5.b Mean seedling shoot length (cm) of cowpea varieties influenced by cold storage**

| | Variety | Initial | 5MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 28.00 | 23.04 | 19.80 | 23.61 |
| | 2.Vellayani Jyothika | 25.90 | 23.63 | 19.91 | 23.15 |
| | 3.Vyjayanthi | 23.07 | 23.72 | 19.01 | 21.93 |
| Overall mean (Group I) | | 25.66 | 23.46 | 19.57 | |
| SE (±) | | 0.67 | 0.31 | 0.53 | |
| **CD** | | **2.32** | **NS** | **NS** | |
| Group II (Semi trailing) | 4.Anaswara | 22.79 | 18.23 | 17.22 | 19.41 |
| | 5.Kairali | 22.10 | 27.04 | 21.45 | 23.53 |
| | 6.Kanakamony | 29.53 | 25.29 | 19.03 | 24.62 |
| | 7.Kashi Kanchan | 27.43 | 19.84 | 19.59 | 22.29 |
| Overall mean (Group II) | | 25.46 | 22.60 | 19.32 | |
| SE (±) | | 1.24 | 0.55 | 0.48 | |
| **CD** | | **4.05** | **1.80** | **1.57** | |
| Group III (Bush) | 8.Sreya | 24.07 | 23.47 | 19.65 | 22.40 |
| | 9.Hridya | 21.68 | 17.19 | 17.03 | 18.63 |
| | 10.Bhagyalakshmi | 24.80 | 19.41 | 18.01 | 20.74 |
| Overall mean (Group III) | | 23.52 | 20.02 | 18.23 | |
| SE (±) | | 0.83 | 0.52 | 0.30 | |
| **CD** | | **NS** | **1.80** | **1.04** | |
| SE (±) | | 0.54 | 0.27 | 0.25 | |
| **CD (for group means)** | | **1.59** | **0.78** | **0.73** | |
| Monthly Overall mean | | 24.94 | 22.09 | 19.07 | |
| SE (±) | | 0.98 | 0.48 | 0.45 | |
| **CD (for variety means)** | | **2.90** | **1.42** | **1.33** | |

MAS: Months after storage

## 4.6 Seedling root length

### 4.6.a Under ambient conditions of storage

Mean seedling root length of cowpea varieties, along with results of statistical analysis are furnished in table 4.6.a.

**Variability among genotypes**

The initial seedling root length of seeds varied from 7.85 cm (Anaswara) to 12.93 cm (Vellayani Jyothika); and that after ten months of storage from 6.27 cm (Anaswara) to 8.35 cm (Kairali). Considering the overall performance of seeds during storage, the seedling root length of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, initially before storage, the highest seedling root length was recorded in Vellayani Jyothika (12.93 cm) and the lowest was in Anaswara (7.85 cm). Here, the varieties Vellayani Jyothika (12.93 cm), Lola (12.60 cm), Kashi Kanchan (12.60 cm), Kanakamony (12.07 cm), Kairali (12.03 cm), Bhagyalakshmi (11.87 cm) and Sreya (11.63 cm) were on par with each other and Hridya (8.37 cm) and Anaswara (7.85 cm) were on par. And that after ten months of storage, the highest was in Kairali (8.35 cm) and the lowest was in Anaswara (6.27 cm) and it varied significantly from others. The varieties Kairali (8.35 cm), Kanakamony (8.30 cm) and Kashi Kanchan (8.29 cm) were on par with each other.

Considering the overall performance of varieties, Kairali (9.36 cm) of group II and Lola (9.26 cm) of group I had the highest seedling root length and Hridya (7.00 cm) had the lowest seedling root length.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing type showed the highest seedling root length and the lowest was recorded by bush type varieties.

The seedling root length varied from 11.90 cm (initial) to 7.65 cm (10MAS) in group I, 11.14 cm (initial) to 7.80 cm (10MAS) in group II and 10.62 cm (initial) to 6.73 cm (5MAS) in group III.

Comparing the group means, before storage, trailing (11.90 cm) and semi trailing (11.14 cm) were on par and semi trailing (11.14 cm) and bush type (10.62cm) were on par. The highest and the lowest seedling root length were recorded in trailing and bush type respectively (11.90 cm and 10.62 cm). After ten months of storage, semi trailing (7.80 cm) and trailing (7.65 cm) varieties were on par. The highest was in semi trailing (7.80 cm) and the lowest was in bush type (6.99 cm) and it varied significantly from others.

Considering the variety means of seedling root length under trailing types (Group I), varied significantly among varieties except one, two, four, eight, nine and ten months after storage. Vellayani Jyothika (12.93 cm) and Lola (12.60 cm) were on par and Vyjayanthi (10.17 cm) varied significantly from others. After ten months of storage, Vyjayanthi (7.84 cm) and Lola (7.72 cm) were on par. Vellayani Jyothika with the lowest seedling root length (7.39 cm) varied significantly from others.

In the case of semi trailing type varieties (Group II), it varied significantly except one and two months after storage. Initially before storage and after ten months of storage, Kashi Kanchan, Kanakamony and Kairali were on par with each other and Anaswara varied significantly from others with the lowest seedling root length.

Variety means for seedling root length among bush type (Group III) significantly varied except three, four, five and seven months of storage. Initially before storage, Bhagyalakshmi (11.87 cm) and Sreya (11.63 cm) were on par and Hridya (8.37 cm) varied significantly from others with the lowest seedling root length. After ten months of storage, Sreya (7.59 cm) varied significantly from others with the highest seedling root length. Hridya (6.77 cm) and Bhagyalakshmi (6.60 cm) were on par.

The overall monthly mean seedling root length of varieties decreased gradually from 11.21 cm (initial) to 7.51 cm (10MAS) during storage.

| Table 4.6.a Mean seedling root length (cm) of cowpea varieties influenced by period of storage | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Variety** | **Initial** | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8MAS** | **9MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 12.60 | 10.20 | 9.83 | 9.41 | 9.24 | 8.93 | 8.73 | 8.69 | 8.26 | 8.21 | 7.72 | 9.26 |
| | 2.Vellayani Jyothika | 12.93 | 11.07 | 8.67 | 7.69 | 7.57 | 7.42 | 7.55 | 7.55 | 7.93 | 7.70 | 7.39 | 8.50 |
| | 3.Vyjayanthi | 10.17 | 8.33 | 9.43 | 11.48 | 9.33 | 9.39 | 8.56 | 8.20 | 8.06 | 8.35 | 7.84 | 9.01 |
| Overall mean (Group I) | | 11.90 | 9.87 | 9.31 | 9.53 | 8.71 | 8.58 | 8.28 | 8.15 | 8.08 | 8.09 | 7.65 | |
| SE (±) | | 0.65 | 0.92 | 0.74 | 0.35 | 0.47 | 0.21 | 0.14 | 0.17 | 0.34 | 0.22 | 0.11 | |
| **CD** | | **2.25** | **NS** | **NS** | **1.21** | **NS** | **0.73** | **0.49** | **0.59** | **NS** | **NS** | **NS** | |
| Group II (Semi trailing) | 4.Anaswara | 7.85 | 8.80 | 9.57 | 8.06 | 7.39 | 7.27 | 7.25 | 6.80 | 6.43 | 6.15 | 6.27 | 7.44 |
| | 5.Kairali | 12.03 | 10.73 | 9.63 | 9.83 | 9.74 | 9.37 | 8.78 | 8.15 | 8.09 | 8.25 | 8.35 | 9.36 |
| | 6.Kanakamony | 12.07 | 9.47 | 8.67 | 8.90 | 8.76 | 8.73 | 8.67 | 8.50 | 8.12 | 8.19 | 8.30 | 8.94 |
| | 7.Kashi Kanchan | 12.60 | 9.63 | 9.20 | 8.83 | 8.69 | 8.37 | 8.61 | 8.47 | 8.77 | 8.64 | 8.29 | 9.10 |
| Overall mean (Group II) | | 11.14 | 9.66 | 9.27 | 8.91 | 8.65 | 8.44 | 8.33 | 7.98 | 7.85 | 7.81 | 7.80 | |
| SE (±) | | 0.66 | 0.53 | 0.65 | 0.23 | 0.32 | 0.18 | 0.10 | 0.15 | 0.24 | 0.19 | 0.10 | |
| **CD** | | **2.16** | **NS** | **NS** | **0.75** | **1.05** | **0.59** | **0.33** | **0.49** | **0.78** | **0.62** | **0.33** | |
| Group III (Bush) | 8.Sreya | 11.63 | 8.87 | 8.60 | 7.19 | 7.14 | 6.95 | 6.87 | 7.07 | 7.86 | 7.76 | 7.59 | 7.96 |
| | 9.Hridya | 8.37 | 8.37 | 6.43 | 6.83 | 6.79 | 6.54 | 6.63 | 6.73 | 6.79 | 6.77 | 6.77 | 7.00 |
| | 10.Bhagyalakshmi | 11.87 | 10.80 | 7.20 | 6.66 | 6.57 | 6.69 | 6.85 | 6.61 | 6.80 | 6.63 | 6.60 | 7.57 |
| Overall mean (Group III) | | 10.62 | 9.35 | 7.41 | 6.89 | 6.83 | 6.73 | 6.78 | 6.80 | 7.15 | 7.05 | 6.99 | |
| SE (±) | | 0.45 | 0.41 | 0.45 | 0.19 | 0.14 | 0.15 | 0.04 | 0.15 | 0.26 | 0.11 | 0.11 | |
| **CD** | | **1.56** | **1.42** | **1.56** | **NS** | **NS** | **NS** | **0.14** | **NS** | **0.90** | **0.38** | **0.38** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.33 | 0.35 | 0.34 | 0.15 | 0.18 | 0.10 | 0.06 | 0.09 | 0.16 | 0.10 | 0.06 | |
| **CD (for group means)** | | **0.98** | **NS** | **1.01** | **0.43** | **0.55** | **0.29** | **0.17** | **0.26** | **0.46** | **0.29** | **0.18** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 11.21 | 9.63 | 8.72 | 8.49 | 8.12 | 7.97 | 7.85 | 7.68 | 7.71 | 7.67 | 7.51 | |
| SE (±) | | 0.61 | 0.64 | 0.62 | 0.26 | 0.34 | 0.18 | 0.10 | 0.16 | 0.28 | 0.18 | 0.11 | |
| **CD (for variety means)** | | **1.80** | **1.89** | **1.83** | **0.77** | **1.01** | **0.53** | **0.30** | **0.47** | **0.83** | **0.53** | **0.33** | |

MAS: Months after storage

### 4.6.b Seedling root length under cold storage

Mean seedling root length of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.6.b.

**Variability among genotypes**

The initial seedling root length of seeds varied from 7.85 cm (Anaswara) to 12.93 cm (Vellayani Jyothika); and that after ten months of storage from 6.57 cm (Anaswara) to 8.55 cm (Kairali). Considering the overall performance of seeds during storage, the seedling root length of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, before storage, the highest seedling root length was recorded in Vellayani Jyothika (12.93 cm) and the lowest in Anaswara (7.85 cm). Here, the varieties Vellayani Jyothika (12.93 cm), Lola (12.60 cm), Kashi Kanchan (12.60 cm), Kanakamony (12.07 cm), Kairali (12.03 cm), Bhagyalakshmi (11.87 cm) and Sreya (11.63 cm) were on par with each other and Hridya (8.37 cm) and Anaswara (7.85 cm) were on par. And that after ten months of storage, the highest was in Kairali (8.55 cm) and the lowest was in Anaswara (6.57 cm). Kairali (8.55 cm), Kashi Kanchan (8.53 cm), Vyjayanthi (8.23 cm) and Lola (8.21 cm) were on par with each other. Bhagyalakshmi (6.91 cm), Hridya (6.88 cm) and Anaswara (6.57 cm) were on par with each other.

Considering the overall performance of varieties, Kairali (10.04 cm) of group II had the highest seedling root length and Anaswara (7.23 cm) had the lowest seedling root length.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing type showed the highest seedling root length and the lowest was recorded by bush type varieties.

The seedling root length varied from 11.90 cm (initial) to 7.97 cm (10MAS) in group I, 11.14 cm (initial) to 7.94 cm (10MAS) in group II and 10.62 cm (initial) to 6.94 cm (5MAS) in group III.

Comparing the group means, before storage, trailing (11.90 cm) and semi trailing (11.14 cm) were on par and semi trailing (11.14 cm) and bushy (10.62cm) were on par. The highest and the lowest seedling root length were recorded in trailing and bushy respectively (11.90 cm and 10.62 cm). After ten months of storage, trailing (7.97 cm) and semi trailing (7.94 cm) varieties were on par. The highest was in trailing (7.97 cm) and the lowest was in bush type (7.16 cm) and it varied significantly from others.

Considering the variety means of seedling root length under trailing type (Group I), semi trailing type (Group II) and bush type (Group III) varieties significantly varied from initial to ten months after storage. In the case of trailing type varieties, after ten months of storage, Vyjayanthi (8.23 cm) and Lola (8.21 cm) were on par and Vellayani Jyothika (7.46 cm) varied significantly from others with the lowest seedling root length.

In the case of semi trailing type, Kairali (8.55 cm) and Anaswara (6.57 cm) recorded the highest and the lowest seedling root length respectively. Kairali (8.55 cm), Kashi Kanchan (8.53 cm) and Kanakamony (8.11 cm) were on par with each other. Anaswara (6.57 cm) varied significantly from others.

Among bush type, after ten months of storage, Sreya (7.69 cm) varied significantly from others with the highest seedling root length. Bhagyalakshmi (6.91) and Hridya (6.88 cm) were on par.

The overall monthly mean seedling root length of varieties decreased gradually from 11.21 (initial) to 7.71 (10MAS) under cold storage.

**Table 4.6.b Mean seedling root length (cm) of cowpea varieties influenced by cold storage**

| | Variety | Initial | 5MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 12.60 | 8.99 | 8.21 | 9.93 |
| | 2.Vellayani Jyothika | 12.93 | 7.65 | 7.46 | 9.35 |
| | 3.Vyjayanthi | 10.17 | 9.98 | 8.23 | 9.46 |
| Overall mean (Group I) | | 11.90 | 8.87 | 7.97 | |
| SE (±) | | 0.65 | 0.05 | 0.16 | |
| **CD** | | **2.25** | **0.17** | **0.55** | |
| Group II (Semi trailing) | 4.Anaswara | 7.85 | 7.28 | 6.57 | 7.23 |
| | 5.Kairali | 12.03 | 9.55 | 8.55 | 10.04 |
| | 6.Kanakamony | 12.07 | 8.95 | 8.11 | 9.71 |
| | 7.Kashi Kanchan | 12.60 | 8.65 | 8.53 | 9.93 |
| Overall mean (Group II) | | 11.14 | 8.61 | 7.94 | |
| SE (±) | | 0.66 | 0.31 | 0.17 | |
| **CD** | | **2.16** | **1.01** | **0.56** | |
| Group III (Bush) | 8.Sreya | 11.63 | 7.31 | 7.69 | 8.88 |
| | 9.Hridya | 8.37 | 6.69 | 6.88 | 7.31 |
| | 10.Bhagyalakshmi | 11.87 | 6.83 | 6.91 | 8.54 |
| Overall mean (Group III) | | 10.62 | 6.94 | 7.16 | |
| SE (±) | | 0.45 | 0.13 | 0.11 | |
| **CD** | | **1.56** | **0.45** | **0.38** | |
| SE (±) | | 0.33 | 0.11 | 0.08 | |
| **CD (for group means)** | | **0.98** | **0.34** | **0.25** | |
| Monthly overall mean | | 11.21 | 8.19 | 7.71 | |
| SE (±) | | 0.61 | 0.21 | 0.15 | |
| **CD (for variety means)** | | **1.80** | **0.62** | **0.44** | |

MAS: Months after storage

## 4.7 Seedling dry weight

### 4.7.a Under ambient conditions of storage

Mean seedling dry weight of cowpea varieties, along with results of statistical analysis are furnished in table 4.7.a.

**Variability among genotypes**

The initial seedling dry weight of seeds varied from 0.014 g (Hridya) to 0.114 g (Vellayani Jyothika); and that after ten months of storage from 0.017 g (Hridya) to 0.082 g (Vellayani Jyothika). Considering the overall performance of seeds during storage, the seedling dry weight of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, before storage, the highest seedling dry weight was recorded in Vellayani Jyothika (0.114 g) and the lowest was in Hridya (0.014 g). Vellayani Jyothika (0.114 g), Lola (0.097 g) and Vyjayanthi (0.091 g) were on par with each other. And Hridya (0.014 g), Bhagyalakshmi (0.037 g) and Kashi Kanchan (0.043 g) were on par. After ten months of storage, the highest seedling dry weight was recorded by Vellayani Jyothika (0.082 g) and the lowest was in Hridya (0.017 g). Vellayani Jyothika (0.082 g), Vyjayanthi (0.071 g), Anaswara (0.068 g), Lola (0.067 g), Kairali (0.063 g) and Sreya (0.054 g) were on par with each other. Kashi Kanchan (0.043 g), Kanakamony (0.040 g), Bhagyalakshmi (0.031 g) and Hridya (0.017 g) were on par with each other.

Considering the overall performance of varieties, Vellayani Jyothika (0.095 g) of group I had the highest seedling dry weight and Hridya (0.020 g) had the lowest seedling dry weight.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing type showed the highest seedling dry weight and the lowest was recorded by bush type varieties.

The seedling dry weight varied from 0.101 g (initial) to 0.073 g (10MAS) in group I, 0.062 g (2MAS) to 0.053 g (10MAS) in group II and 0.048 g (1, 2, 3MAS) to 0.034 g (10MAS) in group III.

Comparing the group means, before storage, three groups varied significantly from each other. The highest seedling dry weight was recorded by trailing type (0.101 g) and the lowest by bush type (0.041 g). After ten months of storage, semi trailing type (0.053 g) and bush type (0.034 g) were on par. Trailing type (0.073 g) varied significantly from others and recorded the highest seedling dry weight.

Considering the variety means of seedling dry weight under trailing types (Group I), varied significantly among varieties except at initial month before storage. After ten months of storage, all the three varieties were on par with each other among trailing type and the highest was recorded in Vellayani Jyothika (0.082 g) and the lowest was in Lola (0.067 g).

In the case of semi trailing type varieties (Group II), it varied significantly except one month after storage (1MAS). Initially before storage and ten months after storage, all the four varieties under semi trailing were on par with each other.

Variety means for seedling dry weight among bush type (Group III) significantly varied from initial to ten months after storage. Initially before storage and ten months after storage, Sreya and Bhagyalakshmi were on par and Bhagyalakshmi and Hridya were on par.

The overall monthly mean seedling dry weight of varieties decreased gradually from 0.068 g (2MAS) to 0.054 g (10MAS) during storage.

**Table 4.7.a Mean seedling dry weight (g) of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 0.097 | 0.076 | 0.095 | 0.078 | 0.076 | 0.077 | 0.078 | 0.075 | 0.071 | 0.068 | 0.067 | 0.086 |
| | 2.Vellayani Jyothika | 0.114 | 0.100 | 0.105 | 0.099 | 0.099 | 0.094 | 0.092 | 0.086 | 0.087 | 0.085 | 0.082 | 0.095 |
| | 3.Vyjayanthi | 0.091 | 0.090 | 0.084 | 0.075 | 0.075 | 0.073 | 0.075 | 0.074 | 0.074 | 0.074 | 0.071 | 0.078 |
| Overall mean (Group I) | | 0.101 | 0.089 | 0.095 | 0.084 | 0.083 | 0.081 | 0.082 | 0.078 | 0.077 | 0.076 | 0.073 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | |
| **CD** | | **NS** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.070 | 0.073 | 0.080 | 0.072 | 0.072 | 0.073 | 0.071 | 0.070 | 0.069 | 0.069 | 0.068 | 0.072 |
| | 5.Kairali | 0.065 | 0.061 | 0.072 | 0.067 | 0.067 | 0.067 | 0.069 | 0.066 | 0.064 | 0.063 | 0.063 | 0.066 |
| | 6.Kanakamony | 0.048 | 0.038 | 0.048 | 0.046 | 0.047 | 0.044 | 0.045 | 0.044 | 0.042 | 0.041 | 0.040 | 0.044 |
| | 7.Kashi Kanchan | 0.043 | 0.038 | 0.049 | 0.049 | 0.048 | 0.046 | 0.048 | 0.046 | 0.042 | 0.042 | 0.042 | 0.045 |
| Overall mean (Group II) | | 0.057 | 0.053 | 0.062 | 0.059 | 0.059 | 0.058 | 0.058 | 0.057 | 0.054 | 0.054 | 0.053 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | |
| **CD** | | **0.033** | **NS** | **0.033** | **0.033** | **0.033** | **0.033** | **0.033** | **0.033** | **0.033** | **0.033** | **0.033** | |
| Group III (Bush) | 8.Sreya | 0.071 | 0.076 | 0.071 | 0.069 | 0.066 | 0.064 | 0.060 | 0.058 | 0.059 | 0.056 | 0.054 | 0.064 |
| | 9.Hridya | 0.014 | 0.028 | 0.024 | 0.024 | 0.021 | 0.020 | 0.019 | 0.019 | 0.017 | 0.017 | 0.017 | 0.020 |
| | 10.Bhagyalakshmi | 0.037 | 0.039 | 0.049 | 0.050 | 0.043 | 0.039 | 0.034 | 0.035 | 0.034 | 0.031 | 0.031 | 0.038 |
| Overall mean (Group III) | | 0.041 | 0.048 | 0.048 | 0.048 | 0.043 | 0.041 | 0.038 | 0.037 | 0.037 | 0.035 | 0.034 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | |
| **CD** | | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | **0.035** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.002 | 0.004 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | |
| **CD (for group means)** | | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | **0.009** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 0.065 | 0.062 | 0.068 | 0.063 | 0.061 | 0.060 | 0.059 | 0.057 | 0.056 | 0.055 | 0.054 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | |
| **CD (for variety means)** | | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | **0.030** | |

MAS: Months after storage

### 4.7.b Seedling dry weight under cold storage

Mean seedling dry weight of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.7.b.

**Variability among genotypes**

The initial seedling dry weight of seeds varied from 0.014 g (Hridya) to 0.114 g (Vellayani Jyothika) and that after ten months of storage from 0.018 g (Hridya) to 0.084 g (Vellayani Jyothika). Considering the overall performance of seeds during storage, the seedling dry weight of varieties varied and declined significantly from initial to ten months after storage.

On examining the varietal variations, after ten months of storage, the highest seedling dry weight was recorded by Vellayani Jyothika (0.084 g) which was on par with Vyjayanthi (0.077 g), Lola (0.069 g), Anaswara (0.068 g) and Kairali (0.062 g). The lowest was recorded by the variety Hridya (0.018 g). Kashi Kanchan (0.043 g), Kanakamony (0.041 g), Bhagyalakshmi (0.033 g) and Hridya (0.018 g) were on par with each other.

Considering the overall performance of varieties, Vellayani Jyothika (0.098 g) of group I had the highest seedling dry weight and Hridya (0.018 g) had the lowest seedling dry weight.

