Seed treatment with botanicals to enhance seedling vigour in chilli(*Capsicum annuum* L.)

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Seed treatment with botanicals to enhance seedling vigour in chilli (*Capsicum annuum* L.)" is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Seed treatment with botanicals to enhance seedling vigour in chilli (*Capsicum annuum* L.)"** is a record of research work done independently by **Ms.SANDHYA R.** (2014-11-227) 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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R. Sr.

Sandhya R.

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LIST OF ABBREVIATIONS

KAU	- Kerala Agricultural University
^{o}C	- degree Celsius
nm	- nanometer
g	- gram
kg	- kilogram
cm	- centimetre
mg	- milligram
dSm^{-1}	- desi Siemens per metre
OD	- Optical Density
ALP	- Arappu leaf powder
FLP	- Fenugreek leaf powder
PLP	- Pungam leaf powder
CLP	- Custard apple leaf powder
NLP	- Neem leaf powder

Introduction

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is a spice and vegetable crop of global importance valued for its colour, flavour and nutritional value. Chilli is widely cultivated throughout warm temperate, tropical and subtropical countries. It belongs to family Solanaceae and is native to tropical South America. It is famous for its pleasant aromatic flavour, pungency, high colouring substance and also a rich source of minerals and vitamins A, B and C.

The major chilli growing countries are India, China, Indonesia, Korea, Pakistan, Turkey and Sri Lanka. India produces 9.21 lakh tonnes of chilli per annum, grown on an area of 8.92 lakh hectares with a productivity of 1.00 tonne per hectare, thereby, contributing to nearly one fourth of the world's production (Kavitha, 2002). Major chilli growing states of India are Andhra Pradesh, Karnataka and Maharashtra with the highest productivity in Andhra Pradesh. Presently, it is not a question of producing good quality seeds that are acceptable and competitive in the international market, but India is in the need of reorientation of strategy of vegetable seed production. Quality seed is the foremost effective input for successful crop production. It requires good germination to produce a vigourous seedling ensuring high yields. Without good seed, the investment on fertilizers, water, pesticides and other inputs will not pay the desired dividends. Good quality seed acts as a catalyst for realizing the potential of all other inputs in agriculture. Therefore, production of quality seed and maintenance of high germination is of utmost importance in a seed programme, where it is a multiple concept comprising several physical, chemical and biological components influenced by several biotic factors, abiotic factors, etc.

In Kerala, owing to high temperature and high relative humidity the ageing process of the seed hastens and as a result, the viability of stored seeds reduces. Safe storage of seeds is advantageous, as it reduces the burden of seed production every year, besides timely supplying of desired genetic stocks for use in years following periods of low production. Storage condition also influence the seed quality and play important role in maintaining viability of seeds. Hence, storage and preservation of seed stocks till the next season, is as important as producing quality seeds. In order to preserve the seed quality and maintain high level of germination, seed treatments can be resorted to enhance the storability of seeds.

Nowadays, organic seed production is gaining importance. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities such as soil, plant, animals and people. Organic farming can provide a better economic alternative as; the inputs are of lesser cost and produce fetches higher price. The promotion of organic farming can lead to the development of eco-friendly production techniques using natural products. Owing to the disadvantages caused by the excessive use of inorganics in agriculture, efforts are being made to utilize organic inputs for seed treatments.

Seed treatments are necessary to promote good seedling establishment, to minimize yield loss, to maintain and improve quality and to avoid the spread of harmful organisms. Seed treatment has the potential to deliver agents "in the right amount, at the right place and at the right time". They tend to improve the physiological status of seed, thereby resulting in improved germinability, greater storability, better field performance and higher seed yield. Seed treatment with botanicals have good value, for mostly, they are cheap, easy for the grower to use and give useful protection from pests and diseases during, germination and early stage of crop growth. The use of botanicals for pre-treatment of seed is now receiving much attention, because of its proven advantages over the synthetic options. Hence, standardization of seed treatment with botanicals would be of great advantage to reduce the problems in maintenance of seed quality during storage. Leaf and fruit powders of herbal plants are widely used for seed treatment (Bashyam, 1999). The performance of dry seed treatment with crude plant materials in powder form have been found to significantly slow down the deterioration of seeds under various ageing conditions (De *et al.,* 2004 in wheat; Rudrapal and Basu, 2004 in french bean; Senguptaet *al.,* 2005 in onion; Kundagramiet *al.,* 2008 in rice).