**Variability based on growth habit**

Analysis of group means showed a significant declining trend from initial to ten months after storage. Varieties belonging to trailing type showed the highest seedling dry weight and the lowest was recorded by bush type varieties.

The seedling dry weight varied from 0.101 g (initial) to 0.077 g (10MAS) in group I, 0.060 g (5MAS) to 0.054 g (10MAS) in group II and 0.044 g (5MAS) to 0.035 g (10MAS) in group III.

Comparing the group means after ten months of storage, three groups varied significantly from each other. The highest seedling dry weight was recorded by trailing type and the lowest by bush type.

Considering the variety means of seedling dry weight under trailing types (Group I), varied significantly among varieties except at initial month before storage. After ten months of storage, all the three varieties were on par with each other among trailing type and the highest was recorded in Vellayani Jyothika (0.084 g) and the lowest was in Lola (0.069 g). In the case of semi trailing (Group II) and bush type (Group III) varieties it varied significantly from initial to ten months after storage.

Among semi trailing type, after ten months of storage, all the four varieties were on par with each other. The highest seedling dry weight was recorded in the variety Anaswara (0.068 g) and the lowest by Kanakamony (0.041 g).

In the case of bush type (Group III) varieties, after ten months of storage, Sreya and Bhagyalakshmi were on par and Bhagyalakshmi and Hridya were on par.

The overall monthly mean seedling dry weight of varieties decreased gradually from 0.065 g (initial) to 0.055 g (10MAS) under cold storage.

| Table 4.7.b Mean seedling dry weight (g) of cowpea varieties influenced by cold storage | | | | | |
|---|---|---|---|---|---|
| | **Variety** | **Initial** | **5MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 0.097 | 0.080 | 0.069 | 0.082 |
| | 2.Vellayani Jyothika | 0.114 | 0.096 | 0.084 | 0.098 |
| | 3.Vyjayanthi | 0.091 | 0.073 | 0.077 | 0.080 |
| Overall mean (Group I) | | 0.101 | 0.083 | 0.077 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | |
| **CD** | | **NS** | **0.035** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.070 | 0.075 | 0.068 | 0.071 |
| | 5.Kairali | 0.065 | 0.069 | 0.062 | 0.065 |
| | 6.Kanakamony | 0.048 | 0.047 | 0.041 | 0.045 |
| | 7.Kashi Kanchan | 0.043 | 0.049 | 0.043 | 0.045 |
| Overall mean (Group II) | | 0.057 | 0.060 | 0.054 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | |
| **CD** | | **0.033** | **0.033** | **0.033** | |
| Group III (Bush) | 8.Sreya | 0.071 | 0.070 | 0.055 | 0.065 |
| | 9.Hridya | 0.014 | 0.022 | 0.018 | 0.018 |
| | 10.Bhagyalakshmi | 0.037 | 0.039 | 0.033 | 0.036 |
| Overall mean (Group III) | | 0.041 | 0.044 | 0.035 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | |
| **CD** | | **0.035** | **0.035** | **0.035** | |
| SE (±) | | 0.002 | 0.002 | 0.002 | |
| **CD (for group means)** | | **0.009** | **0.009** | **0.009** | |
| Monthly overall mean | | 0.065 | 0.062 | 0.055 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | |
| **CD (for variety mean)** | | **0.030** | **0.029** | **0.029** | |

MAS: Months after storage

### 4.8 Seedling vigour index I

### 4.8.a Under ambient conditions of storage

Mean seedling vigour index I of cowpea varieties, along with results of statistical analysis are furnished in table 4.8.a.

**Variability among genotypes**

The initial vigour index I of seed varied from 2878 (Hridya) to 4160 (Kanakamony); and that after ten months of storage from 839 (Vellayani Jyothika) to 1751 (Kashi Kanchan). Considering the overall performance of seeds during storage, the vigour index I of varieties differed significantly from initial to ten months after storage.

On examining the varietal variations, initially before storage, the highest vigour index I was recorded by Kanakamony (4160) which was on par with Kashi Kanchan (3902) and Lola (3894). The lowest was recorded by the variety Hridya (2878). Hridya (2878), Anaswara (3038), Vyjayanthi (3076) and Kairali (3243) were on par with each other. And that after ten months of storage, Kashi Kanchan (1751) recorded the highest vigour index I and was on par with Kanakamony (1704). The lowest was recorded in Vellayani Jyothika (839) and varied significantly from others.

Considering the overall performance of varieties, Kanakamony (2700) of group II had the highest vigour index I and Hridya (1869) had the lowest vigour index I.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after storage. Varieties belonging to semi trailing showed the highest vigour index I and the lowest was recorded by bush type varieties.

The vigour index I varied from 3564 (initial) to 1208 (10MAS) in group I, 3586 (initial) to 1515 (10MAS) in group II and 3291 (initial) to 1171 (10MAS) in group III.

Comparing the group means at initially before storage, the highest vigour index I was recorded by semi trailing (3586) and it was on par with trailing (3564). Bush type (3291) varied significantly from others with the lowest vigour

index I. And that after ten months of storage, semi trailing was recorded the highest vigour index I (1515) and varied significantly from others. The lowest was recorded in bush type (1171) which was on par with trailing type (1208).

Considering the variety means of vigour index I under trailing types (Group I) varied significantly among varieties before storage and from five months of storage. Initially before storage, Lola (3894) was the variety with the highest vigour index I and was on par with Vellayani Jyothika (3723). The lowest was recorded in Vyjayanthi (3076) and it varied significantly from others. After ten months of storage, Vyjayanthi (1424) and Lola (1361) were on par in which Vyjayanthi recorded the highest. Vellayani Jyothika (839) recorded the lowest and differed significantly from others.

In the case of semi trailing type varieties (Group II), it varied significantly except at two months after storage. Initially before storage, Kanakamony (4160) and Kashi Kanchan (3902) were on par and Kairali (3243) and Anaswara (3038) were on par recording the highest and the lowest vigour index I in Kanakamony and Anaswara respectively. Ten months after storage, Kashi Kanchan (1751) and Kanakamony (1704) were on par and Kairali (1343) and Anaswara (1262) were on par recording the highest and the lowest vigour index I in Kashi Kanchan and Anaswara respectively.

Variety means for vigour index I among bush type (Group III) significantly varied except at four and seven months of storage. Initially before storage, Bhagyalakshmi (3575) and Sreya (3421) were on par. The highest vigour index I was recorded in Bhagyalakshmi and the lowest was in Hridya (2878) which varied significantly from others. After ten months of storage, Sreya (1317) recorded the highest vigour index I and varied significantly from others. Bhagyalakshmi (1143) and Hridya (1054) were on par and the lowest was in Hridya.

The overall monthly mean vigour index I of varieties decreased gradually from 3491 (initial) to 1320 (10MAS) during storage.

**Table 4.8.a Mean seedling vigour index I of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 3894 | 3605 | 3369 | 3091 | 2748 | 2460 | 2043 | 1747 | 1631 | 1590 | 1361 | 2504 |
| | 2.Vellayani Jyothika | 3723 | 3588 | 3330 | 3001 | 2757 | 2666 | 1882 | 1509 | 968 | 903 | 839 | 2288 |
| | 3.Vyjayanthi | 3076 | 3078 | 3066 | 3171 | 2735 | 2636 | 2193 | 1940 | 1859 | 1530 | 1424 | 2428 |
| Overall mean (Group I) | | 3564 | 3424 | 3255 | 3088 | 2747 | 2587 | 2040 | 1732 | 1486 | 1341 | 1208 | |
| SE (±) | | 140.54 | 151.86 | 109.59 | 99.80 | 105.88 | 97.02 | 59.91 | 65.03 | 79.36 | 46.95 | 47.33 | |
| **CD** | | **486.87** | **NS** | **NS** | **NS** | **NS** | **NS** | **207.55** | **225.28** | **274.93** | **162.65** | **163.97** | |
| Group II (Semi trailing) | 4.Anaswara | 3038 | 3177 | 3018 | 2353 | 2214 | 2152 | 1679 | 1547 | 1497 | 1298 | 1262 | 2112 |
| | 5.Kairali | 3243 | 3369 | 3181 | 3222 | 2810 | 2737 | 2287 | 1974 | 1571 | 1443 | 1343 | 2471 |
| | 6.Kanakamony | 4160 | 3753 | 3206 | 3011 | 2856 | 2865 | 2437 | 2078 | 2032 | 1592 | 1704 | 2700 |
| | 7.Kashi Kanchan | 3902 | 3061 | 2964 | 2722 | 2468 | 2422 | 2534 | 2157 | 2184 | 1883 | 1751 | 2550 |
| Overall mean (Group II) | | 3586 | 3340 | 3092 | 2827 | 2587 | 2544 | 2234 | 1939 | 1821 | 1554 | 1515 | |
| SE (±) | | 141.21 | 92.48 | 110.67 | 75.94 | 72.76 | 78.50 | 60.78 | 88.06 | 78.01 | 86.91 | 31.60 | |
| **CD** | | **461.24** | **302.07** | **NS** | **248.05** | **237.66** | **256.41** | **198.53** | **287.63** | **254.81** | **283.88** | **103.22** | |
| Group III (Bush) | 8.Sreya | 3421 | 3160 | 3075 | 2661 | 2387 | 2221 | 1672 | 1555 | 1637 | 1538 | 1317 | 2240 |
| | 9.Hridya | 2878 | 2726 | 2476 | 2307 | 2047 | 1841 | 1456 | 1315 | 1269 | 1188 | 1054 | 1869 |
| | 10.Bhagyalakshmi | 3575 | 3059 | 2518 | 2179 | 2104 | 2163 | 1671 | 1538 | 1476 | 1226 | 1143 | 2059 |
| Overall mean (Group III) | | 3291 | 2982 | 2690 | 2383 | 2180 | 2075 | 1600 | 1469 | 1461 | 1317 | 1171 | |
| SE (±) | | 89.44 | 55.56 | 100.00 | 84.17 | 88.90 | 54.20 | 40.87 | 60.30 | 46.34 | 49.59 | 39.26 | |
| **CD** | | **309.85** | **192.48** | **346.43** | **291.59** | **NS** | **187.77** | **141.59** | **NS** | **160.54** | **171.79** | **136.01** | |
| | | | | | | | | | | | | | |
| SE (±) | | 69.93 | 58.14 | 58.74 | 47.18 | 48.53 | 43.02 | 30.27 | 40.48 | 38.61 | 36.42 | 21.45 | |
| **CD (for group means)** | | **206.70** | **171.83** | **173.63** | **139.45** | **143.45** | **127.16** | **89.48** | **119.64** | **114.11** | **107.63** | **63.40** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 3491 | 3258 | 3020 | 2772 | 2513 | 2416 | 1985 | 1736 | 1612 | 1419 | 1320 | |
| SE (±) | | 127.68 | 106.14 | 107.25 | 86.14 | 88.61 | 78.55 | 55.27 | 73.90 | 70.49 | 66.49 | 39.16 | |
| **CD (for variety means)** | | **377.33** | **313.67** | **316.95** | **254.57** | **261.87** | **232.14** | **163.34** | **218.39** | **208.32** | **196.50** | **115.73** | |

MAS: Months after storage

### 4.8.b Seedling vigour index I under cold storage

Mean seedling vigour index I of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.8.b.

**Variability among genotypes**

The initial vigour index I of seed varied from 2878 (Hridya) to 4160 (Kanakamony); and that after ten months of storage from 1117 (Vellayani Jyothika) to 1779 (Kashi Kanchan). Considering the overall performance of seeds during storage, the vigour index I of varieties differed significantly from initial to ten months after storage.

On examining the varietal variations, after ten months of cold storage, Kashi Kanchan (1779) was the variety with the highest vigour index I and was on par with Sreya (1755) and Lola (1706). The lowest was recorded by Vellayani Jyothika (1117) and it varied significantly from others.

Considering the overall performance of varieties, Kanakamony (2944) of group II had the highest vigour index I and Hridya (1988) had the lowest vigour index I.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after storage. Varieties belonging to semi trailing showed the highest vigour index I and the lowest was recorded by bush type varieties.

The vigour index I varied from 3564 (initial) to 1448 (10MAS) in group I, 3586 (initial) to 1582 (10MAS) in group II and 3291 (initial) to 1420 (10MAS) in group III.

Comparing the group means after ten months of cold storage, the highest vigour index I was recorded in semi trailing and it varied significantly from others. The lowest was in bush type and was on par with trailing.

Considering the variety means of vigour index I under trailing types (Group I) varied significantly among varieties except at five month of storage. After ten months of storage, the three varieties among trailing varied significantly. The highest and the lowest vigour index I was recorded in Lola (1706) and Vellayani Jyothika (1117) respectively.

In the case of semi trailing (Group II) and bush type (Group III) varieties varied significantly from initial to ten months after storage. Among semi trailing type, the highest vigour index I was recorded by Kashi Kanchan (1779) and was on par with Kairali (1601). Similarly, Kairali and Kanakamony (1562) were on par and Kanakamony and Anaswara (1387) were on par. The lowest vigour index I was recorded in Anaswara.

Among bush type, Sreya (1755) showed the highest vigour index I and varied significantly from others. Bhagyalakshmi (1308) and Hridya (1195) were on par and the variety Hridya showed the lowest vigour index I.

The overall monthly mean vigour index I of varieties decreased gradually from 3491 (initial) to 1493 (10MAS) under cold storage.

| Table 4.8.b Mean seedling vigour index I of cowpea varieties influenced by cold storage | | | | | |
|---|---|---|---|---|---|
| | **Variety** | **Initial** | **5MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 3894 | 2589 | 1706 | 2730 |
| | 2.Vellayani Jyothika | 3723 | 2685 | 1117 | 2508 |
| | 3.Vyjayanthi | 3076 | 2781 | 1521 | 2459 |
| Overall mean (Group I) | | 3564 | 2685 | 1448 | |
| SE (±) | | 140.54 | 63.09 | 67.87 | |
| **CD** | | **486.87** | **NS** | **235.12** | |
| Group II (Semi trailing) | 4.Anaswara | 3038 | 2190 | 1387 | 2205 |
| | 5.Kairali | 3243 | 2927 | 1601 | 2590 |
| | 6.Kanakamony | 4160 | 3109 | 1562 | 2944 |
| | 7.Kashi Kanchan | 3902 | 2517 | 1779 | 2733 |
| Overall mean (Group II) | | 3586 | 2686 | 1582 | |
| SE (±) | | 141.21 | 57.70 | 59.00 | |
| **CD** | | **461.24** | **188.47** | **192.71** | |
| Group III (Bush) | 8.Sreya | 3421 | 2360 | 1755 | 2512 |
| | 9.Hridya | 2878 | 1891 | 1195 | 1988 |
| | 10.Bhagyalakshmi | 3575 | 2162 | 1308 | 2348 |
| Overall mean (Group III) | | 3291 | 2138 | 1420 | |
| SE (±) | | 89.44 | 40.03 | 36.86 | |
| **CD** | | **309.85** | **138.68** | **127.69** | |
| SE (±) | | 69.93 | 30.03 | 30.90 | |
| **CD (for group means)** | | **206.70** | **88.77** | **91.32** | |
| Monthly overall mean | | 3491 | 2521 | 1493 | |
| SE (±) | | 127.68 | 54.83 | 56.41 | |
| **CD (for variety means)** | | **377.33** | **162.04** | **166.71** | |

MAS: Months after storage

## 4.9 Seedling vigour index II

### 4.9.a Under ambient conditions of storage

Mean seedling vigour index II of cowpea varieties, along with results of statistical analysis are furnished in table 4.9.a.

**Variability among genotypes**

The initial vigour index II of seed varied from 1.36 (Hridya) to 10.98 (Vellayani Jyothika) and that after ten months of storage from 0.75 (Hridya) to 3.67 (Vyjayanthi). Considering the overall performance of seeds during storage, the vigour index II of varieties differed significantly from initial to ten months after storage.

On examining the varietal variations, before storage, the highest vigour index II was recorded by Vellayani Jyothika (10.98) and it varied significantly from others. The lowest was recorded by Hridya (1.36) and it varied significantly from others. And that after ten months of storage, the highest was recorded by Vyjayanthi (3.67) and it was on par with Anaswara (3.64) and Lola (3.43). Hridya (0.75) was the variety with the lowest vigour index II and it varied significantly from others.

Considering the overall performance of varieties, Vellayani Jyothika (6.83) of group I had the highest vigour index II and Hridya (1.49) had the lowest vigour index II.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after storage. Varieties belonging to trailing showed the highest vigour index II and the lowest was recorded by bush type varieties.

The vigour index II decreased from 9.55 (initial) to 3.21 (10MAS) in group I, 5.55 (initial) to 2.83 (10MAS) in group II and 4.56 (1MAS) to 1.63 (10MAS) in group III.

Comparing the group means, before storage and that after ten months of storage, the three groups varied significantly from each other. The highest and the lowest vigour index II were recorded in trailing and bush type respectively.

Considering the variety means of vigour index II under trailing types (Group I) varied significantly among varieties after two months of storage. After ten months of storage, the highest was recorded by Vyjayanthi (3.67) and was on par with Lola (3.43). The lowest was recorded in Vellayani Jyothika (2.54) and it differed significantly from others. Variety means for vigour index II among semi trailing (Group II) and bush type (Group III) significantly varied from initial to ten months after storage.

Among semi trailing varieties, at initially before storage, Anaswara (6.96) recorded the highest vigour index II and was on par with Kairali (6.22). The lowest was recorded by Kashi Kanchan (4.24) and was on par with Kanakamony (4.77). And that after ten months of storage, the four varieties among semi trailing varied significantly. The highest and the lowest were recorded in Anaswara (3.64) and Kanakamony (2.28) respectively.

In the case of bush type, at initially before storage and ten months after storage, the three varieties varied significantly. The highest and the lowest were recorded by Sreya and Hridya respectively.

The overall monthly mean vigour index II of varieties decreased gradually from 6.31 (2MAS) to 2.58 (10MAS) during storage.

**Table 4.9.a Mean seedling vigour index II of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 9.28 | 7.41 | 8.99 | 6.63 | 6.31 | 6.02 | 5.23 | 4.33 | 4.09 | 3.86 | 3.43 | 5.96 |
| | 2.Vellayani Jyothika | 10.98 | 9.60 | 10.04 | 8.94 | 8.91 | 8.12 | 5.93 | 4.53 | 2.89 | 2.68 | 2.54 | 6.83 |
| | 3.Vyjayanthi | 8.38 | 8.43 | 7.75 | 6.51 | 6.21 | 5.89 | 5.40 | 4.99 | 4.72 | 3.89 | 3.67 | 5.99 |
| Overall mean (Group I) | | 9.55 | 8.48 | 8.93 | 7.36 | 7.14 | 6.68 | 5.52 | 4.62 | 3.90 | 3.48 | 3.21 | |
| SE (±) | | 0.65 | 0.50 | 0.37 | 0.18 | 0.20 | 0.18 | 0.24 | 0.13 | 0.26 | 0.12 | 0.17 | |
| **CD** | | **NS** | **NS** | **1.28** | **0.62** | **0.69** | **0.62** | **NS** | **0.45** | **0.90** | **0.42** | **0.59** | |
| Group II (Semi trailing) | 4.Anaswara | 6.96 | 7.17 | 7.83 | 6.31 | 6.22 | 6.12 | 4.65 | 4.44 | 4.29 | 3.78 | 3.64 | 5.58 |
| | 5.Kairali | 6.22 | 5.62 | 6.01 | 5.67 | 5.34 | 5.33 | 4.67 | 4.33 | 3.42 | 3.21 | 2.82 | 4.79 |
| | 6.Kanakamony | 4.77 | 3.83 | 4.69 | 4.17 | 4.01 | 3.78 | 3.40 | 2.96 | 2.77 | 2.28 | 2.28 | 3.54 |
| | 7.Kashi Kanchan | 4.24 | 3.58 | 4.78 | 4.61 | 4.18 | 3.97 | 3.99 | 3.13 | 2.85 | 2.60 | 2.57 | 3.68 |
| Overall mean (Group II) | | 5.55 | 5.05 | 5.83 | 5.19 | 4.94 | 4.80 | 4.18 | 3.72 | 3.33 | 2.97 | 2.83 | |
| SE (±) | | 0.48 | 0.82 | 0.26 | 0.24 | 0.17 | 0.19 | 0.15 | 0.11 | 0.17 | 0.17 | 0.06 | |
| **CD** | | **1.57** | **2.68** | **0.85** | **0.78** | **0.56** | **0.62** | **0.49** | **0.36** | **0.56** | **0.56** | **0.20** | |
| Group III (Bush) | 8.Sreya | 6.80 | 7.29 | 6.30 | 5.71 | 5.20 | 4.71 | 3.63 | 3.21 | 3.32 | 3.08 | 2.68 | 4.72 |
| | 9.Hridya | 1.36 | 2.62 | 2.32 | 2.10 | 1.76 | 1.57 | 1.15 | 1.04 | 0.92 | 0.83 | 0.75 | 1.49 |
| | 10.Bhagyalakshmi | 3.34 | 3.78 | 4.40 | 4.20 | 3.53 | 3.27 | 2.12 | 2.15 | 1.88 | 1.54 | 1.46 | 2.88 |
| Overall mean (Group III) | | 3.83 | 4.56 | 4.34 | 4.00 | 3.50 | 3.18 | 2.30 | 2.13 | 2.04 | 1.82 | 1.63 | |
| SE (±) | | 0.24 | 0.51 | 0.28 | 0.22 | 0.17 | 0.17 | 0.12 | 0.09 | 0.05 | 0.04 | 0.04 | |
| **CD** | | **0.83** | **1.77** | **0.97** | **0.76** | **0.59** | **0.59** | **0.42** | **0.31** | **0.17** | **0.14** | **0.14** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.27 | 0.36 | 0.16 | 0.12 | 0.10 | 0.10 | 0.10 | 0.06 | 0.10 | 0.07 | 0.06 | |
| **CD (for group means)** | | **0.79** | **1.05** | **0.49** | **0.35** | **0.29** | **0.29** | **0.29** | **0.18** | **0.30** | **0.21** | **0.17** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 6.23 | 5.93 | 6.31 | 5.49 | 5.17 | 4.88 | 4.02 | 3.51 | 3.12 | 2.78 | 2.58 | |
| SE (±) | | 0.49 | 0.65 | 0.30 | 0.22 | 0.18 | 0.18 | 0.18 | 0.11 | 0.18 | 0.13 | 0.10 | |
| **CD (for variety means)** | | **1.45** | **1.92** | **0.89** | **0.65** | **0.53** | **0.53** | **0.53** | **0.33** | **0.53** | **0.38** | **0.30** | |

MAS: Months after storage

### 4.9.b Seedling vigour index II under cold storage

Mean seedling vigour index II of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.9.b.

**Variability among genotypes**

The initial vigour index II of seed varied from 1.36 (Hridya) to 10.98 (Vellayani Jyothika); and that after ten months of storage from 0.88 (Hridya) to 4.32 (Vyjayanthi). Considering the overall performance of seeds during storage, the vigour index II of varieties differed significantly from initial to ten months after cold storage.