The ageing process is irreversible once commenced. However, it can be controlled to a certain extent by adopting new technologies. Invariably most crops require storage for one or more planting season during which period the deterioration is inevitable (Soltaniet *al.*, 2009). It has been proven that the deteriorative effect of seed ageing is mainly due to production of free radicals (Bailly, 2004; Baillyet *al.,* 2008) and use of antioxidants can quench the free radicals and retain seed vigour during germination (Maeda *et al.,* 2005; Sattler *et al.,* 2006).In order to alleviate the deterioration process in seeds, nanotechnological approaches offer plausible solutions. Nanotechnology is an emerging science that promises to solve many of the agriculture-related problems with tremendous improvement compared to conventional agriculture systems. Improved properties of the nanoparticles compared to normal size materials have greater opportunity to reduce the load of unwanted chemicals especially plant protectants. Nanomaterials have proved to enhance the germination, seedling vigour, biomass of seedlings and physiological parameters like photosynthetic activity and nitrogen metabolism in many crop plants. Nanoparticles, acting as antioxidants, are an effective scavenger of free radicals and suppress the propagation of lipid peroxidation. Some of the natural sources of antioxidants are arappu leaf powder, custard apple leaf powder, fenugreek leaf powder, arappu leaf powder and neem leaf powder.

The varieties may vary greatly in their potential for retaining germination and vigour of the seed under ambient storage conditions. It seems worthwhile to take up studies on seed quality parameters to determine the effect on seed vigour with regard to their deterioration behaviour, as the information on storage life of treated chilli seeds under high humid conditions of Kerala is meager.

Knowledge on storability of treated chilli seeds under ambient conditions will be of immense use to seed industry and farming community. The present study comprises of the commonly used botanicals such as arappu (*Albizia amara*), fenugreek (*Trigonella foenum-graecum*), pungam (*Pongamia glabra*), custard apple (*Anona squamosa)* and neem (*Azadirachta indica*) for seed treatment of chilli. The study was planned with the following objectives,

1. To elucidate the effect of botanicals on viability and vigour of chilli seeds during storage.
2. To compare the efficacy of normal grade and nano size botanicals on seedling vigour in chilli.
3. To know the varietal variation for seed storability potential.
4. To study the effect of seed treatment with botanicals on seed microflora.

Review of Literature

2. REVIEW OF LITERATURE

The success of a seed production programme lies in the maintenance of vigour and viability of seeds until the next sowing season. Generally, the poor performance of seed is due to several factors, of which, physiological quality of seed after storage is of immense importance. In many seeds, the use of various plant products in maintaining seed storability is in vogue as they are considered to be eco-friendly, safe and cost effective. A brief review of literature pertaining to longevity and storability of seed; the physiological, biochemical aspects of seed deterioration, and the effect of seed invigoration with plant products on seed quality and field performance is presented in this chapter.

2.1. Factors affecting seed storage

The effect of environmental factors on seed storage has been studied by many researchers from time to time. It is well known that, low moisture content, cool temperature and low oxygen tension will influence or affect the longevity of seeds in storage.

The storage life is doubled for every one per cent decrease in seed moisture content and every 50°C fall in temperature (Harrington, 1972). Such effects are applicable when the temperature ranges between 0°C and 50°C. *Ginkgo biloba* stored at 4°C preserved tissue viability, but only part of the seeds germinated (Tommasi *et al.*, 2006). Koostra and Harrington (1969) opined that lower moisture content (4-5 per cent or below) was more harmful than higher moisture content (5-6 per cent or above), which might probably be due to the damage caused by lipid auto-oxidation.

In most vegetable seeds, physical factors such as high temperature and relative humidity decreased seed vigour and viability during storage (Bhatia *et al.*, 2002 in soybean and Bellard *et al.*, 2006 in bittergourd). As seed moisture content is directly associated with atmospheric relative humidity, it can be safely said that relative humidity extends a great influence on seed longevity (Harrington, 1972 in lettuce; Agrawal and Siddique 1993; Palanisamy and Vanangamudi, 1987 in bhendi; Khattra *et al.,* 1988 in pigeon pea; Pallavi *et al.,* 2003 in sunflower; Vanniarajan *et al.,* 2004 in black gram).

Additionally, other biotic factors on seed storage affect the quality of seeds to greater extent such as oxygen pressure (Roberts and Abdalla, 1968), microflora (Bhatia *et al.,* 2002) and insects (Lande *et al.,* 1986 in peanut; Patil *et al.,* 2006 in chickpea). Lipid degradation in groundnut and soybean seeds was found to be higher in elevated atmospheric oxygen environment than intact seeds at normal environment (Priestley *et al.,* 1985). Loss of germination was detected in peach seeds stored at temperature above 0°C which was due to the excessive production of Reactive Oxygen Species (ROS) (Ratajczak and Pukacka, 2005).

2.2. Impact of storage period on seed deterioration

2.2.1. Physiological changes

Seed deterioration is the loss of seed quality, viability and vigour due to the effect of adverse environmental factors (Kapoor *et al.,* 2010). The rate of seed deterioration has a major impact on the physiological potential of the seeds. The exact mechanisms that lead to the loss of seed viability are by no means completely elucidated and the susceptibility of seeds to ageing varies among families and species (Walters *et al.,* 2005; Niedzielski *et al.,* 2009; Nagel and Borner, 2010).

Kharab and Dahiya (2000) reported changes in colour, delayed germination, reduced tolerance to adverse storage conditions and reduction in seedling growth during ageing in pigeon pea. As the period of storage progressed, the root and shoot length, dry matter production, vigour index, protein content, protease content and amylase content gradually decreased in all the treatments however it was the highest in the control of greengram and blackgram (Gomathi, 2011). Sowmiyabhanu (2014) on evaluating the storability of rice, blackgram, cotton and sunflower observed reduction in germination, speed of emergence, seedling growth and vigour index due to ageing. Similar results were also reported by Sumathi (2010) in *Psoralea corylifolia* and Venudevan (2013) in *Aegle marmelos.*

2.2.2. Biochemical changes

Heydecker (1972) stated that deterioration of vigour in stored seeds was associated with the weakening of cell membrane. Increased leachate was related to low metabolic activity of seed (Abdul-Baki and Anderson, 1973). Membrane integrity as a measure of vigour and viability had been reported widely. The loss of membrane integrity and a decrease in proportion of unsaturated fatty acids have been reported as causes for seed deterioration and presumably a loss in membrane permeability under unfavorable condition of storage resulting in increased leachate of seed constituents and thus loss in viability (Sen and Osborne, 1977). Parrish and Leopold (1978) reported that changes in seeds of soybean after accelerated ageing showed subsequent loss of vigour and increased leakage of electrolytes.

Stewart and Bewley (1980) reported that an increase in leakage of metabolites from aged soybean axes could be associated with increased lipid peroxidation. In oilseeds, germination of groundnut seed was negatively correlated with electrical conductivity of seed leachates and its soluble sugar and free amino acid concentration (Paramasivam *et al.*, 1990). Ponquett *et al.*, (1992) contributed more evidence to the relationship between lipid autoxidation and seed aging in soybean. Changes in lipids during storage of groundnut and other oil seeds were associated with seed deterioration and could be measured using differential scanning colorimetry (Vertucci, 1992). Agrawal and Siddique (1993) suggested that in soybean seeds, poor membrane structures and leaky cells are usually associated with low vigour seeds. Tajbakhsh (2000) observed that when seeds imbibed water, internal seed substances like potassium, phosphate, sugar, amino acids and other substances leached out due to membrane deterioration and it was also proved that as the membrane damage increased, leachate conductivity increased. Reduction in protein, lipid and polyunsaturated fatty acid content and increased volatile production during storage of soybean seeds were observed (Braccini *et al.*, 2000).