On examining the varietal variations, after ten months of cold storage, the highest was recorded by Vyjayanthi (4.32) and it was on par with Lola (4.17). Hridya (0.88) was the variety with the lowest vigour index II and it varied significantly from others.

Considering the overall performance of varieties, Vellayani Jyothika (7.54) of group I had the highest vigour index II and Hridya (1.32) had the lowest vigour index II.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after storage. Varieties belonging to trailing showed the highest vigour index II and the lowest was recorded by bush type varieties.

The vigour index II decreased from 9.55 (initial) to 3.97 (10MAS) in group I, 5.55 (initial) to 3.10 (10MAS) in group II and 3.83 (initial) to 2.06 (10MAS) in group III.

Comparing the group means after ten months of storage, three groups varied significantly from each other. The highest and the lowest vigour index II were recorded by trailing (3.97) and bush type (2.06) respectively.

Considering the variety means of vigour index II under trailing types (Group I) varied significantly among varieties except at initially before storage. After ten months of storage, Vyjayanthi (4.32) and Lola (4.17) were on par recording the highest vigour index II in Vyjayanthi. Vellayani Jyothika (3.41) recorded the lowest and varied significantly from others.

In the case of semi trailing (Group II) and bush type (Group III) varieties, it varied significantly from initial to ten months after storage. After ten months of storage, among semi trailing, all the four varieties varied significantly. The highest and the lowest were recorded in Anaswara (3.98) and Kanakamony (2.35) respectively.

Considering the bush type, after ten months of storage, all the three varieties varied significantly. The highest and the lowest were recorded in Sreya (3.54) and Hridya (0.88) respectively.

The overall monthly mean vigour index II of varieties decreased gradually from 6.23 (initial) to 3.05 (10MAS) under cold storage.

**Table 4.9.b Mean seedling vigour index II of cowpea varieties influenced by cold storage**

| | Variety | Initial | 5MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 9.28 | 6.46 | 4.17 | 6.64 |
| | 2.Vellayani Jyothika | 10.98 | 8.22 | 3.41 | 7.54 |
| | 3.Vyjayanthi | 8.38 | 6.00 | 4.32 | 6.23 |
| Overall mean (Group I) | | 9.55 | 6.89 | 3.97 | |
| SE (±) | | 0.65 | 0.24 | 0.15 | |
| **CD** | | **NS** | **0.83** | **0.52** | |
| Group II (Semi trailing) | 4.Anaswara | 6.96 | 6.46 | 3.98 | 5.80 |
| | 5.Kairali | 6.22 | 5.50 | 3.32 | 5.01 |
| | 6.Kanakamony | 4.77 | 4.23 | 2.35 | 3.78 |
| | 7.Kashi Kanchan | 4.24 | 4.32 | 2.74 | 3.77 |
| Overall mean (Group II) | | 5.55 | 5.13 | 3.10 | |
| SE (±) | | 0.48 | 0.13 | 0.11 | |
| **CD** | | **1.57** | **0.42** | **0.36** | |
| Group III (Bush) | 8.Sreya | 6.80 | 5.38 | 3.54 | 5.24 |
| | 9.Hridya | 1.36 | 1.72 | 0.88 | 1.32 |
| | 10.Bhagyalakshmi | 3.34 | 3.23 | 1.75 | 2.77 |
| Overall mean (Group III) | | 3.83 | 3.44 | 2.06 | |
| SE (±) | | 0.24 | 0.13 | 0.02 | |
| **CD** | | **0.83** | **0.45** | **0.07** | |
| SE (±) | | 0.27 | 0.09 | 0.06 | |
| **CD (for group means)** | | **0.79** | **0.28** | **0.17** | |
| Monthly overall mean | | 6.23 | 5.15 | 3.05 | |
| SE (±) | | 0.49 | 0.17 | 0.11 | |
| **CD (for variety means)** | | **1.45** | **0.50** | **0.33** | |

MAS: Months after storage

### 4.10 Electrical conductivity of seed leachate

### 4.10.a Under ambient conditions of storage

Mean electrical conductivity of seed leachate of cowpea varieties, along with results of statistical analysis are furnished in table 4.10.a.

**Variability among genotypes**

The initial electrical conductivity of seed leachate varied from 0.206 $dSm^{-1}$ (Anaswara) to 0.349 $dSm^{-1}$ (Vellayani Jyothika); and that after ten months of storage from 0.239 $dSm^{-1}$ (Anaswara) to 0.643 $dSm^{-1}$ (Kashi Kanchan). Considering the overall performance of seeds during storage, the electrical conductivity of seed leachate of varieties varied and increased significantly from initial to ten months after storage.

On examining the varietal variations, at initially before storage, the highest electrical conductivity of seed leachate was recorded in Vellayani Jyothika (0.349 $dSm^{-1}$). Vellayani Jyothika (0.349 $dSm^{-1}$), Bhagyalakshmi (0.336 $dSm^{-1}$), Vyjayanthi (0.321 $dSm^{-1}$) and Kairali (0.307 $dSm^{-1}$) were on par with each other. After ten months of storage, Kashi Kanchan (0.643 $dSm^{-1}$) recorded the highest electrical conductivity of seed leachate and it varied significantly from others. Anaswara (0.239 $dSm^{-1}$) recorded the lowest electrical conductivity of seed leachate and it varied significantly from others.

Considering the overall performance of varieties, Anaswara (0.215 $dSm^{-1}$) of group II had the lowest electrical conductivity of seed leachate and Kashi Kanchan (0.524 $dSm^{-1}$) had the highest electrical conductivity of seed leachate.

**Variability based on growth habit**

Analysis of group means showed a significant increasing trend from initial to ten months after storage. Varieties belonging to bush type showed the lowest electrical conductivity of seed leachate and the highest was recorded by semi trailing type varieties.

The electrical conductivity of seed leachate varied from 0.296 $dSm^{-1}$ (2MAS) to 0.428 $dSm^{-1}$ (10MAS) in group I, 0.270 $dSm^{-1}$ (initial) to 0.480 $dSm^{-1}$ (10MAS) in group II and 0.274 $dSm^{-1}$ (2MAS) to 0.374 $dSm^{-1}$ (9MAS) in group III.

Comparing the group means at initially before storage, three groups were on par with each other recording the lowest electrical conductivity of seed leachate in semi trailing (0.270 $dSm^{-1}$) and the highest was in trailing (0.310 $dSm^{-1}$). After ten months of storage, the three groups varied significantly from each other. The lowest electrical conductivity of seed leachate was in bush type (0.370 $dSm^{-1}$) and the highest was in semi trailing (0.480 $dSm^{-1}$).

Considering the varietal means of electrical conductivity of seed leachate under trailing type (Group I) varied significantly among varieties except at initial month before storage and eight months after storage. At first month of storage and ten months after storage, Vellayani Jyothika and Vyjayanthi were on par and Lola varied significantly from others.

In the case of semi trailing type varieties (Group II), it varied significantly except at initial month before storage. At ten months after storage the four varieties in semi trailing types varied significantly. The lowest electrical conductivity of seed leachate was in Anaswara (0.239 $dSm^{-1}$) and the highest was in Kashi Kanchan (0.643 $dSm^{-1}$).

Varietal means for electrical conductivity of seed leachate among bush type (Group III) significantly varied only from fourth months of storage. After ten months of storage, Bhagyalakshmi recorded the highest electrical conductivity of seed leachate (0.430 $dSm^{-1}$) and varied significantly from others. The varieties Sreya (0.331 $dSm^{-1}$) and Hridya (0.349 $dSm^{-1}$) were on par and Sreya recorded the lowest electrical conductivity of seed leachate.

The overall monthly mean electrical conductivity of seed leachate of varieties increased gradually from 0.285 $dSm^{-1}$ (initial) to 0.431 $dSm^{-1}$ (10MAS) during storage.

**Table 4.10.a Mean electrical conductivity of seed leachate ($dSm^{-1}$) of cowpea varieties influenced by period of storage**

| | Variety | Initial | 1MAS | 2MAS | 3MAS | 4MAS | 5MAS | 6MAS | 7MAS | 8MAS | 9MAS | 10MAS | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 0.259 | 0.232 | 0.267 | 0.237 | 0.243 | 0.276 | 0.309 | 0.333 | 0.326 | 0.344 | 0.375 | 0.291 |
| | 2.Vellayani Jyothika | 0.349 | 0.363 | 0.281 | 0.377 | 0.381 | 0.417 | 0.421 | 0.435 | 0.446 | 0.450 | 0.450 | 0.397 |
| | 3.Vyjayanthi | 0.321 | 0.370 | 0.339 | 0.367 | 0.379 | 0.401 | 0.401 | 0.393 | 0.433 | 0.463 | 0.460 | 0.393 |
| Overall mean (Group I) | | 0.310 | 0.322 | 0.296 | 0.327 | 0.334 | 0.365 | 0.377 | 0.387 | 0.402 | 0.419 | 0.428 | |
| SE (±) | | 0.020 | 0.030 | 0.010 | 0.030 | 0.020 | 0.010 | 0.020 | 0.010 | 0.040 | 0.020 | 0.010 | |
| **CD** | | **NS** | **0.104** | **0.035** | **0.104** | **0.069** | **0.035** | **0.069** | **0.035** | **NS** | **0.069** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.206 | 0.236 | 0.178 | 0.193 | 0.208 | 0.224 | 0.225 | 0.224 | 0.217 | 0.216 | 0.239 | 0.215 |
| | 5.Kairali | 0.307 | 0.372 | 0.414 | 0.384 | 0.395 | 0.399 | 0.466 | 0.516 | 0.538 | 0.546 | 0.554 | 0.445 |
| | 6.Kanakamony | 0.280 | 0.275 | 0.267 | 0.267 | 0.266 | 0.283 | 0.379 | 0.413 | 0.468 | 0.489 | 0.482 | 0.352 |
| | 7.Kashi Kanchan | 0.287 | 0.320 | 0.357 | 0.526 | 0.568 | 0.598 | 0.594 | 0.626 | 0.624 | 0.623 | 0.643 | 0.524 |
| Overall mean (Group II) | | 0.270 | 0.301 | 0.304 | 0.343 | 0.359 | 0.376 | 0.416 | 0.445 | 0.462 | 0.469 | 0.480 | |
| SE (±) | | 0.020 | 0.020 | 0.040 | 0.030 | 0.030 | 0.010 | 0.020 | 0.010 | 0.030 | 0.020 | 0.010 | |
| **CD** | | **NS** | **0.065** | **0.131** | **0.098** | **0.098** | **0.033** | **0.065** | **0.033** | **0.098** | **0.065** | **0.033** | |
| Group III (Bush) | 8.Sreya | 0.270 | 0.297 | 0.237 | 0.271 | 0.273 | 0.315 | 0.325 | 0.321 | 0.336 | 0.330 | 0.331 | 0.301 |
| | 9.Hridya | 0.237 | 0.318 | 0.264 | 0.291 | 0.295 | 0.338 | 0.342 | 0.339 | 0.332 | 0.339 | 0.349 | 0.313 |
| | 10.Bhagyalakshmi | 0.336 | 0.380 | 0.320 | 0.386 | 0.391 | 0.420 | 0.406 | 0.439 | 0.445 | 0.454 | 0.430 | 0.401 |
| Overall mean (Group III) | | 0.281 | 0.332 | 0.274 | 0.316 | 0.320 | 0.358 | 0.358 | 0.366 | 0.371 | 0.374 | 0.370 | |
| SE (±) | | 0.020 | 0.030 | 0.020 | 0.040 | 0.010 | 0.010 | 0.020 | 0.020 | 0.010 | 0.010 | 0.010 | |
| **CD** | | **NS** | **NS** | **NS** | **NS** | **0.035** | **0.035** | **0.069** | **0.069** | **0.035** | **0.035** | **0.035** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.001 | 0.014 | 0.017 | 0.017 | 0.013 | 0.006 | 0.011 | 0.007 | 0.015 | 0.010 | 0.005 | |
| **CD (for group means)** | | **0.042** | **NS** | **NS** | **0.050** | **0.042** | **0.009** | **0.030** | **0.030** | **0.042** | **0.030** | **0.009** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 0.285 | 0.316 | 0.292 | 0.330 | 0.340 | 0.367 | 0.387 | 0.404 | 0.417 | 0.425 | 0.431 | |
| SE (±) | | 0.020 | 0.030 | 0.030 | 0.030 | 0.020 | 0.010 | 0.020 | 0.010 | 0.030 | 0.020 | 0.010 | |
| **CD (for variety means)** | | **0.059** | **0.089** | **0.089** | **0.089** | **0.059** | **0.030** | **0.059** | **0.030** | **0.089** | **0.059** | **0.030** | |

MAS: Months after storage

### 4.10.b Electrical conductivity of seed leachate under cold storage

Mean electrical conductivity of seed leachate of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.10.b.

**Variability among genotypes**

The initial electrical conductivity of seed leachate varied from 0.206 $dSm^{-1}$ (Anaswara) to 0.349 $dSm^{-1}$ (Vellayani Jyothika); and that after ten months of storage from 0.208 $dSm^{-1}$ (Anaswara) to 0.607 $dSm^{-1}$ (Kashi Kanchan). Considering the overall performance of seeds during storage, the electrical conductivity of seed leachate of varieties varied and increased significantly from initial to ten months after storage.

On examining the varietal variations, after ten months of cold storage, the highest electrical conductivity of seed leachate was recorded by Kashi Kanchan (0.607 $dSm^{-1}$) and it varied significantly from other varieties. The lowest was recorded by Anaswara (0.208 $dSm^{-1}$) and it varied significantly from others.

Considering the overall performance of varieties, Anaswara (0.212 $dSm^{-1}$) of group II had the lowest electrical conductivity of seed leachate and Kashi Kanchan (0.487 $dSm^{-1}$) had the highest electrical conductivity of seed leachate.

**Variability based on growth habit**

Analysis of group means showed a significant increasing trend from initial to ten months after storage. Varieties belonging to bush type showed the lowest electrical conductivity of seed leachate and the highest was recorded by semi trailing type varieties.

The electrical conductivity of seed leachate varied from 0.310 $dSm^{-1}$ (initial) to 0.422 $dSm^{-1}$ (10MAS) in group I, 0.270 $dSm^{-1}$ (initial) to 0.449 $dSm^{-1}$

(10MAS) in group II and 0.281 $dSm^{-1}$ (initial) to 0.375 $dSm^{-1}$ (10MAS) in group III.

Comparing the group means after ten months of storage, the three groups varied significantly from each other. The lowest electrical conductivity of seed leachate was in bush type (0.375 $dSm^{-1}$) and the highest was in semi trailing (0.449 $dSm^{-1}$).

Considering the variety means of electrical conductivity of seed leachate under trailing type (Group I), semi trailing type (Group II) and bush type (Group III) varied significantly among varieties except at initial month before storage. Among trailing type, the three varieties varied significantly. The lowest was recorded by Lola (0.348 $dSm^{-1}$) and the highest was in Vellayani Jyothika (0.483 $dSm^{-1}$).

Among semi trailing type, the four varieties varied significantly. The lowest was recorded by Anaswara (0.208 $dSm^{-1}$) and the highest was by Kashi Kanchan (0.607 $dSm^{-1}$).

Considering bush type varieties, the highest electrical conductivity of seed leachate was recorded in Bhagyalakshmi (0.453 $dSm^{-1}$) and it varied significantly from others. The lowest was in Hridya (0.334 $dSm^{-1}$) which was on par with Sreya (0.337 $dSm^{-1}$).

The overall monthly mean electrical conductivity of seed leachate of varieties increased gradually from 0.285 $dSm^{-1}$ (initial) to 0.419 $dSm^{-1}$ (10MAS) under cold storage.

| Table 4.10.b Mean electrical conductivity of seed leachate ($dSm^{-1}$) of cowpea varieties influenced by cold storage | | | | | |
|---|---|---|---|---|---|
| | **Variety** | **Initial** | **5MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 0.259 | 0.212 | 0.348 | 0.273 |
| | 2.Vellayani Jyothika | 0.349 | 0.392 | 0.483 | 0.408 |
| | 3.Vyjayanthi | 0.321 | 0.360 | 0.436 | 0.372 |
| Overall mean (Group I) | | 0.310 | 0.321 | 0.422 | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| **CD** | | **NS** | **0.035** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.206 | 0.223 | 0.208 | 0.212 |
| | 5.Kairali | 0.307 | 0.326 | 0.517 | 0.383 |
| | 6.Kanakamony | 0.280 | 0.280 | 0.463 | 0.341 |
| | 7.Kashi Kanchan | 0.287 | 0.566 | 0.607 | 0.487 |
| Overall mean (Group II) | | 0.270 | 0.349 | 0.449 | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| **CD** | | **NS** | **0.033** | **0.033** | |
| Group III (Bush) | 8.Sreya | 0.270 | 0.265 | 0.337 | 0.291 |
| | 9.Hridya | 0.237 | 0.344 | 0.334 | 0.305 |
| | 10.Bhagyalakshmi | 0.336 | 0.413 | 0.453 | 0.401 |
| Overall mean (Group III) | | 0.281 | 0.341 | 0.375 | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| **CD** | | **NS** | **0.035** | **0.035** | |
| SE (±) | | 0.001 | 0.005 | 0.005 | |
| **CD (for group means)** | | **0.042** | **0.009** | **0.009** | |
| Monthly overall mean | | 0.285 | 0.338 | 0.419 | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| **CD (for variety means)** | | **0.059** | **0.029** | **0.029** | |

MAS: Months after storage

### 4.11 Dehydrogenase enzyme activity

### 4.11.a Under ambient conditions of storage

Mean dehydrogenase enzyme activity of cowpea varieties, along with results of statistical analysis are furnished in table 4.11.a. (Plate 4).

**Variability among genotypes**

The initial dehydrogenase enzyme activity of seeds varied from 0.402 (Hridya) to 1.311 (Vyjayanthi) and that after ten months of storage from 0.157 (Sreya) to 0.572 (Vyjayanthi). Considering the overall performance of seeds during storage, the dehydrogenase enzyme activity of varieties differed and declined significantly from initial to ten months after storage.

On examining the varietal variations, before storage, the highest dehydrogenase enzyme activity was recorded by Vyjayanthi (1.311) and it varied significantly from other varieties. Hridya (0.402) was the variety with the lowest dehydrogenase enzyme activity and Hridya varied significantly from others. And that after ten months of storage, the highest dehydrogenase enzyme activity was recorded by Vyjayanthi (0.572) and it varied significantly from other varieties. The variety with the lowest dehydrogenase enzyme activity was Sreya (0.157) which was on par with Kanakamony (0.177) and Hridya (0.169).

Considering the overall performance of varieties, Vyjayanthi (0.940) of group I had the highest dehydrogenase enzyme activity and Hridya (0.281) had the lowest dehydrogenase enzyme activity.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after storage. Varieties belonging to trailing showed the highest dehydrogenase enzyme activity and the lowest was recorded by bush type varieties.

The dehydrogenase enzyme activity varied from 0.891 (initial) to 0.378 (10MAS) in group I, 0.813 (initial) to 0.238 (10MAS) in group II and 0.685 (initial) to 0.201 (10MAS) in group III.

Comparing the group means, before storage, and after ten months of storage the three groups varied significantly from each other. The highest

dehydrogenase enzyme activity was recorded by trailing type (0.891 at initial and 0.378 at 10MAS) and the lowest was in bush type (0.685 at initial and 0.201 at 10MAS).

Considering the variety means of dehydrogenase enzyme activity under trailing type (Group I) varied significantly among varieties from initial to ten months after storage. At initially before storage, and after ten months of storage, the three varieties differed significantly. Vyjayanthi showed the highest dehydrogenase enzyme activity and Lola showed the lowest.

In the case of semi trailing type (Group II) and bush type (Group III) varieties, it varied significantly except at two and three month after storage. Among semi trailing, before storage, Kashi Kanchan (1.073) was the variety with the highest dehydrogenase enzyme activity and it varied significantly from other varieties. The lowest dehydrogenase enzyme activity was recorded by Anaswara (0.619) which was on par with Kanakamony (0.666). After ten months of storage, Kairali (0.312) and Kanakamony (0.177) showed the highest and the lowest dehydrogenase enzyme activity respectively and differed significantly from others.

Among bush type, before storage, the three varieties differed significantly. The highest and the lowest dehydrogenase enzyme activity was recorded in Sreya (0.870) and Hridya (0.402) respectively. After ten months of storage, Bhagyalakshmi (0.276) recorded the highest and varied significantly from others. Sreya (0.157) and Hridya (0.169) were on par. The lowest was recorded by Sreya.

The overall monthly mean dehydrogenase enzyme activity of varieties decreased gradually from 0.798 (initial) to 0.269 (10MAS) during storage.

| Table 4.11.a Mean dehydrogenase enzyme activity of cowpea varieties influenced by period of storage | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Variety** | **Initial** | **1MAS** | **2MAS** | **3MAS** | **4MAS** | **5MAS** | **6MAS** | **7MAS** | **8MAS** | **9MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 0.648 | 0.637 | 0.534 | 0.451 | 0.385 | 0.285 | 0.263 | 0.262 | 0.249 | 0.245 | 0.238 | 0.382 |
| | 2.Vellayani Jyothika | 0.714 | 0.718 | 0.735 | 0.577 | 0.507 | 0.490 | 0.405 | 0.397 | 0.344 | 0.327 | 0.324 | 0.503 |
| | 3.Vyjayanthi | 1.311 | 1.298 | 1.326 | 1.153 | 0.966 | 0.953 | 0.790 | 0.786 | 0.593 | 0.590 | 0.572 | 0.940 |
| Overall mean (Group I) | | 0.891 | 0.884 | 0.865 | 0.727 | 0.619 | 0.576 | 0.486 | 0.482 | 0.395 | 0.387 | 0.378 | |
| SE (±) | | 0.01 | 0.09 | 0.13 | 0.10 | 0.02 | 0.01 | 0.03 | 0.01 | 0.05 | 0.02 | 0.01 | |
| **CD** | | **0.035** | **0.310** | **0.450** | **0.350** | **0.069** | **0.035** | **0.104** | **0.035** | **0.170** | **0.069** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.619 | 0.601 | 0.520 | 0.373 | 0.334 | 0.292 | 0.269 | 0.248 | 0.246 | 0.243 | 0.219 | 0.360 |
| | 5.Kairali | 0.892 | 0.887 | 0.793 | 0.522 | 0.466 | 0.421 | 0.413 | 0.383 | 0.369 | 0.335 | 0.312 | 0.527 |
| | 6.Kanakamony | 0.666 | 0.626 | 0.370 | 0.315 | 0.307 | 0.254 | 0.246 | 0.218 | 0.205 | 0.187 | 0.177 | 0.325 |
| | 7.Kashi Kanchan | 1.073 | 1.052 | 0.731 | 0.471 | 0.423 | 0.442 | 0.382 | 0.389 | 0.254 | 0.251 | 0.242 | 0.519 |
| Overall mean (Group II) | | 0.813 | 0.792 | 0.604 | 0.420 | 0.383 | 0.352 | 0.328 | 0.310 | 0.269 | 0.254 | 0.238 | |
| SE (±) | | 0.02 | 0.08 | 0.10 | 0.06 | 0.02 | 0.02 | 0.03 | 0.01 | 0.03 | 0.01 | 0.01 | |
| **CD** | | **0.065** | **0.260** | **NS** | **NS** | **0.065** | **0.065** | **0.098** | **0.033** | **0.098** | **0.033** | **0.033** | |
| Group III (Bush) | 8.Sreya | 0.870 | 0.806 | 0.723 | 0.320 | 0.314 | 0.283 | 0.235 | 0.224 | 0.214 | 0.190 | 0.157 | 0.394 |
| | 9.Hridya | 0.402 | 0.357 | 0.355 | 0.325 | 0.326 | 0.316 | 0.244 | 0.217 | 0.188 | 0.187 | 0.169 | 0.281 |
| | 10.Bhagyalakshmi | 0.784 | 0.772 | 0.716 | 0.522 | 0.423 | 0.394 | 0.353 | 0.333 | 0.317 | 0.283 | 0.276 | 0.470 |
| Overall mean (Group III) | | 0.685 | 0.645 | 0.598 | 0.389 | 0.354 | 0.331 | 0.277 | 0.258 | 0.240 | 0.220 | 0.201 | |
| SE (±) | | 0.02 | 0.08 | 0.12 | 0.07 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | |
| **CD** | | **0.069** | **0.280** | **NS** | **NS** | **0.104** | **0.069** | **0.069** | **0.035** | **0.035** | **0.069** | **0.035** | |
| | | | | | | | | | | | | | |
| SE (±) | | 0.010 | 0.045 | 0.063 | 0.045 | 0.010 | 0.009 | 0.014 | 0.006 | 0.017 | 0.009 | 0.005 | |
| **CD (for group means)** | | **0.030** | **0.140** | **0.189** | **0.122** | **0.030** | **0.030** | **0.042** | **0.009** | **0.051** | **0.030** | **0.009** | |
| | | | | | | | | | | | | | |
| Monthly overall mean | | 0.798 | 0.775 | 0.680 | 0.503 | 0.445 | 0.413 | 0.360 | 0.346 | 0.298 | 0.284 | 0.269 | |
| SE (±) | | 0.02 | 0.09 | 0.12 | 0.07 | 0.02 | 0.02 | 0.03 | 0.01 | 0.03 | 0.02 | 0.01 | |
| **CD (for variety means)** | | **0.060** | **0.270** | **0.350** | **0.210** | **0.060** | **0.060** | **0.090** | **0.030** | **0.090** | **0.060** | **0.030** | |

MAS: Months after storage

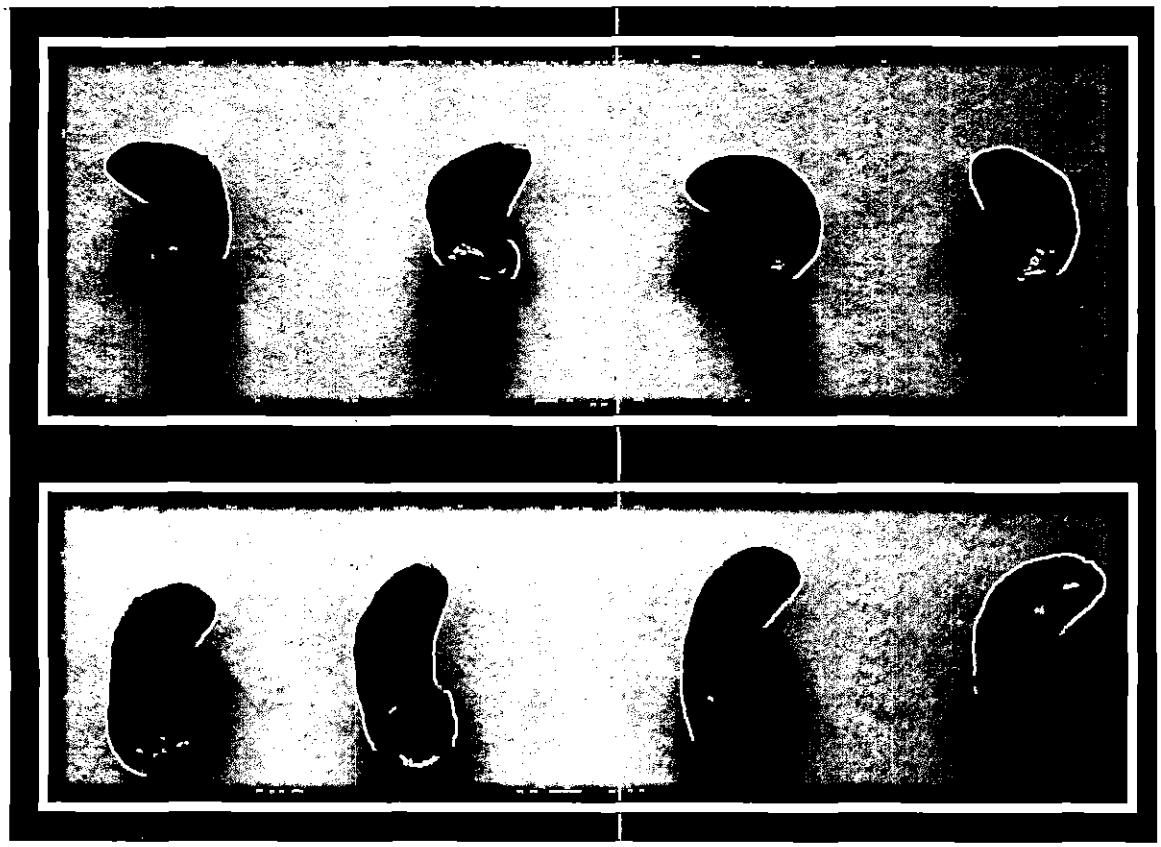


**Plate 4. Dehydrogenase enzyme test-stained embryos**

### 4.11.b Dehydrogenase enzyme activity under cold storage

Mean dehydrogenase enzyme activity of cowpea varieties stored in cold storage were compared for seed quality attributes at five and ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.11.b.

**Variability among genotypes**

The initial dehydrogenase enzyme activity of seed varied from 0.402 (Hridya) to 1.311 (Vyjayanthi); and that after ten months of storage from 0.180 (Sreya) to 0.568 (Vyjayanthi). Considering the overall performance of seeds during storage, the dehydrogenase enzyme activity of varieties differed and declined significantly from initial to ten months after storage.

On examining the varietal variations, after ten months of storage, the highest dehydrogenase enzyme activity was recorded in Vyjayanthi (0.568) and it varied significantly from other varieties. Sreya (0.180) was the variety with the lowest dehydrogenase enzyme activity and Sreya varied significantly from others.

Considering the overall performance of varieties, Vyjayanthi (0.954) of group I had the highest dehydrogenase enzyme activity and Hridya (0.298) had the lowest dehydrogenase enzyme activity.

**Variability based on growth habit**

Analysis of group means showed a significant decreasing trend from initial to ten months after cold storage. Varieties belonging to trailing showed the highest dehydrogenase enzyme activity and the lowest was recorded by bush type varieties.

The dehydrogenase enzyme activity varied from 0.891 (initial) to 0.374 (10MAS) in group I, 0.813 (initial) to 0.267 (10MAS) in group II and 0.685 (initial) to 0.224 (10MAS) in group III.

Comparing the group means after ten months of storage, the three groups varied significantly from each other. The highest dehydrogenase enzyme activity was in trailing (0.374) and the lowest was in bush type (0.224).

Considering the variety means of dehydrogenase enzyme activity, trailing types (Group I), semi trailing type (Group II) and bush type (Group III) varied significantly among varieties from initial to ten months after storage. Among trailing types, after ten months of cold storage, three varieties differed significantly. The highest dehydrogenase enzyme activity was recorded in Vyjayanthi (0.568) and lowest was in Lola (0.227).

Among semi trailing type, the highest dehydrogenase enzyme activity was in Kairali (0.354) and it differed significantly from others. The lowest was recorded by Kanakamony (0.209) which was on par with Anaswara (0.241).

Considering bush type varieties, the highest dehydrogenase enzyme activity was recorded in Bhagyalakshmi (0.297) and it varied significantly from other varieties. The lowest dehydrogenase enzyme activity was recorded by Sreya (0.180) and was on par with Hridya (0.194).

The overall monthly mean dehydrogenase enzyme activity of varieties decreased gradually from 0.798 (initial) to 0.286 (10MAS) under cold storage.

| Table 4.11.b Mean dehydrogenase enzyme activity of cowpea varieties influenced by cold storage | | | | | |
|---|---|---|---|---|---|
| | **Variety** | **Initial** | **5MAS** | **10MAS** | **Overall mean** |
| Group I (Trailing) | 1.Lola | 0.648 | 0.259 | 0.227 | 0.378 |
| | 2.Vellayani Jyothika | 0.714 | 0.531 | 0.326 | 0.524 |
| | 3.Vyjayanthi | 1.311 | 0.983 | 0.568 | 0.954 |
| Overall mean (Group I) | | 0.891 | 0.591 | 0.374 | |
| SE (±) | | 0.010 | 0.010 | 0.010 | |
| **CD** | | **0.035** | **0.035** | **0.035** | |
| Group II (Semi trailing) | 4.Anaswara | 0.619 | 0.328 | 0.241 | 0.396 |
| | 5.Kairali | 0.892 | 0.442 | 0.354 | 0.563 |
| | 6.Kanakamony | 0.666 | 0.232 | 0.209 | 0.369 |
| | 7.Kashi Kanchan | 1.073 | 0.547 | 0.262 | 0.627 |
| **Overall mean (Group II)** | | **0.813** | **0.387** | **0.267** | |
| SE (±) | | 0.02 | 0.010 | 0.010 | |
| CD | | 0.065 | 0.033 | 0.033 | |
| Group III (Bush) | 8.Sreya | 0.870 | 0.302 | 0.180 | 0.451 |
| | 9.Hridya | 0.402 | 0.297 | 0.194 | 0.298 |
| | 10.Bhagyalakshmi | 0.784 | 0.404 | 0.297 | 0.495 |
| **Overall mean (Group III)** | | **0.685** | **0.334** | **0.224** | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| CD | | 0.069 | 0.035 | 0.035 | |
| SE (±) | | 0.010 | 0.006 | 0.006 | |
| **CD (for group means)** | | **0.030** | **0.009** | **0.009** | |
| Monthly overall mean | | 0.798 | 0.433 | 0.286 | |
| SE (±) | | 0.020 | 0.010 | 0.010 | |
| **CD (for variety means)** | | **0.060** | **0.029** | **0.029** | |

MAS: Months after storage

### 4.12 Seed microflora and insect incidence

### 4.12.a Under ambient conditions of storage

Mean seed infection per cent of cowpea varieties at start and end of storage period, along with results of statistical analysis are furnished in table 4.12.a.

**Variability among genotypes**

The initial infection per cent of seed varied from 13.33 per cent (Vyjayanthi, Kanakamony and Kashi Kanchan) to 33.33 per cent (Anaswara and Hridya); and that after ten months of storage from 36.67 per cent (Vellayani Jyothika, Kairali and Kanakamony) to 56.67 per cent (Lola). Considering the overall performance of seeds during storage, the seed infection per cent of varieties differed significantly in initial and ten months after storage.

On examining the varietal variations, before storage, the highest per cent infection was recorded in Anaswara and Hridya (33.33%) and were on par with Lola (30.00%) and Bhagyalakshmi (26.67%). The lowest was recorded by Kanakamony, Kashi Kanchan and Vyjayanthi (13.33%) and were on par with each other. And that after ten months of storage, the highest was recorded in Lola (56.67%) and was on par with Sreya (53.33%), Anaswara (53.33%), Bhagyalakshmi (53.33%), Kashi Kanchan (43.33%) and Hridya (43.33%). The lowest was in Vellayani Jyothika (36.67%), Kairali (36.67%) and Kanakamony (36.67%) and were on par with each other.

Considering the overall performance of varieties, the highest infection was found in Lola and Anaswara (43.34% and 43.33%). Kanakamony was the variety which recorded the lowest infection (25.00%).

**Variability based on growth habit**

Analysis of group means showed an increasing trend of infection from initial to ten months of storage. The highest was recorded by bush type and the lowest was in semi trailing.

The seed infection per cent varied from 20.00 per cent (initial) to 44.45 per cent (10MAS) in group I, 19.17 per cent (initial) to 42.50 per cent (10MAS) in group II and 26.67 per cent (initial) to 50.00 per cent (10MAS) in group III.

Comparing the group means, there was no significant difference between groups at initial and ten months of storage.

Considering the variety means of seed microflora infection per cent under trailing type (Group I) varied significantly only after ten months of storage. The highest infection was recorded by Lola (56.67%) and it varied significantly from others. The lowest was in the variety Vellayani Jyothika (36.67%) which was on par with Vyjayanthi (40.00%).

Under semi trailing type, varied significantly between varieties only at initially before storage. Anaswara recorded the highest (33.33%) and varied significantly from others. The lowest was recorded by Kanakamony and Kashi Kanchan (13.33%) and were on par with Kairali (16.67%).

Among bush type, it varied significantly only before storage. Hridya recorded the highest (33.33%) and was on par with Bhagyalakshmi (26.67%). The lowest was recorded by Sreya (20.00%) and was on par with Bhagyalakshmi.

The overall monthly mean infection per cent of varieties increased from 21.67 per cent (initial) to 45.33 per cent (10MAS) during storage.

Seed microflora identified were *Rhizopus sp.* and *Aspergillus sp.* (Plate 5).

There was no insect incidence observed during the period of storage.

**Table 4.12.a Mean seed infection (%) of cowpea varieties influenced by period of storage**

| | Variety | Initial | 10MAS | Overall mean |
|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 30.00 | 56.67 | 43.34 |
| | 2.Vellayani Jyothika | 16.67 | 36.67 | 26.67 |
| | 3.Vyjayanthi | 13.33 | 40.00 | 26.67 |
| Overall mean (Group I) | | 20.00 | 44.45 | |
| SE (±) | | | 4.30 | |
| **CD** | | **NS** | **14.89** | |
| Group II (Semi trailing) | 4.Anaswara | 33.33 | 53.33 | 43.33 |
| | 5.Kairali | 16.67 | 36.67 | 26.67 |
| | 6.Kanakamony | 13.33 | 36.67 | 25.00 |
| | 7.Kashi Kanchan | 13.33 | 43.33 | 28.33 |
| Overall mean (Group II) | | 19.17 | 42.50 | |
| SE (±) | | 4.40 | | |
| **CD** | | **14.38** | **NS** | |
| Group III (Bush) | 8.Sreya | 20.00 | 53.33 | 36.67 |
| | 9.Hridya | 33.33 | 43.33 | 38.33 |
| | 10.Bhagyalakshmi | 26.67 | 53.33 | 40.00 |
| Overall mean (Group III) | | 26.67 | 50.00 | |
| SE (±) | | 2.72 | | |
| **CD** | | **9.42** | **NS** | |
| **CD (for group means)** | | **NS** | **NS** | |
| Monthly overall mean | | 21.67 | 45.33 | |
| SE (±) | | 3.93 | 4.81 | |
| CD (for variety means) | | 11.64 | 14.25 | |

MAS: Months after storage

**4.12.b Seed infection per cent under cold of storage**

Mean seed infection per cent of cowpea varieties stored in cold storage were compared for seed quality attributes at ten months after storage, with those stored in ambient conditions. The results of statistical analysis are furnished in table 4.12.b.

**Variability among genotypes**

After ten months of cold storage, infection per cent of seed varied from 26.67 per cent (Vyjayanthi) to 50.00 per cent (Lola). Considering the overall

performance of seeds during storage, the seed infection per cent of varieties differed significantly at ten months after storage.

On examining the varietal variations, after ten months of storage, the highest was recorded in Lola (50.00%) and was on par with Anaswara (46.67%), Bhagyalakshmi (43.33%) and Sreya (43.33%). The lowest was in Vyjayanthi (26.67%). Kanakamony (33.33%), Hridya (30.00%) and Kashi Kanchan (30.00%) were on par with each other.

Considering the overall performance of varieties, the highest infection was found in Lola and Anaswara (40.00%). Vyjayanthi was the variety which recorded the lowest infection (20.00%).

**Variability based on growth habit**

Analysis of group means showed an increasing trend of infection from initial to ten months of cold storage. The highest was recorded by bush type and the lowest was in semi trailing.

The seed infection per cent varied from 20.00 per cent (initial) to 37.78 per cent (10MAS) in group I, 19.17 per cent (initial) to 36.67 per cent (10MAS) in group II and 26.67 per cent (initial) to 38.89 per cent (10MAS) in group III.

Comparing the group means, there was no significant difference between groups at initial and ten months of cold storage.

Considering the variety means of seed microflora infection per cent under trailing type (Group I) varied significantly after ten months of cold storage. The highest and the lowest infection per cent was recorded by Lola (50.00%) and Vyjayanthi (26.67%) respectively and varied significantly from others.

Under semi-trailing type, it did not vary significantly between varieties after ten months of storage.

Among bush type, it varied significantly at ten months of storage. Sreya and Bhagyalakshmi recorded the highest (43.33%). The lowest was recorded by Hridya (30.00%) and it varied significantly from others.

The overall monthly mean infection per cent of varieties increased from 21.67 per cent (initial) to 37.67 per cent (10MAS) under cold storage.

Seed microflora identified were *Rhizopus sp.* and *Aspergillus sp.*

There was no insect incidence observed during the period of storage.

**Table 4.12.b Mean seed infection (%) of cowpea varieties influenced by period of cold storage**

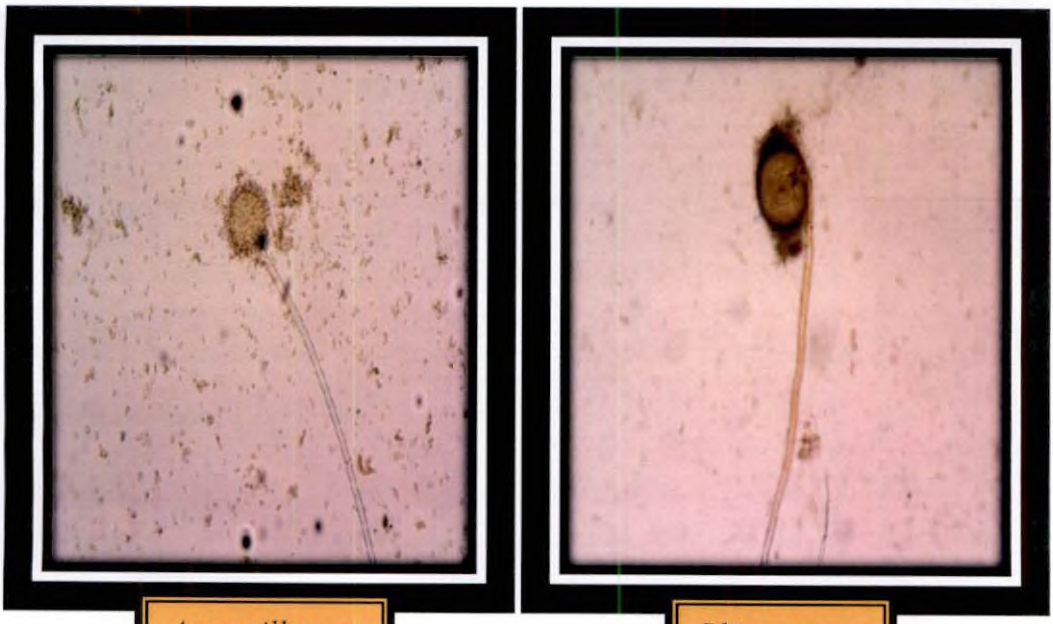
| | Variety | Initial | 10MAS | Overall mean |
|---|---|---|---|---|
| Group I (Trailing) | 1.Lola | 30.00 | 50.00 | 40.00 |
| | 2.Vellayani Jyothika | 16.67 | 36.67 | 26.67 |
| | 3.Vyjayanthi | 13.33 | 26.67 | 20.00 |
| Overall mean (Group I) | | 20.00 | 37.78 | |
| SE (±) | | | 2.72 | |
| **CD** | | **NS** | **9.42** | |
| Group II (Semi trailing) | 4.Anaswara | 33.33 | 46.67 | 40.00 |
| | 5.Kairali | 16.67 | 36.67 | 26.67 |
| | 6.Kanakamony | 13.33 | 33.33 | 23.33 |
| | 7.Kashi Kanchan | 13.33 | 30.00 | 21.67 |
| Overall mean (Group II) | | 19.17 | 36.67 | |
| SE (±) | | 4.40 | | |
| **CD** | | **14.38** | **NS** | |
| Group III (Bush) | 8.Sreya | 20.00 | 43.33 | 31.67 |
| | 9.Hridya | 33.33 | 30.00 | 31.67 |
| | 10.Bhagyalakshmi | 26.67 | 43.33 | 35.00 |
| Overall mean (Group III) | | 26.67 | 38.89 | |
| SE (±) | | 2.72 | 2.72 | |
| **CD** | | **9.42** | **9.42** | |
| **CD (for group means)** | | **NS** | **NS** | |
| Monthly overall mean | | 21.67 | 37.67 | |
| SE (±) | | 3.93 | 3.32 | |
| **CD (for variety means)** | | **11.64** | **9.83** | |

MAS: Months after storage


Before storage

End of storage

**Plate 5. Microflora infections on seed**



*Aspergillus* sp.

*Rhizopus* sp.

**Seed microflora identified**

## 4.13 Correlation analysis of seed quality parameters with germination

### 4.13.a Correlation between seed quality parameters before storage

Results of correlation analysis before storage are furnished in table 4.13.a.

The analysis of seed quality parameters before storage revealed a highly significant positive correlation between germination and speed of germination (0.51). Correlation was significant and positive with vigour index I (0.41) while it was negative with dehydrogenase enzyme activity (-0.37). Similarly, there was a highly significant positive inter-correlation between seedling root length and seedling shoot length (0.54), seedling vigour index II and seedling dry weight (0.99). Both seedling root length (0.76) and seedling shoot length (0.92) were found to be significantly correlated with vigour index I. Electrical conductivity of seed leachate was found to be significantly correlated with seedling root length (0.49) and dehydrogenase enzyme activity (0.39).

### 4.13.b Correlation between seed quality parameters at mid storage period

Results of correlation analysis at mid storage period are furnished in table 4.13.b.

The analysis of seed quality parameters at mid storage period revealed a highly significant positive correlation between germination and speed of germination (0.88) and with vigour index I (0.48). A high significant positive inter-correlation of vigour index I with speed of germination (0.57), seedling shoot length (0.84), seedling root length (0.77), seedling dry weight (0.46) and seedling vigour index II (0.98) was observed.

### 4.13.c Correlation between seed quality parameters at the end of storage period

Results of correlation analysis at the end of storage period are furnished in table 4.13.c.