The loss of vigour might be the outcome of reduction in the synthesis of enzymes, nucleic acid and amino acid in blackgram as reported by Kavitha (2002). Murali *et al.,* (2002) stated that germination and field emergence of the pulse seed decreased while the electrical conductivity of seed leachate increased with increase in storage period. Peroxidation of unsaturated fatty acids led to leaching of electrolytes and other solutes in soybean (Singh and Dadlani, 2003). Verma *et al.,* (2003) reported a decrease in carbohydrates and protein content in deteriorated seeds.

The dehydrogenase enzyme activity is a good stable metabolic marker to estimate the degree of vigour in seeds (Saxena *et al.,* 1987) and have positive association with vigour and viability of seeds (Halder and Gupta, 1982; Kharlukhi, 1983). Changes in the levels of dehydrogenase, catalase, peroxidase, amylase, phosphatase and glutamic acid decarboxylase was found to be associated with seed viability during storage in soybean as noticed by Anuja and Aneja (2004). The decrease in dehydrogenase enzyme activity was observed by Stewart and Bewley (1980) in soybean with advancement in ageing period or entrance of seed into senescence phase. Hridya (2013) observed that, biochemical parameters like electrical conductivity, free fatty acid, lipid peroxidation and lipoxygenase activity recorded lower values and dehydrogenase activity, catalase activity, peroxidise activity, protein and oil contents recorded higher values in acceleratedly aged seeds of soybean. Vanitha *et al.* (2005) reported that artificial ageing reduced the rate of radicle extension and shoot growth in maize, blackgram and sunflower due to non-availability of food reserves. The activity of enzymes like acid phosphatase, phosphomonoesterase, dehydrogenase, amylase, catalase, and peroxidase were also decreased during acceleratedly ageing. Rutzke *et al.* (2008) reported that in aged cabbage seeds, degradation of respiratory pathway (at cytochrome C) leading to fermentation and high ethanol production, resulted in reduced dehydrogenase activity. A decrease in protein content and hydrolyzing enzymes activity such as α- amylase and dehydrogenase with increase in electrical conductivity of seed leachates was observed in accelerated aged maize seeds (Sathish and Sundareswaran, 2010). A gradual reduction in dehydrogenase activity, germination and seedling length with increase in the ageing period have been reported in barley by Nezar *et al.*, (2006) and in peas by Panobianco *et al.*, (2007).

Krishnan *et al.* (2004) found that loss of viability and increase in soybean seed leachate conductivity indicated the changes in thermo dynamic properties of seed water which reflected the seed deterioration under accelerated ageing. Loss of membrane integrity leads to electrolyte leakage which was associated with viability loss in several species (Ratajczak and Pukacka, 2005).

Sujatha and Srimathi (2006) described that seed deterioration alters the differential permeability properties of the membranes. Increase in conductivity might be due to loss of membrane permeability and leaching of the electrolytes such as sugars, amino acids and organic acids in blackgram. When poor seeds are planted in soil, electrolytes probably provide food material for soil fungi causing seed decay and poor stand establishment in bittergourd (Bellard *et al.*, 2006). Reactive oxygen species (ROS) accumulation and lipid peroxidation are generally considered as the major contributors to seed deterioration (Bailly, 2004). During storage, reactive oxygen species are generated in seeds either from molecular oxygen or enzymetically by lipoxygenase and antioxidant enzymes such as superoxide dismutase, catalase, ascorbate peroxidase and peroxidase during storage due to which lipid peroxidation increases (Boonsiri *et al.*, 2007). Kaewnareea *et al.* (2011) opined that seed deterioration during storage is a complex physiological and biochemical processes leading to loss of germination ability. As seed quality declines, there is a concurrent increase in the level of free fatty acids (Navaey *et al.*, 2014).