The analysis of seed quality parameters at the end of storage period also revealed a highly significant positive correlation between germination and speed of germination (0.98) and germination with vigour index I (0.91). Vigour index I had registered a significant positive inter-correlation with speed of germination (0.89), seedling shoot length (0.50) and seedling root length (0.61). The inter-correlation of electrical conductivity of seed leachate with seedling root length (0.74), seedling shoot length (0.65) and vigour index I (0.47) was also found to be significant.

**Table 4.13.a Correlation between seed quality parameters before storage**

| | Germination | Speed of germination | Seedling shoot length | Seedling root length | Seedling dry weight | Vigour index I | Vigour index II | Electrical conductivity of seed leachate | Dehydrogenase enzyme activity |
|---|---|---|---|---|---|---|---|---|---|
| **Germination** | 1 | | | | | | | | |
| **Speed of germination** | 0.51** | 1 | | | | | | | |
| **Seedling shoot length** | 0.26 | 0.31 | 1 | | | | | | |
| **Seedling root length** | 0.02 | 0.23 | 0.54** | 1 | | | | | |
| **Seedling dry weight** | -0.27 | 0.15 | 0.16 | 0.30 | 1 | | | | |
| **Vigour index I** | 0.41* | 0.42 | 0.92** | 0.76** | 0.16 | 1 | | | |
| **Vigour index II** | -0.19 | 0.19 | 0.18 | 0.31 | 0.99** | 0.19 | 1 | | |
| **Electrical conductivity of seed leachate** | -0.01 | 0.29 | 0.13 | 0.49** | 0.23 | 0.29 | 0.22 | 1 | |
| **Dehydrogenase enzyme activity** | -0.37* | 0.15 | -0.02 | 0.25 | 0.28 | 0.01 | 0.25 | 0.39* | 1 |

**Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

**Table 4.13.b Correlation between seed quality parameters at mid storage period**

| | Germination | Speed of germination | Seedling shoot length | Seedling root length | Seedling dry weight | Vigour index I | Vigour index II | Electrical conductivity of seed leachate | Dehydrogenase enzyme activity |
|---|---|---|---|---|---|---|---|---|---|
| **Germination** | 1 | | | | | | | | |
| **Speed of germination** | 0.88** | 1 | | | | | | | |
| **Seedling shoot length** | -0.04 | 0.12 | 1 | | | | | | |
| **Seedling root length** | 0.13 | 0.32 | 0.64** | 1 | | | | | |
| **Seedling dry weight** | 0.05 | 0.30 | 0.53** | 0.35 | 1 | | | | |
| **Vigour index I** | 0.48** | 0.57** | 0.84** | 0.77** | 0.46** | 1 | | | |
| **Vigour index II** | 0.22 | 0.45* | 0.49** | 0.34 | 0.98** | 0.52** | 1 | | |
| **Electrical conductivity of seed leachate** | 0.24 | 0.40* | -0.03 | 0.12 | -0.14 | 0.12 | -0.09 | 1 | |
| **Dehydrogenase enzyme activity** | 0.08 | 0.37* | 0.21 | 0.42* | 0.29 | 0.29 | 0.30 | 0.41* | 1 |

**Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

**Table 4.13.c Correlation between seed quality parameters at the end of storage period**

| | Germination | Speed of germination | Seedling shoot length | Seedling root length | Seedling dry weight | Vigour index I | Vigour index II | Electrical conductivity of seed leachate | Dehydrogenase enzyme activity |
|---|---|---|---|---|---|---|---|---|---|
| **Germination** | 1 | | | | | | | | |
| **Speed of germination** | 0.98** | 1 | | | | | | | |
| **Seedling shoot length** | 0.10 | 0.10 | 1 | | | | | | |
| **Seedling root length** | 0.25 | 0.22 | 0.86** | 1 | | | | | |
| **Seedling dry weight** | -0.30 | -0.37* | 0.33 | 0.16 | 1 | | | | |
| **Vigour index I** | 0.91** | 0.89** | 0.50** | 0.61** | -0.17 | 1 | | | |
| **Vigour index II** | 0.26 | 0.18 | 0.30 | 0.23 | 0.83** | 0.31 | 1 | | |
| **Electrical conductivity of seed leachate** | 0.19 | 0.21 | 0.65** | 0.74** | -0.08 | 0.47** | -0.07 | 1 | |
| **Dehydrogenase enzyme activity** | -0.15 | -0.13 | 0.25 | 0.19 | 0.49** | -0.04 | 0.44* | 0.28 | 1 |

**Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

## 4.14 Path analysis

Path analysis in order to describe the direct and indirect dependencies among the seed quality parameters was done initially before storage, mid storage period (5MAS) and at the end of storage period (10MAS). The results are furnished below:

### 4.14.a Path analysis to deduce the direct and indirect effects of seed quality parameters on seed germination before storage

Results of path analysis of seed germination with seed quality parameters before storage are furnished in table 4.14.a.

Initially before storage, very high positive direct effect (4.211) of vigour index I on germination was noticed. Direct effect of seedling dry weight (0.046) and speed of germination (0.002) on germination was negligible. Very high negative direct effect of seedling root length (-1.717) and seedling shoot length (-2.700) on germination was noticed. The direct effect of electrical conductivity of seed leachate (-0.033), dehydrogenase enzyme activity (-0.032) and seedling vigour index II (-0.021) on germination was a negligible and negative.

### 4.14.b Path analysis to deduce the direct and indirect effects of seed quality parameters at mid storage period

Results of path analysis of seed germination with seed quality parameters at mid storage period are furnished in table 4.14.b.

During the period of mid storage period (5MAS), very high positive direct effect of vigour index I (2.288) and dry weight (0.731) on germination was observed. Direct effect of electrical conductivity of seed leachate (0.028) and speed of germination (0.046) on germination per cent was negligible. There was a very high negative direct effect of seedling shoot length (-1.593) on germination per cent while the negative direct effect of seedling root length (-0.630) and seedling vigour index II (-0.693) on germination was observed. The negative

direct effect of dehydrogenase enzyme activity (-0.018) on germination was negligible.

**4.14.c Path analysis to deduce the direct and indirect effects of seed quality parameters at the end of storage period**

Results of path analysis of seed germination with seed quality parameters at the end of storage period are furnished in table 4.14.c.

At the end of storage period (10MAS) too, a very high positive direct effect of vigour index I (1.129) on germination was observed. Direct effect of electrical conductivity of seed leachate (0.006), speed of germination (0.027) and vigour index II (0.062) on germination per cent was negligible. Direct effect of shoot length on germination per cent (-0.359) was highly significant, compared to effect of seedling root length (-0.149). Direct effect of seedling dry weight (-0.014) and dehydrogenase enzyme activity (-0.007) on germination was not significant.

**Table 4.14.a Path analysis to deduce the direct and indirect effects of seed quality parameters on seed germination before storage**

| | Dry weight | Electrical conductivity of seed leachate | Seedling root length | Seedling shoot length | Speed of germination | Dehydrogenase enzyme activity | Vigour index I | Vigour index II | Germination |
|---|---|---|---|---|---|---|---|---|---|
| **Dry weight** | 0.046 | -0.008 | -0.522 | -0.434 | 0.0002 | -0.009 | 0.681 | -0.021 | -0.266 |
| **Electrical conductivity of seed leachate** | 0.011 | -0.033 | -0.842 | -0.343 | 0.0004 | -0.012 | 1.211 | -0.005 | -0.012 |
| **Seedling root length** | 0.014 | -0.016 | -1.717 | -1.449 | 0.0004 | -0.008 | 3.200 | -0.006 | 0.018 |
| **Seedling shoot length** | 0.007 | -0.004 | -0.921 | -2.700 | 0.0005 | 0.001 | 3.884 | -0.004 | 0.263 |
| **Speed of germination** | 0.007 | -0.010 | -0.400 | -0.834 | 0.0015 | -0.005 | 1.753 | -0.004 | 0.510 |
| **Dehydrogenase enzyme activity** | 0.013 | -0.013 | -0.426 | 0.041 | 0.0002 | -0.032 | 0.049 | -0.005 | -0.373 |
| **Vigour index I** | 0.007 | -0.010 | -1.305 | -2.491 | 0.0006 | -0.0004 | 4.211 | -0.004 | 0.410 |
| **Vigour index II** | 0.046 | -0.007 | -0.526 | -0.484 | 0.0003 | -0.008 | 0.806 | -0.021 | -0.194 |

(Diagonal figures indicate direct effects)

Residual- 0.0092

**Table 4.14.b Path analysis to deduce the direct and indirect effects of seed quality parameters on seed germination at mid storage period**

| | Dry weight | Electrical conductivity of seed leachate | Seedling root length | Seedling shoot length | Speed of germination | Dehydrogenase enzyme activity | Vigour index I | Vigour index II | Germination |
|---|---|---|---|---|---|---|---|---|---|
| **Dry weight** | 0.731 | -0.004 | -0.221 | -0.841 | 0.014 | -0.005 | 1.059 | -0.682 | 0.052 |
| **Electrical conductivity of seed leachate** | -0.099 | 0.028 | -0.075 | 0.045 | 0.018 | -0.007 | 0.265 | 0.065 | 0.240 |
| **Seedling root length** | 0.256 | 0.003 | -0.630 | -1.025 | 0.015 | -0.007 | 1.752 | -0.236 | 0.129 |
| **Seedling shoot length** | 0.386 | -0.001 | -0.405 | -1.593 | 0.005 | -0.004 | 1.915 | -0.341 | -0.037 |
| **Speed of germination** | 0.222 | 0.011 | -0.203 | -0.188 | 0.046 | -0.006 | 1.307 | -0.312 | 0.877 |
| **Dehydrogenase enzyme activity** | 0.211 | 0.011 | -0.266 | -0.334 | 0.017 | -0.018 | 0.666 | -0.207 | 0.081 |
| **Vigour index I** | 0.338 | 0.003 | -0.482 | -1.334 | 0.026 | -0.005 | 2.288 | -0.358 | 0.476 |
| **Vigour index II** | 0.719 | -0.003 | -0.214 | -0.783 | 0.021 | -0.005 | 1.182 | -0.693 | 0.224 |

(Diagonal figures indicate direct effects)

Residual- 0.0052

**Table 4.14.c Path analysis to deduce the direct and indirect effects of seed quality parameters on germination at the end of storage period**

| | Dry weight | Electrical conductivity of seed leachate | Seedling root length | Seedling shoot length | Speed of germination | Dehydrogenase enzyme activity | Vigour index I | Vigour index II | Germination |
|---|---|---|---|---|---|---|---|---|---|
| **Dry weight** | -0.014 | -0.001 | -0.023 | -0.117 | -0.010 | -0.004 | -0.186 | 0.052 | -0.302 |
| **Electrical conductivity of seed leachate** | 0.001 | 0.006 | -0.111 | -0.232 | 0.006 | -0.002 | 0.525 | -0.004 | 0.189 |
| **Seedling root length** | -0.002 | 0.005 | -0.149 | -0.309 | 0.006 | -0.001 | 0.687 | 0.014 | 0.250 |
| **Seedling shoot length** | -0.005 | 0.004 | -0.129 | -0.359 | 0.003 | -0.002 | 0.569 | 0.019 | 0.101 |
| **Speed of germination** | 0.005 | 0.001 | -0.033 | -0.034 | 0.027 | 0.001 | 0.999 | 0.011 | 0.978 |
| **Dehydrogenase enzyme activity** | -0.007 | 0.002 | -0.028 | -0.088 | -0.004 | -0.007 | -0.044 | 0.027 | -0.149 |
| **Vigour index I** | 0.002 | 0.003 | -0.091 | -0.181 | 0.024 | 0.0003 | 1.129 | 0.019 | 0.906 |
| **Vigour index II** | -0.012 | -0.0004 | -0.034 | -0.109 | 0.005 | -0.003 | 0.350 | 0.062 | 0.259 |

(Diagonal figures indicate direct effects)

Residual- 0.0012

## 4.15 Stability analysis on germination per cent of cowpea varieties

The results of stability analysis on germination per cent of cowpea varieties are furnished in table 4.15.

Varieties Anaswara and Kanakamony which had high mean germination, regression coefficient of one and 0.93 ($b \approx 1$) and low deviation from regression can be considered as stable varieties and suited for storage under average environmental (ambient) conditions.

The stability analysis on germination of ten varieties of cowpea indicated that the varieties Vyjayanthi and Kashi Kanchan were suitable to adverse storage conditions on the basis of their high mean germination per cent (78.50 and 83.83 respectively) and regression coefficient of 0.82 and 0.77 respectively which are significantly different from one ($b<1$) indicating their suitability for storage in unfavourable conditions.

Vellayani Jyothika, with a mean germination of 73.58 per cent, regression coefficient of 1.5 which was significantly different from one ($b>1$) and high deviation from regression can be considered as varieties with better storability under favourable or congenial conditions.

**Table 4.15 Stability analysis on germination per cent of cowpea varieties**

| Variety | Mean germination (%) | Regression coefficient (b) | Deviation from regression ($\Delta^2$) |
|---|---|---|---|
| 1. Lola | 77.33 | 0.97 | 3.21 |
| 2.Vellayani Jyothika | 73.58 | 1.50 | 34.25 |
| 3. Vyjayanthi | 78.50 | 0.82 | 1.19 |
| 4. Anaswara | 80.08 | 1.00 | 1.36 |
| 5. Kairali | 75.33 | 0.89 | 6.99 |
| 6. Kanakamony | 82.50 | 0.93 | -0.46 |
| 7. Kashi Kanchan | 83.83 | 0.77 | 5.79 |
| 8. Sreya | 74.17 | 0.96 | 10.25 |
| 9. Hridya | 75.25 | 1.12 | 2.76 |
| 10. Bhagyalakshmi | 76.50 | 1.04 | 2.78 |

Population mean = 77.708 SE (Mean) = 0.11079350E+01
Mean of b = 1.0000 SE of b = 0.65677610E-01

## 4.16 Mahalanobis $D^2$ analysis

Mahalanobis $D^2$ analysis was performed involving important seed quality parameters such as germination, speed of germination, seedling vigour index I and seedling vigour index II recorded before storage, mid storage (5MAS) and at the end of storage (10MAS).

### 4.16.a Mahalanobis $D^2$ analysis before storage

Results of Mahalanobis $D^2$ analysis initially before storage are enumerated in table 4.16.a. It resulted in a cluster diagram as shown in fig. 1.

The diagram indicates that, the cluster IV with only one variety Hridya stood alone. It differed significantly from all other varieties. Kanakamony, Kashi Kanchan and Bhagyalakshmi grouped under cluster I with an intra distance of 5.25. Cluster III included the varieties Vyjayanthi, Anaswara and Kairali with an intra cluster distance of 12.13. The highest intra-cluster distance (24.41) was found in cluster II consisting of varieties Lola, Vellayani Jyothika and Sreya.

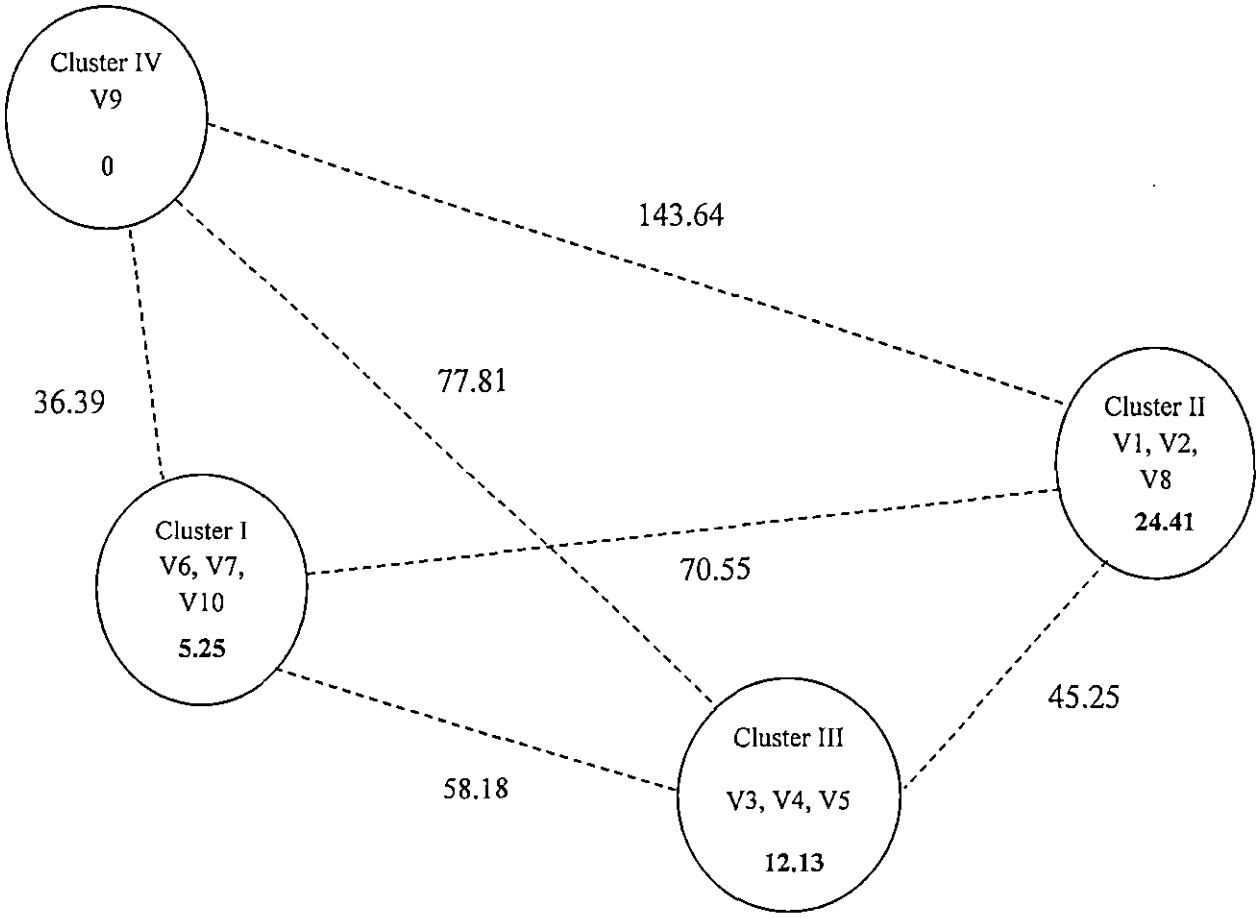
Considering the inter cluster distance, the maximum distance (143.64) was found between cluster II (Lola, Vellayani Jyothika and Sreya) and cluster IV (Hridya) and the minimum (36.39) was found between cluster I (Kanakamony, Kashi Kanchan and Bhagyalakshmi) and cluster IV (Hridya).

**Table 4.16.a Intra and inter cluster distances at initial stage of storage**

| | Cluster I | Cluster II | Cluster III | Cluster IV |
|---|---|---|---|---|
| **Cluster I** (Kanakamony, Kashi Kanchan, Bhagyalakshmi) | 5.25 | | | |
| **Cluster II** (Lola, Vellayani Jyothika, Sreya) | 70.55 | 24.41 | | |
| **Cluster III** (Vyjayanthi, Anaswara, Kairali) | 58.18 | 45.25 | 12.13 | |
| **Cluster IV** (Hridya) | 36.39 | 143.64 | 77.81 | 0.00 |

(Figures along main diagonal are intra cluster distances.)

**Fig. 1 Cluster diagram of cowpea varieties for seed quality parameters before storage**



**4.16.b Mahalanobis $D^2$ analysis at mid storage period (5MAS)**

Results of Mahalanobis $D^2$ analysis at mid storage period (5MAS) is enumerated in table 4.16.b. It resulted in a cluster diagram as shown in fig. 2.

The diagram indicates that, the cluster III which included the varieties Vellayani Jyothika and Anaswara, showed the highest intra distance (126.57) between the varieties followed by cluster IV with varieties Kanakamony and Kashi Kanchan (81.73). With an intra distance of 67.33 included the varieties Lola, Vyjayanthi, Kairali and Sreya came in cluster I. The lowest intra distance (37.19) was found in cluster II with the varieties Hridya and Bhagyalakshmi.

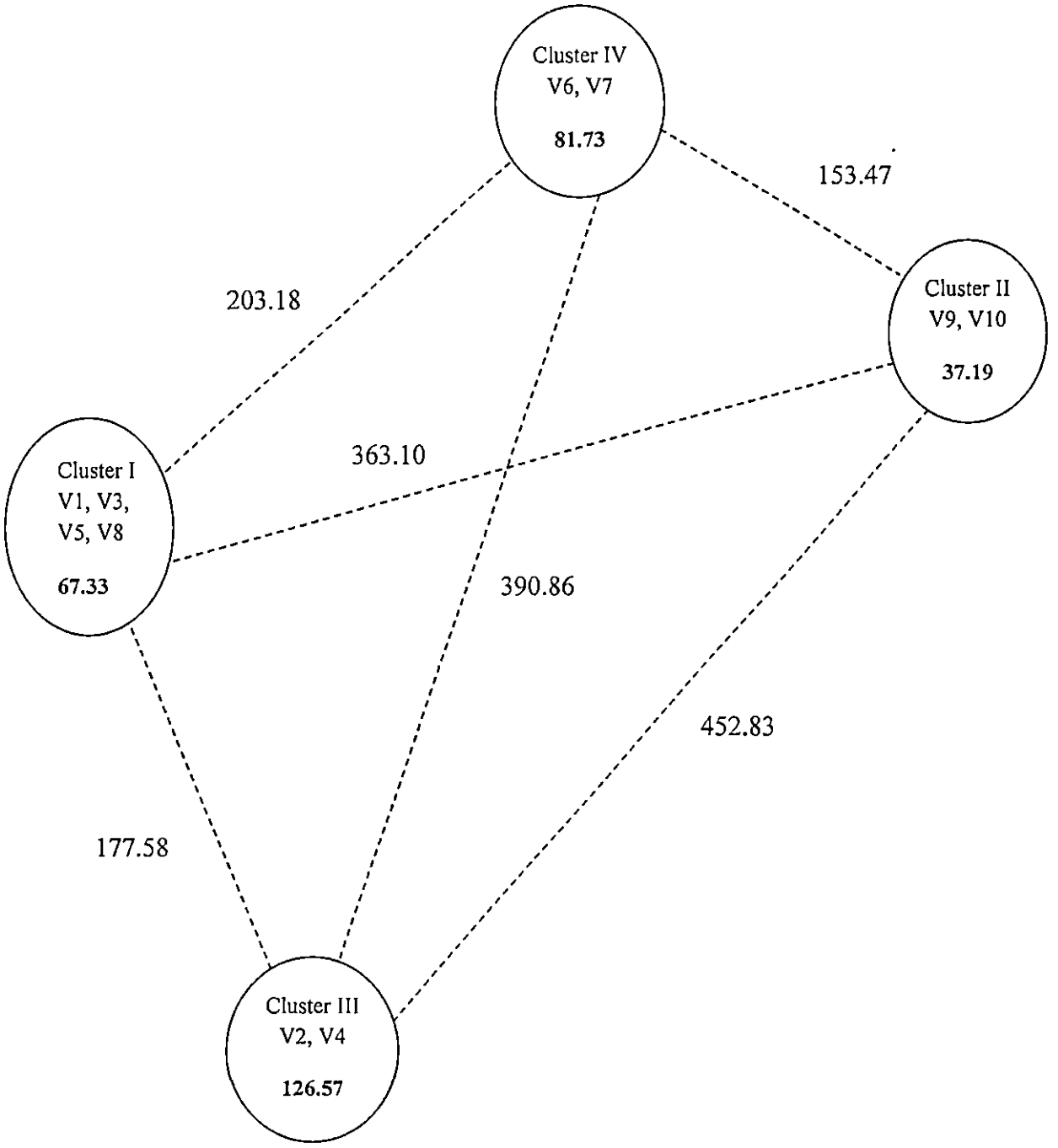
Considering the inter cluster distance, the maximum distance (452.83) was found between cluster II (Hridya and Bhagyalakshmi) and cluster III (Vellayani Jyothika and Anaswara) while the minimum was found between cluster II (Hridya and Bhagyalakshmi) and cluster IV (Kanakamony and Kashi Kanchan).

**Table 4.16.b Intra and inter cluster distances at mid storage period**

| | Cluster I | Cluster II | Cluster III | Cluster IV |
|---|---|---|---|---|
| **Cluster I** (Lola, Vyjayanthi, Kairali, Sreya) | 67.33 | | | |
| **Cluster II** (Hridya, Bhagyalakshmi) | 363.10 | 37.19 | | |
| **Cluster III** (Vellayani Jyothika, Anaswara) | 177.58 | 452.83 | 126.57 | |
| **Cluster IV** (Kanakamony, Kashi Kanchan) | 203.18 | 153.47 | 390.86 | 81.73 |

(Figures along main diagonal are intra cluster distances.)

**Fig. 2 Cluster diagram of cowpea varieties for seed quality parameters at mid storage period (5MAS)**



### 4.16.c Mahalanobis $D^2$ analysis at the end of storage (10MAS)

Results of Mahalanobis $D^2$ analysis at the end of storage period (10MAS) is enumerated in table 4.16.c. It resulted in a cluster diagram as shown in fig. 3.

The diagram indicated that, the cluster IV which included the varieties Hridya and Bhagyalakshmi showed the highest intra cluster distance (103.89) followed by cluster I with varieties Lola, Vellayani Jyothika, Vyjayanthi and Anaswara (66.58). The lowest intra distance (7.32) was found in cluster II with the varieties Kanakamony and Kashi Kanchan.

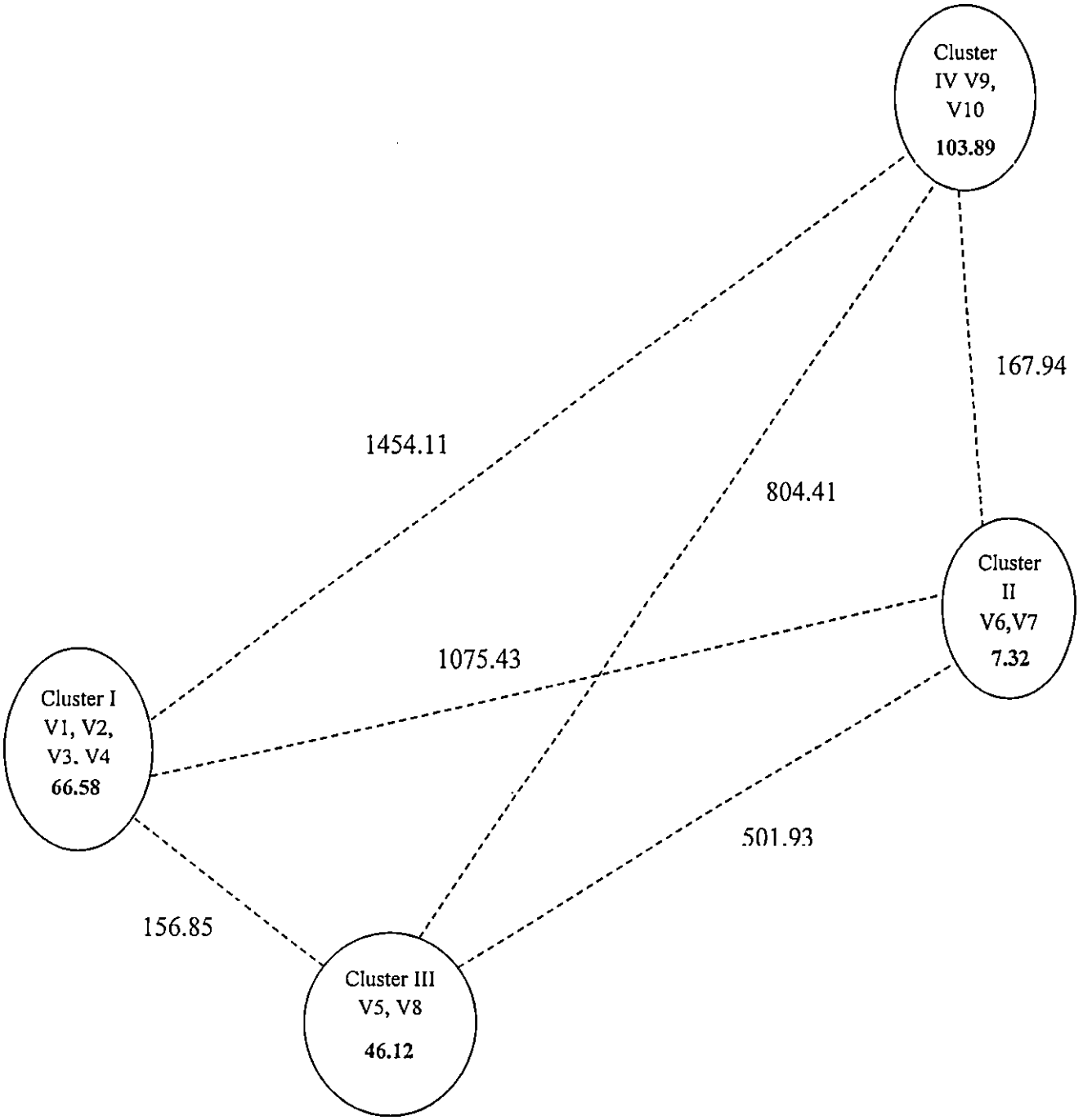
Considering the inter cluster distance, the maximum distance (1454.11) was found between cluster I (Lola, Vellayani Jyothika, Vyjayanthi and Anaswara) and cluster IV (Hridya and Bhagyalakshmi) while the minimum distance (156.85) was between cluster I (Lola, Vellayani Jyothika, Vyjayanthi and Anaswara) and cluster III (Kairali and Sreya).

**Table 4.16.c Intra and inter cluster distances at the end of storage**

| | Cluster I | Cluster II | Cluster III | Cluster IV |
|---|---|---|---|---|
| **Cluster I** (Lola, Vellayani Jyothika, Vyjayanthi, Anaswara) | 66.58 | | | |
| **Cluster II** (Kanakamony, Kashi Kanchan) | 1075.43 | 7.32 | | |
| **Cluster III** (Kairali, Sreya) | 156.85 | 501.93 | 46.12 | |
| **Cluster IV** (Hridya, Bhagyalakshmi) | 1454.11 | 167.94 | 804.41 | 103.89 |

(Figures along main diagonal are intra cluster distances.)

**Fig. 3 Cluster diagram of cowpea varieties for seed quality parameters at the end of storage period (10MAS)**




The results of the studies are discussed in the following chapter in line with the findings of the earlier reports and scientific reasoning.

# Discussion

# 5. DISCUSSION

Seed longevity is affected by numerous factors starting from seed maturation through seed storage and it is difficult to control most of these factors. The longevity of seeds in storage is influenced by four major factors; genetic makeup, initial quality of the seed, moisture content of seed or ambient relative humidity and temperature of storage environment (Gupta *et al.*, 1976). It is well known that, low temperature, atmospheric humidity and optimum moisture content help to maintain the longevity of orthodox seeds.

The varieties vary greatly in their potential for their response to germination and vigour of the seed under ambient storage conditions. There may be inherent differences in varieties with respect to reactions during storage. Germination, vigour and physico-chemical changes may vary between varieties during storage. The overall characters and performance of variety refer to the genetics of seed. It may consist of attributes such as plant type, duration of growth cycle, seed colour and shape. Genetics can determine whether the seed can adapt to local conditions, and often this influence farmer and market demand. Quality of seeds of some varieties may be affected differently by storage conditions than others. The information regarding such inter-relationships would be helpful in assessing the varieties with regard to their seed quality and pattern of seed deterioration.

The results of the studies on "Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties" conducted during February 2014 to May 2015 are discussed in this chapter in line with the findings of the earlier reports and scientific reasoning.

Freshly harvested seeds of ten cowpea varieties were stored in 700 gauge polythene bags for ten months under ambient storage conditions at Vellanikkara, Kerala Agricultural University (KAU), Thrissur. During storage, observations on germination (%), days to first germination, days to fifty per cent germination, speed of germination, seedling shoot length (cm), seedling root length (cm),

seedling dry weight (g), seedling vigour index I, seedling vigour index II, electrical conductivity of seed leachate ($dSm^{-1}$) and dehydrogenase enzyme activity were recorded at monthly intervals. Seed microflora infection per cent were recorded during initial and final stages of the study. Seeds were also stored in cold storage and the same observations were taken at mid and end of storage period. The results of the studies are discussed below.

**5.1 Germination**

The germination per cent is one of the most important seed quality parameters that affect the performance of the seed. In the present study, the germination per cent declined gradually with increasing period of storage from initial stage of storage to ten months after storage. The rate of decrease in germination per cent differed between varieties. All the varieties except Sreya maintained germination per cent above minimum seed certification standards (75%) upto five months of storage. The varieties Kashi Kanchan (82.50%) and Kanakamony (75.83%) maintained germination per cent above minimum seed certification standards (75%) upto six months of storage. Among these two varieties, Kashi Kanchan recorded the highest (82.50%) germination per cent after six months of storage. Thereafter the rate of germination per cent was seen below minimum seed certification standards (75%) in all the varieties. The lowest germination (30.83%) was found in Vellayani Jyothika after ten months of storage (fig. 4). Considering the group performance, the semi trailing varieties recorded the highest germination after ten months of storage. The lowest was in trailing type (fig. 5).

Varietal differences in seed quality during storage have been reported in soybean (Verma and Gupta, 1975; Gupta *et al.* 1976; Arulnandhy, 1983; Vanangamudi, 1988; Kharb *et al.* 1998; Kadam *et al.,* 2011) and in chickpea (Patil, 2000). A number of reports are also available in other crops like cereals, oil crops and vegetables which also support the findings of this study.

The difference in seed germination among the ten cowpea varieties recorded in this study may be due to the inherent genotypic differences, as reported by Delouche (1973); Chauhan *et al.* (1984) and Singh and Gill (1994). Similar results were also reported by Vanangamudi (1988) in soybean, Ramaiah (1994) in sunflower, Kharb *et al.* (1998) in soybean, Kurdikeri *et al.* (2003) in groundnut and Kavitha (2007) in chilli.

Bold seeded varieties like Vellayani Jyothika, Anaswara, Lola and Vyjayanthi exhibited a lower germination compared to other small seeded varieties. Khare and Satpute (1999) reported that germination, seedling and plant vigour were significantly influenced by seed size in pigeonpea.

A comparison between the germination per cent of varieties under ambient and cold storage conditions are furnished in table 5.1. It is found that all the varieties maintained a germination of minimum seed certification standards (75%) even after five months of storage except Sreya (73.33%). Seeds of all the varieties showed a higher germination in cold storage condition than ambient condition after ten months of storage. The highest variation in germination was observed in the variety Sreya after ten months of storage (fig. 6).

The overall germination per cent of seeds of varieties based on growth habit indicated a lower germination per cent for bush types (Sreya, Hridya and Bhagyalakshmi), while the semi trailing and trailing types had a higher germination. Similar reports on lower germination per cent of erect varieties and higher germination per cent of semi-spreading varieties have been reported in groundnut by Swain *et al.* (2001). However, the actual physiological reasons for this require further investigations. The higher biomass enabling a higher photosynthetic efficiency leading to elevated levels of food reserves in seeds of semi-trailing and trailing types might have resulted in a higher germination.

**Table 5.1 Seed quality parameters during storage**

| Varieties (A: Storage in ambient conditions C: Storage in cold conditions) | Germination (%) | | | Speed of germination | | | Vigour index I | | | Vigour index II | | | Electrical conductivity of seed leachate | | | Dehydrogenase enzyme activity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Months after storage | | | Months after storage | | | Months after storage | | | Months after storage | | | Months after storage | | | Months after storage | | |
| | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 | 0 | 5 | 10 |
| 1.Lola – A | 95.83 | 78.33 | 50.83 | 27.92 | 22.10 | 14.53 | 3894 | 2460 | 1361 | 9.28 | 6.02 | 3.43 | 0.26 | 0.28 | 0.38 | 0.65 | 0.29 | 0.24 |
| Lola – C | 95.83 | 80.83 | 60.83 | 27.92 | 22.98 | 18.40 | 3894 | 2589 | 1706 | 9.28 | 6.46 | 4.17 | 0.26 | 0.21 | 0.35 | 0.65 | 0.26 | 0.23 |
| 2.Vellayani Jyothika –A | 95.83 | 86.67 | 30.83 | 30.13 | 27.14 | 9.45 | 3723 | 2666 | 839 | 10.98 | 8.12 | 2.54 | 0.35 | 0.42 | 0.45 | 0.71 | 0.49 | 0.32 |
| Vellayani Jyothika -C | 95.83 | 85.83 | 40.83 | 30.13 | 27.32 | 11.74 | 3723 | 2685 | 1117 | 10.98 | 8.22 | 3.41 | 0.35 | 0.39 | 0.48 | 0.71 | 0.53 | 0.33 |
| 3.Vyjayanthi – A | 92.50 | 80.83 | 51.67 | 29.21 | 25.17 | 15.56 | 3076 | 2636 | 1424 | 8.38 | 5.89 | 3.67 | 0.32 | 0.40 | 0.46 | 1.31 | 0.95 | 0.57 |
| Vyjayanthi - C | 92.50 | 82.50 | 55.83 | 29.12 | 26.07 | 16.96 | 3076 | 2781 | 1521 | 8.38 | 6.00 | 4.32 | 0.32 | 0.36 | 0.44 | 1.31 | 0.98 | 0.57 |
| 4.Anaswara – A | 99.17 | 84.17 | 53.33 | 29.91 | 25.10 | 16.08 | 3038 | 2152 | 1262 | 6.96 | 6.12 | 3.64 | 0.21 | 0.22 | 0.24 | 0.62 | 0.29 | 0.22 |
| Anaswara - C | 99.17 | 85.33 | 58.33 | 29.91 | 26.18 | 17.27 | 3038 | 2190 | 1387 | 6.96 | 6.46 | 3.98 | 0.21 | 0.22 | 0.21 | 0.62 | 0.33 | 0.24 |
| 5.Kairali – A | 95.00 | 79.17 | 45.00 | 30.59 | 23.85 | 13.32 | 3243 | 2737 | 1343 | 6.22 | 5.33 | 2.82 | 0.31 | 0.40 | 0.55 | 0.89 | 0.42 | 0.31 |
| Kairali –C | 95.00 | 80.00 | 53.33 | 30.59 | 23.89 | 16.62 | 3243 | 2927 | 1601 | 6.22 | 5.50 | 3.32 | 0.31 | 0.33 | 0.52 | 0.89 | 0.44 | 0.35 |
| 6.Kanakamony – A | 100.00 | 86.67 | 57.50 | 31.38 | 25.32 | 17.77 | 4160 | 2865 | 1704 | 4.77 | 3.78 | 2.28 | 0.28 | 0.28 | 0.48 | 0.67 | 0.25 | 0.18 |
| Kanakamony – C | 100.00 | 90.83 | 57.50 | 31.38 | 26.60 | 17.53 | 4160 | 3109 | 1562 | 4.77 | 4.23 | 2.35 | 0.28 | 0.28 | 0.46 | 0.67 | 0.23 | 0.21 |
| 7.Kashi Kanchan – A | 97.50 | 85.83 | 61.67 | 29.79 | 26.35 | 18.32 | 3902 | 2422 | 1751 | 4.24 | 3.97 | 2.57 | 0.29 | 0.60 | 0.64 | 1.07 | 0.44 | 0.24 |
| Kashi Kanchan – C | 97.50 | 88.33 | 63.33 | 29.79 | 27.31 | 19.35 | 3902 | 2517 | 1779 | 4.24 | 4.32 | 2.74 | 0.29 | 0.57 | 0.61 | 1.07 | 0.55 | 0.26 |
| 8.Sreya– A | 95.83 | 73.33 | 49.17 | 26.75 | 19.75 | 13.85 | 3421 | 2221 | 1317 | 6.80 | 4.71 | 2.68 | 0.27 | 0.32 | 0.33 | 0.87 | 0.28 | 0.16 |
| Sreya–C | 95.83 | 76.67 | 64.17 | 26.75 | 21.27 | 18.57 | 3421 | 2360 | 1755 | 6.80 | 5.38 | 3.54 | 0.27 | 0.27 | 0.34 | 0.87 | 0.30 | 0.18 |
| 9.Hridya– A | 95.83 | 77.50 | 45.00 | 26.84 | 21.16 | 13.82 | 2878 | 1841 | 1054 | 1.36 | 1.57 | 0.75 | 0.24 | 0.34 | 0.35 | 0.40 | 0.32 | 0.17 |
| Hridya– C | 95.83 | 79.17 | 50.00 | 26.84 | 21.53 | 14.72 | 2878 | 1891 | 1195 | 1.36 | 1.72 | 0.88 | 0.24 | 0.34 | 0.33 | 0.40 | 0.30 | 0.19 |
| 10.Bhagyalakshmi – A | 97.50 | 84.17 | 46.67 | 28.86 | 23.93 | 14.34 | 3575 | 2163 | 1143 | 3.34 | 3.27 | 1.46 | 0.34 | 0.42 | 0.43 | 0.78 | 0.39 | 0.28 |
| Bhagyalakshmi – C | 97.50 | 82.50 | 52.50 | 28.86 | 23.54 | 15.88 | 3575 | 2162 | 1308 | 3.34 | 3.23 | 1.75 | 0.34 | 0.41 | 0.45 | 0.78 | 0.40 | 0.30 |
| Monthly overall meanA | 96.50 | 81.67 | 49.17 | 29.14 | 23.99 | 14.70 | 3491 | 2416 | 1320 | 6.23 | 4.88 | 2.58 | 0.29 | 0.37 | 0.43 | 0.80 | 0.41 | 0.27 |
| Monthly overall meanC | 96.50 | 83.25 | 55.67 | 29.14 | 24.67 | 16.70 | 3491 | 2521 | 1493 | 6.23 | 5.15 | 3.05 | 0.29 | 0.34 | 0.42 | 0.80 | 0.43 | 0.29 |
| Group I – A | 94.72 | 81.94 | 44.44 | 29.09 | 24.80 | 13.18 | 3564 | 2587 | 1208 | 9.55 | 6.68 | 3.21 | 0.31 | 0.37 | 0.43 | 0.89 | 0.58 | 0.38 |
| Group I –C | 94.72 | 83.05 | 52.50 | 29.09 | 25.46 | 15.70 | 3564 | 2685 | 1448 | 9.55 | 6.89 | 3.97 | 0.31 | 0.32 | 0.42 | 0.89 | 0.59 | 0.37 |
| Group II – A | 97.92 | 83.96 | 54.38 | 30.42 | 25.16 | 16.37 | 3586 | 2544 | 1515 | 5.55 | 4.80 | 2.83 | 0.27 | 0.38 | 0.48 | 0.81 | 0.35 | 0.24 |
| Group II – C | 97.92 | 86.12 | 58.12 | 30.42 | 26.00 | 17.69 | 3586 | 2686 | 1582 | 5.55 | 5.13 | 3.10 | 0.27 | 0.35 | 0.45 | 0.81 | 0.39 | 0.27 |
| Group III – A | 96.39 | 78.33 | 46.95 | 27.48 | 21.61 | 14.00 | 3291 | 2075 | 1171 | 3.83 | 3.18 | 1.63 | 0.28 | 0.36 | 0.37 | 0.69 | 0.33 | 0.20 |
| Group III – C | 96.39 | 79.45 | 55.56 | 27.48 | 22.11 | 16.39 | 3291 | 2138 | 1420 | 3.83 | 3.44 | 2.06 | 0.28 | 0.34 | 0.38 | 0.69 | 0.33 | 0.22 |