Many biochemical investigations have proven that lipid peroxidation and free fatty acid accumulation are major causes of seed deterioration including cellular membrane disruption. Seeds deteriorate during storage due to lipid peroxidation (Al-Maskri *et al.*, 2002 and 2003), oxidative modification of proteins by reactive oxygen species (Terskikh *et al.*, 2008) and lipids peroxidation products e.g. aldehydes (Akimoto *et al.*, 2004).

Free radicals are one of the most important causes for oxidative damage of poly unsaturated lipids in cell and cellular components in the biological system. Various forms of free radicals have been observed or detected in living tissues, each with a differing capability for cell damage. Free radical production, primarily initiated by oxygen, had been related to the peroxidation of lipids and other essential compounds found in cells. This causes a host of undesirable events including decreased lipid content, reduced respiratory competence and increased the evolution of volatile compounds such as aldehydes (Wilson and McDonald, 1986).

Lipid peroxidation begins with the generation of a free radical (an atom or a molecule with an unpaired electron) either by auto oxidation or enzymatically by oxidative enzymes such as lipoxygenase present in many seeds. Various forms of free radicals have been observed or detected in a living tissue, each with a differing capability for cell damage (Gille and Joenje, 1991; Larson, 1997). A protective mechanism that could scavenge the harmful peroxidase produced free radicals within the seed thus minimizing their detrimental effect has been identified in soybean and sunflower due to the protective mechanism that involves several free radical and peroxide scavenging enzymes such as catalase, peroxidase and superoxide dismutase and ascorbic acid (Dhakal and Pandey, 2001). Mittler *et al.* (2004) reported that ROS were produced in aerobic organisms within the cell and were normally in balance with antioxidant molecules.

One of the major sources of ROS in metabolically active seeds is the mitochondrial respiratory chain (Bailly, 2004) and the loss of viability during seed ageing was mainly related to the loss of plasma membrane integrity due to the production of free radicals and ROS during storage. Gapper and Dolan (2006) reported that the reactive oxygen species control and regulate biological processes such as cell cycle, programmed cell death and hormone signaling. Kibinza *et al.* (2006) demonstrated that the H_2O_2 induced ATP depletion could trigger cytochrome release, which in turn might lead to loss of viability and germinability in sunflower. Mitochondrial alteration leads to increase in ROS production (Cash *et* *al.,* 2007). Lipid peroxidation enhances free fatty acid level and free radical productivity causing membrane disruption. Free fatty acid damaged mitochondria reduce energy production and free radicals have potential to damage membrane, DNA, enzymes, protein and ultimately cellular repair mechanism (Ghassemi-Golezani *et al.,* 2010).

Leakage of metabolites in larger amounts into the germination medium for aged, deteriorated and injured seeds than from vigourous seeds due to membrane permeability in lima beans, peas and rape seed respectively have been reported by Pollock and Toole (1966), Matthews and Bradnock (1968) and Takayanagi and Murakami (1968). Narayanaswamy (2003) concluded that oil, protein and field emergence of groundnut seeds decreased but free fatty acid and electrical conductivity increased with advancement of storage period. Several tests such as electrical conductivity of leachate of different seeds, leaching of sugars and leaching of amino acids were employed for evaluating the membrane integrity and correlating with seed vigour and viability (Matthews and Bradnock, 1968).

Abdul-Baki and Anderson (1970) suggested that leachable glucose in rapidly aged seeds were not related to the membrane integrity. Parrish and Leopold (1978) reported that changes in seeds of soybean after accelerated ageing showed subsequent loss of vigour and increased leakage of electrolytes. Stewart and Bewley (1980) reported that an increase in leakage of metabolites from aged soybean axes was in associated with increased lipid peroxidation. Mustard seeds invigorated with antioxidants recorded lower electrical conductivity, sugar and amino acids than untreated control.