**Fig. 4 Mean germination (%) of cowpea varieties influenced by duration of storage**

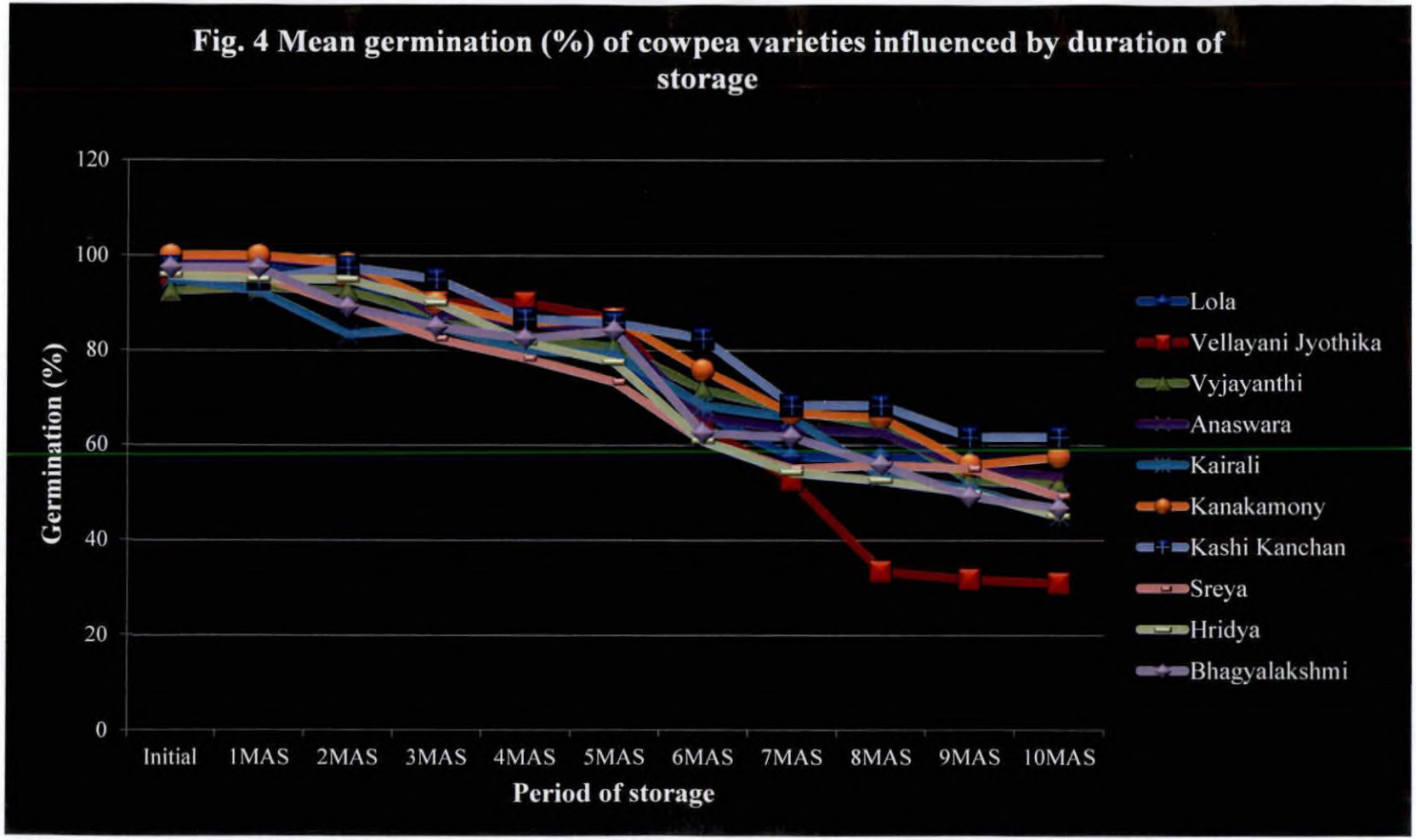


**Fig. 5 Mean germination (%) of cowpea variety groups influenced by duration of storage**

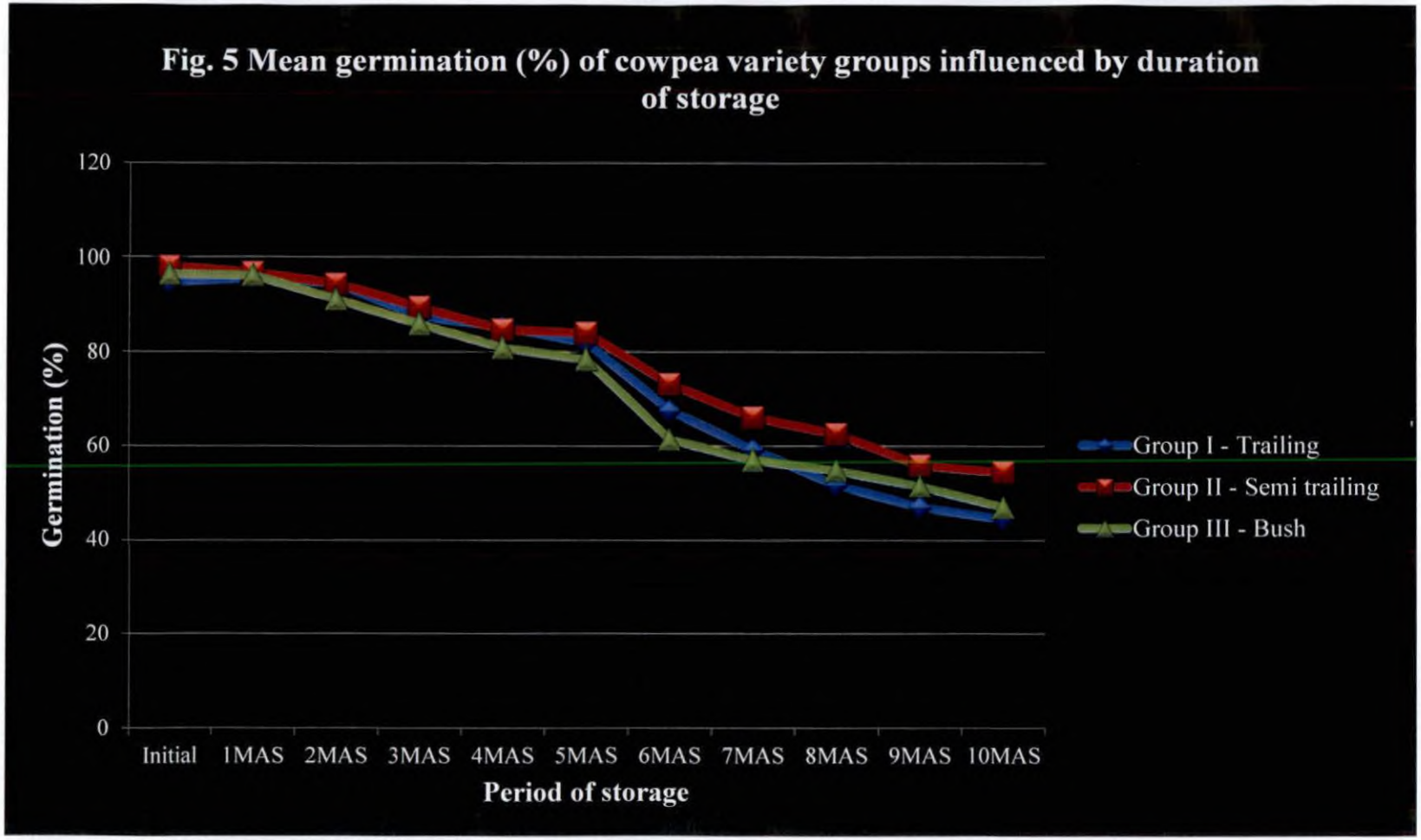
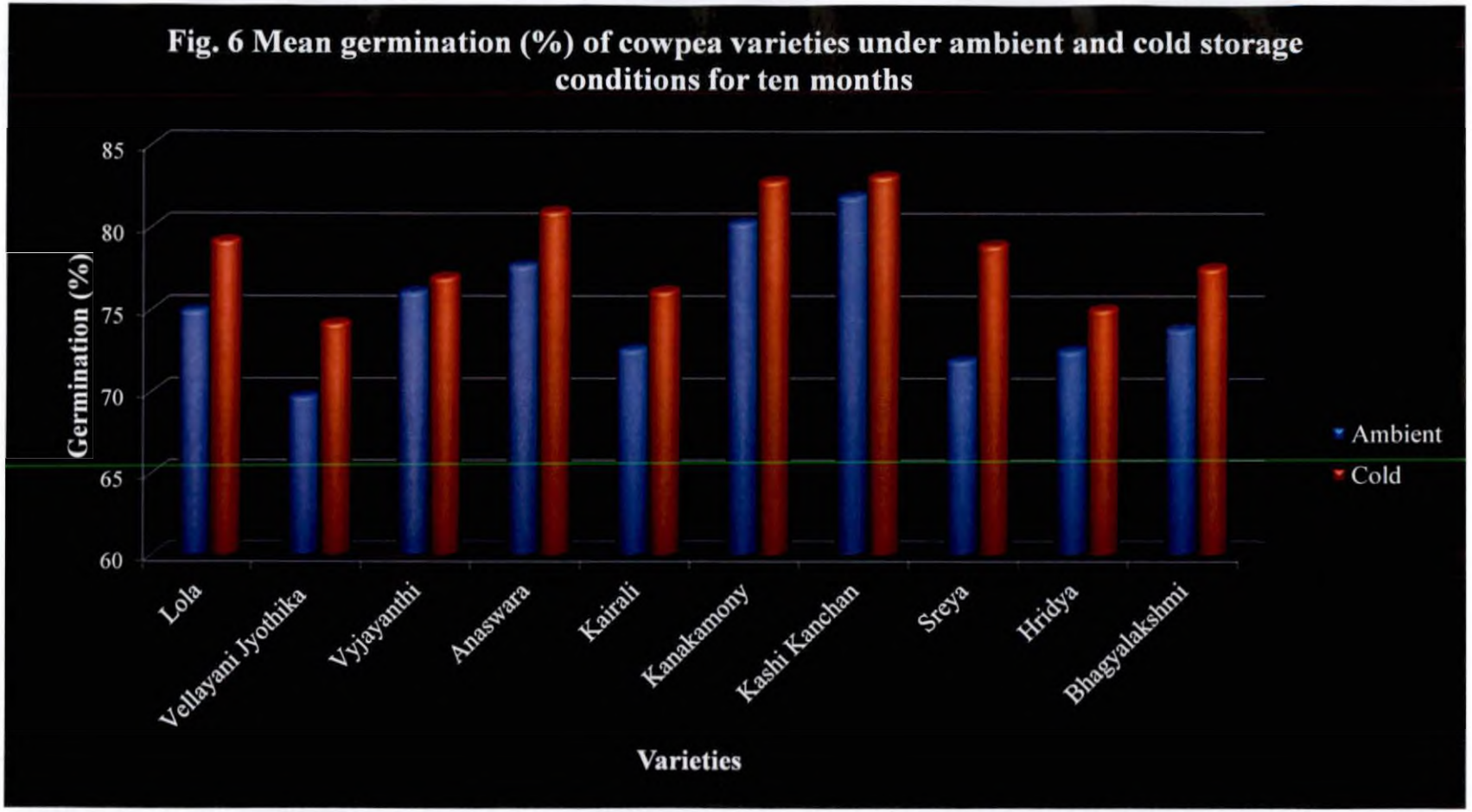


**Fig. 6 Mean germination (%) of cowpea varieties under ambient and cold storage conditions for ten months**



**5.2 Speed of germination**

The speed of germination was decreasing during the period of storage. The rate of decrease varied among varieties. The highest speed of germination was shown by the variety Kashi Kanchan followed by Kanakamony after ten months of storage. The lowest speed of germination was observed in Vellayani Jyothika (fig. 7). Considering the group performance, the semi trailing varieties showed the highest speed of germination after ten months of storage. The lowest was in trailing type (fig. 8). Kumbar (1999) and Divya-Shree (2006) also reported similar results in chickpea and sunflower respectively.

On comparing speed of germination under ambient and cold conditions (table 5.1), almost all the varieties showed a higher speed of germination in cold storage when compared to ambient storage. It is observed that though germination per cent and vigour were higher for the varieties Kashi Kanchan and Kanakamony, their dehydrogenase enzyme activity were comparatively low. Cowpea seeds have a small embryo and large cotyledon. So, it is possible that the degradation of cells mainly occur in cotyledons and less affected in embryo cells. However, this requires further investigations.

**5.3 Seedling length**

The seedling shoot length and root length was higher in case of semi trailing varieties Kairali, Kanakamony and Kashi Kanchan and decreased gradually from initial to ten months after storage. The lowest seedling shoot length and root length was observed in Hridya and Anaswara respectively. The variation in seedling shoot length and seedling root length was similar as observed in the study of Kumbar (1999), Yadav and Sharma (1999) and Patil (2000) in chickpea, Grabe and Metzer (1969) in soybean. Studies conducted by Ching and Schoolcraft (1968) and Villiers (1972) proved that reduction in seedling length due to ageing was a result of disintegration of cellular membranes.

**5.4 Seedling vigour index**

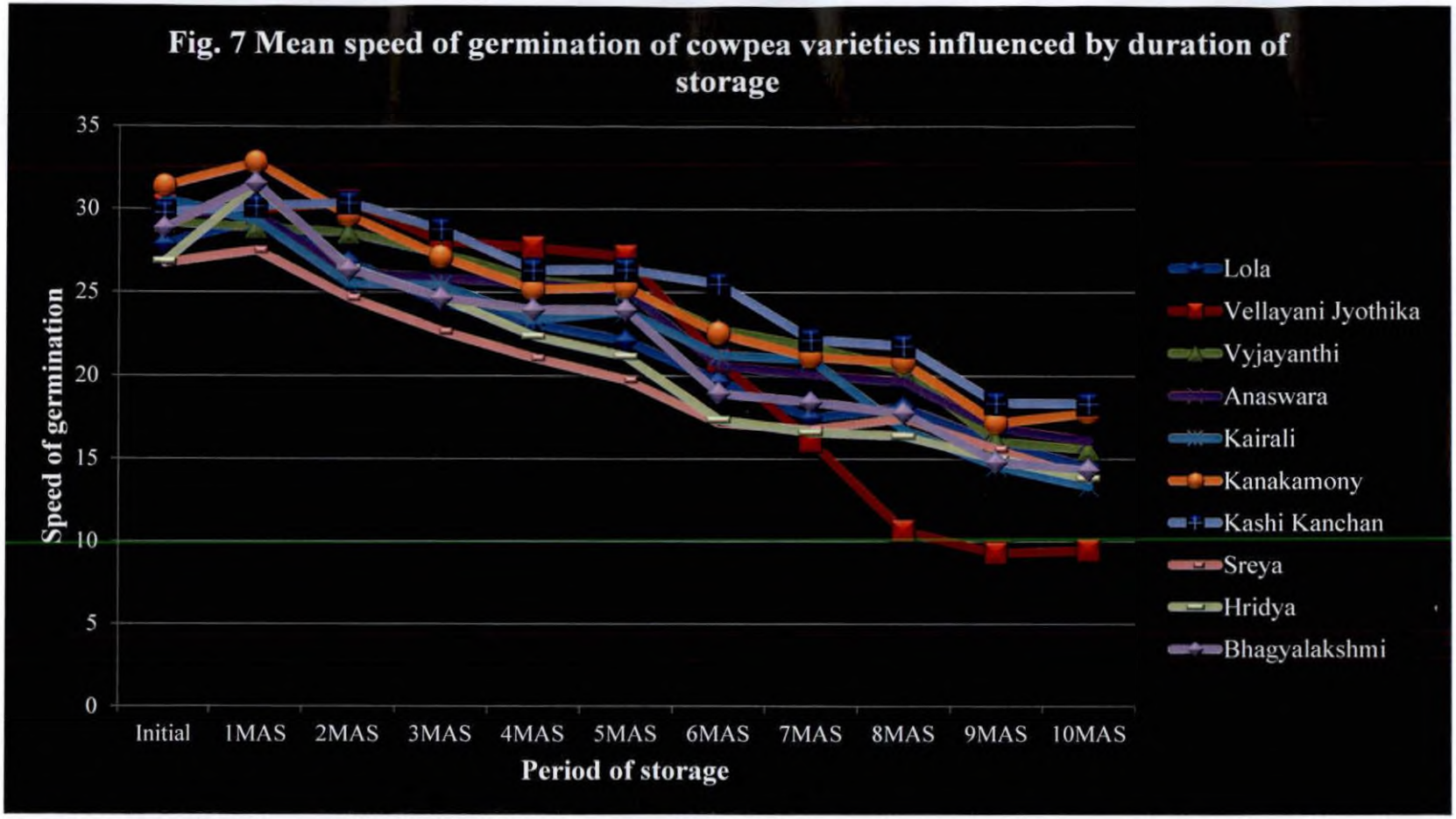
Seedling vigour index is one of the most important parameters that determine the seed quality during storage. Seedling vigour index I decreased gradually from initial to ten months after storage. The rate of decrease varied between individual varieties (fig. 9) and among three groups (fig. 10). The highest vigour was exhibited by Kashi Kanchan (1751) followed by Kanakamony (1704). Vellayani Jyothika recorded the lowest vigour index I (839) after ten months of storage. The trend of variation of seedling vigour index II was similar as in the case of vigour index I but the maximum was observed in Vyjayanthi (3.67) and the lowest in Hridya (0.75).

Comparing the seedling vigour index I of varieties in ambient storage condition and cold storage condition, after ten months of storage, all the varieties except Kanakamony showed higher vigour index I in cold condition than ambient condition (table 5.1).

Similarly, comparing the vigour index II of varieties in ambient storage condition and cold storage condition, after ten months of storage, all the varieties showed higher vigour index II in cold condition than ambient condition (table 5.1).

Ramamoorthy *et al.* (1989) in maize, Gowda (1981) in sunflower, Singh and Khatra (1984) in groundnut also observed the reduction in seedling vigour due to ageing and also could observe the variation between different varieties.

**Fig. 7 Mean speed of germination of cowpea varieties influenced by duration of storage**



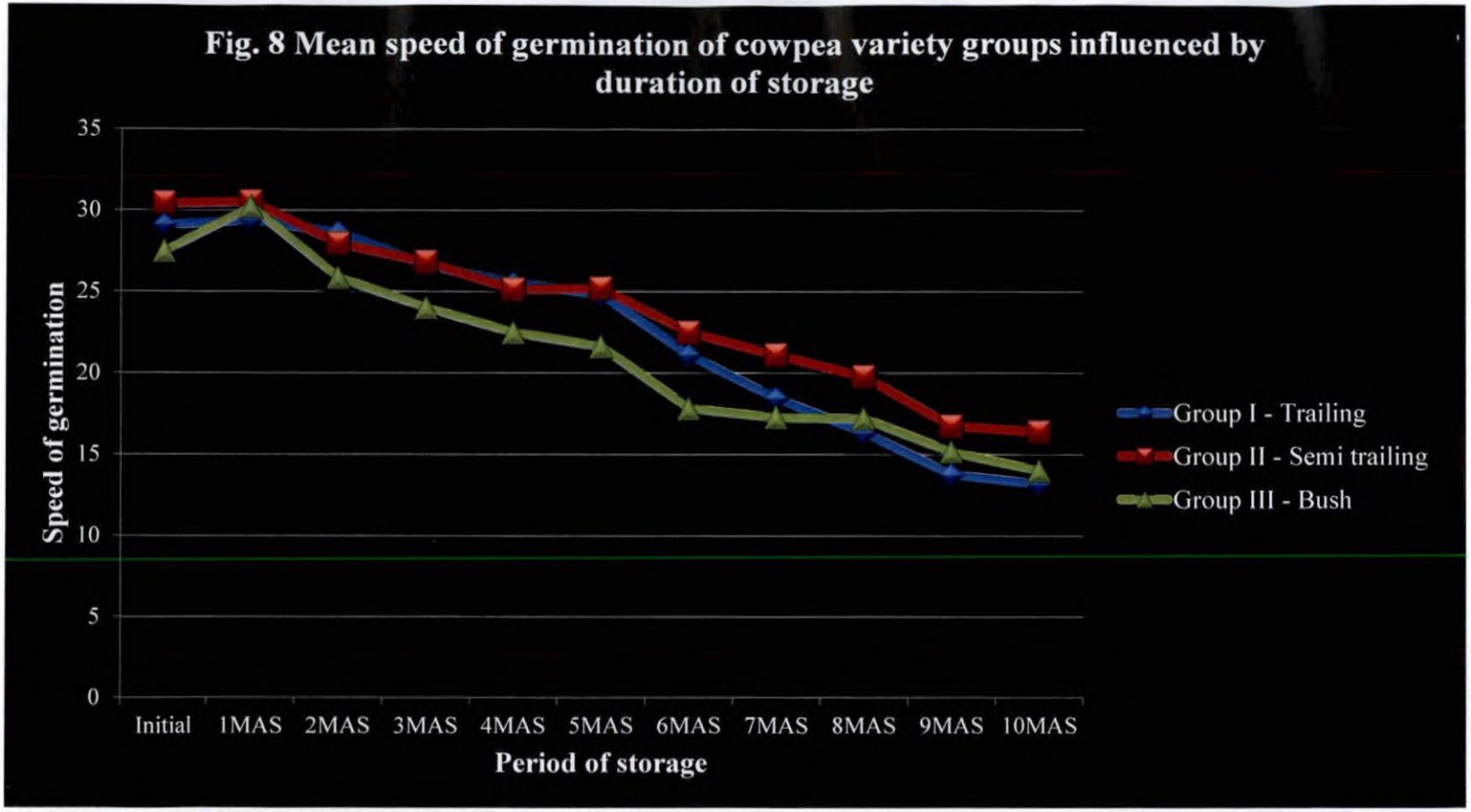
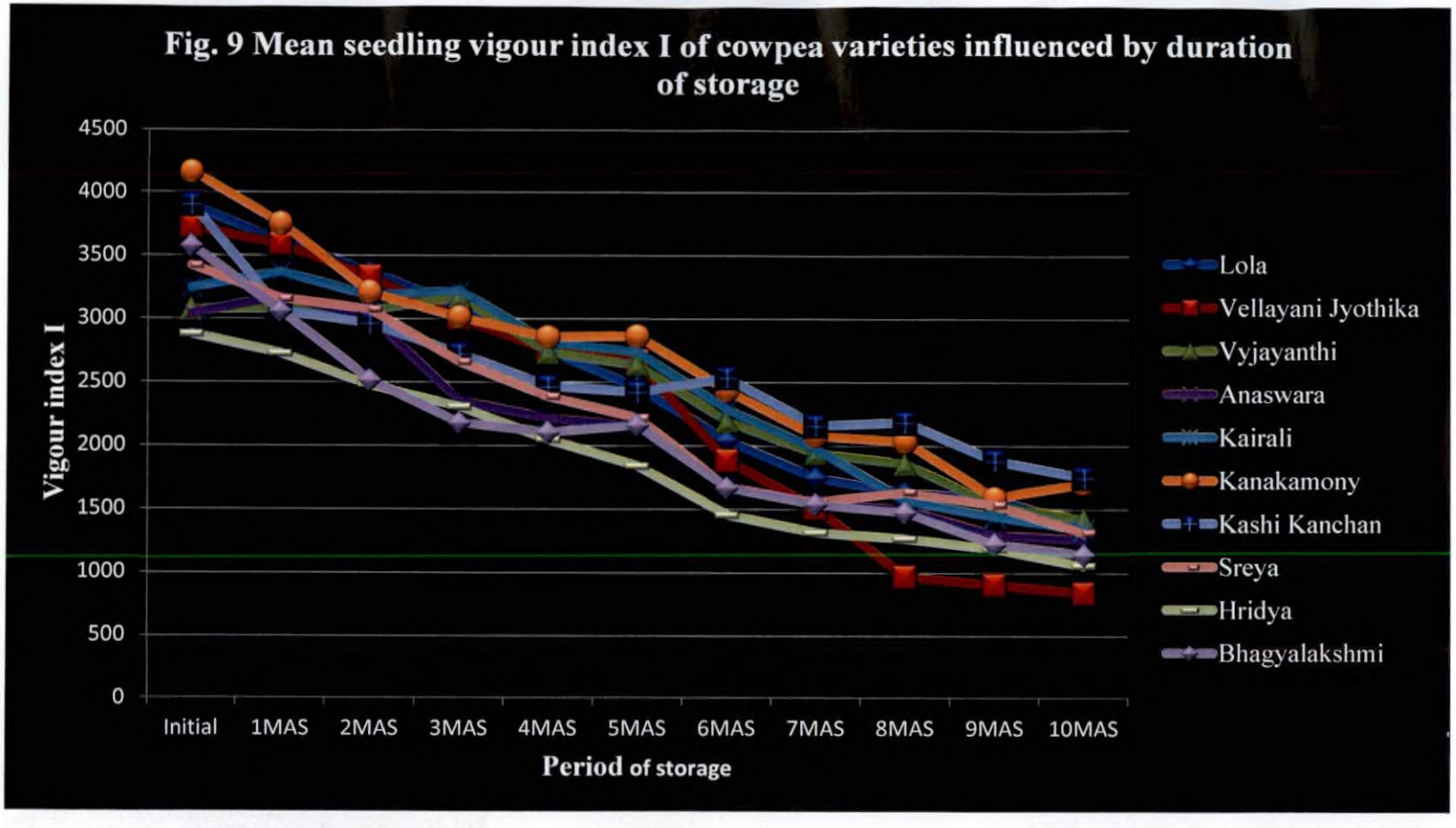


Fig. 8 Mean speed of germination of cowpea variety groups influenced by duration of storage
Speed of germination
35
30
25
20
15
10
5
0
Initial
1MAS
2MAS
3MAS
4MAS
5MAS
6MAS
7MAS
8MAS
9MAS
10MAS
Period of storage
Group I - Trailing
Group II - Semi trailing
Group III - Bush

**Fig. 9 Mean seedling vigour index I of cowpea varieties influenced by duration of storage**



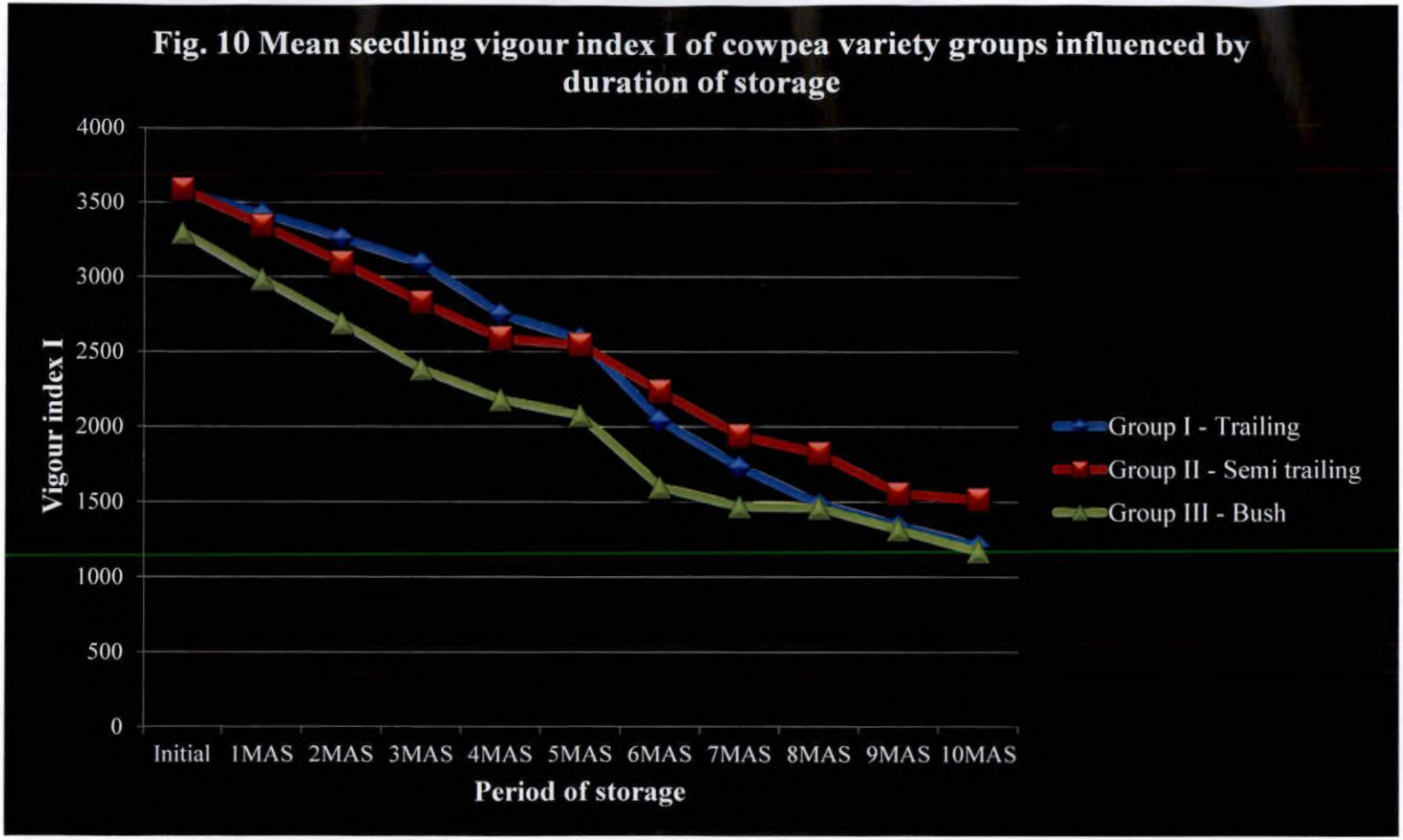


Fig. 10 Mean seedling vigour index I of cowpea variety groups influenced by duration of storage
Vigour index I
4000
3500
3000
2500
2000
1500
1000
500
0
Initial
1MAS
2MAS
3MAS
4MAS
5MAS
6MAS
7MAS
8MAS
9MAS
10MAS
Period of storage
Group I - Trailing
Group II - Semi trailing
Group III - Bush

## 5.5 Electrical conductivity of seed leachate

Increase in electrical conductivity of seed leachate indicates a higher level of membrane degradation of cells and resultant decrease in storage potential of seed. On storage, there was a gradual increase in electrical conductivity of seed leachate and it differed among varieties and groups, indicating varietal variations.

The highest electrical conductivity of seed leachate was observed in Kashi Kanchan (0.643 $dSm^{-1}$) and the lowest was in Anaswara (0.239 $dSm^{-1}$) after ten months of storage. Considering the groups, the highest electrical conductivity of seed leachate was observed in seeds of semi trailing type and the lowest in bush types.

Unlike earlier reports, here the highest electrical conductivity was recorded by the variety Kashi Kanchan which recorded the highest germination. This may be because of the increased membrane permeability leading to increased germination process which can be considered as a varietal character. However, it requires further investigations and confirmation.

Comparing the electrical conductivity of seed leachate of varieties in ambient storage condition and cold storage condition, it is found that in all the varieties except Hridya the electrical conductivity of seed leachate was lower in cold storage condition (indicating a slower rate of deterioration) than ambient storage condition after five months of storage. After ten months of storage, all the varieties except Vellayani Jyothika, Sreya and Bhagyalakshmi showed lower electrical conductivity of seed leachate in cold condition than ambient condition (table 5.1).

Higher measure of the leachate exudation as measured by electrical conductivity was associated with loss of vigour and viability. This also indicates that, greater membrane damage has occurred with seed ageing (Manoharan, 1999). Increased leaching of solutes was related to degradation of cell membrane

and low metabolic activity of seed (Abdul-Baki and Anderson, 1972; Powell and Mathews, 1986).

Kumbar (1999) in chickpea, Divya-Shree, (2006) and Nataraj *et al.* (2011), in sunflower, Sandyarani (2002) in cotton and Saha and Sultana (2008) in soybean also reported a similar same result regarding electrical conductivity of seed leachate during ageing of seeds.

**5.6 Dehydrogenase enzyme activity**

Dehydrogenase enzyme activity is an indication of the viability of seeds. The viability is generally the liveliness of a seed. Hence the viability is directly related to germination, speed of germination and vigour. The dehydrogenase enzyme activity of seeds of all varieties reduced in this study also because of the reduction in viability. It also indicates that, within the dry embryo, the mitochondrial dehydrogenase enzymes essential to repair of senescent lesion lose activity and cause progressive decline in per cent viability of seeds as the period of storage is extended. Maximum dehydrogenase enzyme activity after ten months of storage was shown by seeds of Vyjayanthi (0.572) and minimum activity by Sreya (0.157).

In general seeds of varieties in cold storage condition exhibited a higher dehydrogenase enzyme activity after ten months of storage (table 5.1), compared to those kept in ambient conditions.

The results are in conformity with those of Mrutyunjaya (2003) and Nataraj *et al.* (2011) in sunflower.

**5.7 Seed microflora and insect incidence**

During storage it was observed that, the seed infection per cent on seeds increased after ten months of storage. It varied between varieties also. The highest infection was found in Lola and the lowest in Kanakamony, Kairali and Vellayani Jyothika. *Aspergillus sp.* and *Rhizopus sp.* were the major seed microflora

identified. Christensen and Kauffmann (1969) and Krishnamurthy and Raveesha (1996) reported an increase in the infection of seed microflora on storage.

Comparing the seed infection per cent of seeds of varieties in ambient storage condition and cold storage condition, there was a decrease in infection per cent in cold storage in all varieties than in ambient storage.

As the seed moisture content was brought to a safer level of eight per cent before packing, no insect incidence was observed during the period of storage.

In general, germination, speed of germination, vigour indices and dehydrogenase activity of seeds reduced gradually from initial stage to final stage of storage and electrical conductivity of seed leachate shown an increasing trend.

Comparing the germination, speed of germination, seedling shoot length, seedling root length, seedling dry weight, vigour index I, vigour index II, electrical conductivity of seed leachate, dehydrogenase enzyme activity and seed microflora infection per cent of varieties in ambient storage condition and cold storage condition, it was clear that in case of almost all the varieties, all the parameters observed were higher in cold storage condition than ambient storage condition except that of electrical conductivity of seed leachates. Comparative studies of seed storage in ambient and cold conditions was reported by Maurya (1971), Nagaveni (2005) and Verma and Gupta (1975) in soybean and Singh and Setia (1974) in onion also support the findings of this study.

## 5.8 Correlation and path analysis

Association of seed quality parameters with germination was assessed through statistical correlation. Similarly, the inter relationships of seed quality parameters *ie.* direct and indirect effects on germination were studied by path analysis. Correlation and path analysis was conducted for data pertaining to initial storage, mid storage (5MAS) and at the end of storage (10MAS). The results of

correlation studies indicated a highly significant and positive correlation between vigour index I and speed of germination with germination per cent.

Path analysis indicated significant direct effect of germination per cent and seedling vigour index I.

**5.9 Stability analysis**

The adaptability and stability of a genotype are useful parameters for recommending the varieties for known cropping conditions. Eberhart and Russel (1966) proposed an assessment of cultivar response to environmental changes through a stability analysis based on three parameters – mean, linear regression coefficient (b) and deviation from regression. The genotypes are grouped according to the mean performance coupled with the size of their regression coefficients (less than, equal to or greater than one). Those varieties with the regression coefficient of unity indicate average stability. If the regression coefficient is less than one, it means the genotype has greater susceptibility to unfavourable environmental changes having low stability. If the regression coefficient is greater than one, it means improved performance under congenial conditions with low stability. Regression coefficient of zero would express absolute stability.

Generally a variety having b = 1 and a high mean and the lowest deviation from regression would be considered as the most widely adapted or stable variety, while those with b value of one and low mean yield (over the environments) would indicate a poorly adapted genotype.

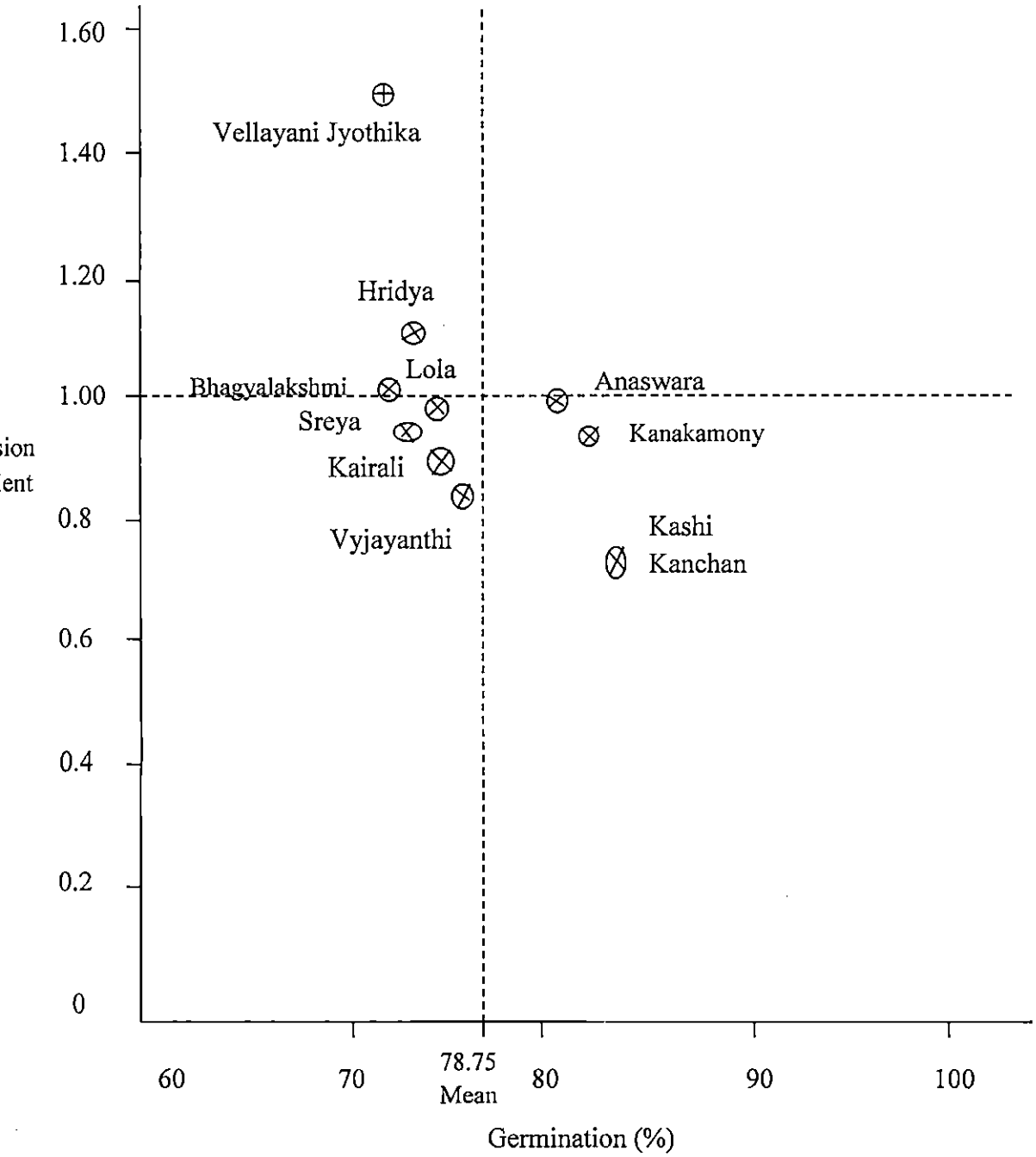
Variety with higher overall mean, regression coefficient above 1.0, and high deviation from regression indicate higher performance of variety at congenial conditions.

The theory and tool of stability analysis based on genetic x environmental interactions under varied environments proposed by Eberhart and Russel (1966)

was employed in this study to understand the stability of cowpea varieties for their ability to maintain seed quality during storage.

Stability analysis on germination of ten varieties of cowpea varieties (fig. 11) indicated that, the varieties Vyjayanthi and Kashi Kanchan were suitable to adverse storage conditions. Varieties Anaswara and Kanakamony can be considered as stable varieties, they have a high mean germination, bi value tended to unity and had low deviation from regression, indicating that these varieties are suited for storage under average environmental conditions. Vellayani Jyothika can be considered as the variety suited for storing under favourable or congenial conditions *ie.* their performance in adverse storage conditions will not be satisfactory.

**Fig. 11 Stability analysis on germination of ten varieties of cowpea**



## 5.15 Mahalanobis $D^2$ analysis

$D^2$ analysis is a statistical tool developed by Mahalanobis (1930) to group genotypes into specific or distinct clusters, based on intra and inter cluster distances or genetic relationships. This tool was employed in this study to group cowpea varieties based on their ability to maintain seed quality parameters during storage.

The analysis was done based on observations before storage, at mid and the end of storage period. Results indicated that, the intra cluster distance was less between the varieties Kanakamony and Kashi Kanchan and also between Hridya and Bhagyalakshmi. This means Kanakamony and Kashi Kanchan are closely related with respect to their seed quality parameters and pattern of seed senescence; similarly Hridya and Bhagyalakshmi are also closely related to each other. The inter cluster distance between some group of varieties was very high showing the variations between the varietal groups in their seed quality parameters and storability. Inter cluster distance between Lola, Vellayani Jyothika and Vyjayanthi which belong to trailing type was very high with Kanakamony and Kashi Kanchan (semi trailing) and also with Bhagyalakshmi and Hridya (bush).

The overall assessment of varieties indicates that varieties can be grouped into the following groups or clusters, based on seed quality and storage behaviour.

Group I – Kanakamony, Kashi Kanchan

Group II – Hridya, Bhagyalakshmi

Group III - Lola, Vyjayanthi

Group IV - Vellayani Jyothika, Anaswara

Group V - Kairali, Sreya

**Practical implications**

- Seeds of cowpea varieties dried to eight per cent moisture level can be safely stored at ambient conditions of Thrissur up to five months.
- Varieties which are having high storage potential (Kanakamony and Kashi Kanchan) can be preferred for commercial seed production and they can be employed in breeding programmes.
- Seeds of varieties which loose quality at a faster rate (Vellayani Jyothika, Kairali and Hridya) during storage are not suited for storage for more than six months under ambient storage conditions (25-30°C).

**Future line of work**

- Molecular characterisation for identification of specific genes which impart high seed quality.
- Physiological and biochemical bases for varietal variations in seed quality and storability in relation to growth habit needs further research.

# *Summary*

## 6. SUMMARY

The investigation on the "Variability in seed quality and storability of cowpea (*Vigna* spp.) varieties" conducted at College of Horticulture, Vellanikkara, Thrissur at two different atmospheric conditions for ten months of storage revealed the following information:

Freshly harvested cowpea seeds of eight per cent moisture content stored at ambient conditions of mean maximum temperature of around 28-35°C and relative humidity of 72-98 per cent under Kerala conditions could be stored up to five months retaining the minimum seed certification standards (75% germination).

Among the varieties, Kashi Kanchan and Kanakamony had higher storability and quality. Vellayani Jyothika and Hridya lost quality at a faster rate. In general, the semi-trailing types had better seed quality characters.

Based on storage study, stability and cluster analysis, the varieties which retained maximum germination and quality parameters were Kashi Kanchan and Kanakamony and the varieties which have shown poor performance were Vellayani Jyothika, Kairali and Hridya.

There was a higher germination and other quality parameters under cold storage condition than in ambient condition irrespective of varieties.

The germination per cent, seedling length, seedling dry weight, seedling vigour and dehydrogenase enzyme activity were decreasing gradually and electrical conductivity of seed leachate was increasing on storage irrespective of varieties.

The microflora infection per cent in seeds was increasing significantly during storage in both ambient and cold storage conditions. There was a significant reduction in infection per cent in the case of cold storage than ambient

storage. The major group of seed microflora identified were *Aspergillus* sp. and *Rhizopus* sp.

There was a highly significant and positive correlation between vigour index I and speed of germination with germination per cent. Path analysis indicated significant direct effect of seedling vigour index I on germination.

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# Annexure

## ANNEXURE-I

**Monthly meteorological data during the experimental period (2014-15) recorded at the College of Horticulture, Vellanikkara, Thrissur**

| Month | Temperature (°C) | | Relative humidity (%) | |
|---|---|---|---|---|
| | Mean max. | Mean min. | I (7.30 am) | II (2.25 pm) |
| July-2014 | 28.5 | 23.1 | 94.8 | 78.6 |
| August-2014 | 29.5 | 23.2 | 96.7 | 76.1 |
| September-2014 | 31.3 | 23.4 | 94.7 | 69.1 |
| October-2014 | 32.0 | 23.7 | 91.5 | 69.0 |
| November-2014 | 31.6 | 23.5 | 83.6 | 59.3 |
| December-2014 | 31.9 | 23.2 | 77.6 | 53.5 |
| January-2015 | 32.5 | 22.1 | 72.2 | 36.2 |
| February-2015 | 34.3 | 23.0 | 72.7 | 37.1 |
| March-2015 | 35.8 | 24.9 | 83.0 | 34.2 |
| April-2015 | 34.0 | 24.6 | 88.9 | 58.0 |
| May-2015 | 32.8 | 24.7 | 92.0 | 64.0 |

# VARIABILITY IN SEED QUALITY AND STORABILITY OF COWPEA (*Vigna* spp.) VARIETIES

By

**ASWATHI C.**

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**ABSTRACT OF THE THESIS**

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**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY**
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## Abstract

Seed is the basic input in agriculture contributing to 15-20 per cent of productivity. In most cases, it becomes essential to store seeds and therefore maintenance of seed quality during storage is inevitable. During storage, a number of physiological and biochemical changes occur in seeds which result in ageing or seed senescence. The rate at which the process of seed ageing takes place depends on the weather conditions of the storage atmosphere and the ability of seed to resist the degradative changes. Genetic makeup of the species and varieties also decide the senescence pattern.

Cowpea is an important vegetable crop of Kerala. An array of improved varieties is available for cultivation. Storage experiments were conducted with seeds of ten different varieties of cowpea (Lola, Vellayani Jyothika, Vyjayanthi, Anaswara, Kairali, Kanakamony, Kashi Kanchan, Sreya, Hridya and Bhagyalakshmi) belonging to trailing, semi trailing and bush growth habits to assess the genetic variations in seed quality parameters, seed senescence pattern and seed longevity. Seeds obtained from summer crop (February-June, 2014) were stored in polyethylene bags of 700G and observations on seed quality parameters were recorded at monthly intervals.

Results indicated that, irrespective of varieties, the seed quality parameters *viz.* germination, speed of germination, seedling vigour and dehydrogenase enzyme activity decreased while electrical conductivity of seed leachate and seed microflora infection per cent increased with increase in duration of storage.

Irrespective of varieties, a higher germination, speed of germination, seedling vigour and dehydrogenase enzyme activity coupled with a significant reduction of electrical conductivity of seed leachate and seed microflora infection was observed in seeds stored under cold storage (20±2°C) compared to those stored under ambient storage condition (25-30°C).

Among the varieties, the highest germination, speed of germination and seedling vigour index I were recorded in Kashi Kanchan followed by Kanakamony. The two varieties also retained a germination per cent of above minimum seed certification standards (75% germination) for six months of storage. The lowest germination, speed of germination and seedling vigour index I were recorded in variety Vellayani Jyothika (trailing type).

Based on growth habit, it was observed that the highest germination per cent, speed of germination, seedling vigour index I and the lowest infection of seed microflora were recorded in the semi trailing varieties followed by trailing type. The bush types were found to be on par with trailing types for the above characters.

Considering the varietal variations based on storage study, stability and cluster analysis, the varieties which retained maximum germination and quality parameters were Kashi Kanchan and Kanakamony and the varieties which shown poor performance were Vellayani Jyothika, Kairali and Hridya.

There was a high significant and positive correlation between vigour index I and speed of germination with germination per cent. Path analysis indicated significant direct effect of seedling vigour index I on germination.

Considering the seed quality parameters during storage, varieties Kashi Kanchan and Kanakamony proved to have high storage potential. These can be preferred to employ in future breeding programmes aimed towards improving seed storability.

Further studies and confirmation are required to reveal the reasons for faster senescence in seeds of varieties *viz.* Vellayani Jyothika, Kairali and Hridya.