Membrane deterioration under high seed moisture content was involved in the loss of vigour and viability during storage (Lin, 1988). Chen and Zhou (1990) reported that ion exosmosis would be used as a physiological index for seed viability during long storage. Agrawal and Siddique (1993) suggested that soybean seeds, poor membrane structures and leaky cells are usually associated with low vigour seeds. These would result in greater loss of electrolytes such as amino acids, organic acids and sugars from imbibed seeds.

Michalczyk *et al.* (1998) observed positive correlation between phospholipid degradation level of seed exudates and conductivity and viability depression due to prolonged storage. During ageing, ROS accumulation and lipid peroxidation generate changes in the structural and functional properties of membrane lipids, which increase membrane permeability (Simon, 1974). This loss of membrane integrity leads to electrolyte leakage, which increases the electrical conductivity of seed leaching and is associated with viability loss in several species (Aiazzi *et al.,* 1997; Ratajczak and Pukacka, 2005).

Maskri *et al.* (2003) concluded that carrot seeds aged rapidly showing significant reduction in the seed viability and seedling growth. Loss of seed viability was associated with increased seed conductivity (electrolyte leakage), lipid peroxidation build up and by increasing levels of un-saturated fatty acid contents, which were produced upon accelerated ageing treatment. Krishnan *et al.* (2004) found that loss of viability and increase in soybean seed leachate conductivity indicates the changes in thermodynamic properties of seed water which reflect the seed deterioration during storage under accelerated ageing. Kaewnareea *et al.* (2008) observed that in sweet pepper seeds, five fatty acid concentrations had changed as the accelerated aging time increased. The major change of those fatty acids appeared during ten to twenty days of ageing time and was associated with the ability of seed germination and K^+ leakage concentration. In sweet pepper seeds the decrease in germinability was well correlated with increase in membrane deterioration, as assayed by electrical conductivity and electrolyte leakage. In soaked seeds malondialdehyde was the major product of lipid peroxidation which rapidly increased from 0-75 mg g^{-1} within ten days of accelerated ageing. (Kaewnareea *et al.*, 2011).

2.2.3. Loss of enzyme activity

Attempts have been made to correlate enzyme activity and loss of seed viability. The activities of dehydrogenase and glutamic acid decarboxylase have been associated with seed viability. Important findings were made by Moore (1969) in respect of dehydrogenase and Grabe (1965) in decarboxylase activity.

The changes in amylase, cytochrome oxidase, glutamic acid decarboxylase and dehydrogenase have been investigated in deteriorating seeds.

Abdul-Baki and Anderson (1972) and Thangaraj *et al.* (1973) reported that high glutamic acid decarboxylase activity (GADA) was related to high germinability. There is a close relationship between GADA and membrane permeability following seed deterioration. Subsequently, Ramamoorthy and Karivaratharaju (1985) showed that the vigour and viability of groundnut (*Arachis hypogea* L.) seeds were associated with increased capacity to metabolize glucose coupled with increased synthesis of ethanol-insoluble material. The loss of seed viability was characterized by decrease in amylase production, but these changes appeared to affect the germination rate and not the final germinability (Petruzzelli and Taranto, 1990). Das and Sen-Mandi (1992) reported that during germination of both fresh and aged seeds there was an increase in scutellar amylase.

Gu *et al.* (1993) reported that hydration-dehydration treatment increased the activity of superoxide dismutase, catalase and peroxidase in germinating seeds of tomato and reduced seed leakage. Degradation and inactivation of enzymes due to changes in their macromolecular structures is one of the most important hypothesis proposed regarding causes of ageing in seeds (Basavarajappa *et al.*, 1991; Bailly, 2004; Mc Donald, 2004). The embryos seem more equipped with antioxidant systems than endosperms. However, the antioxidant enzymes were scarcely regulated and unable to counteract oxidative stress occurring during the long-term storage. Rao *et al.* (2006) reported that absence of active enzymes scavenging free radicals, degradation products of thermo-labile lipid peroxidation accumulate in the aged seeds, finally resulting in complete loss of onion seed viability.

Bailly *et al.* (2008) reported that to control free radical-induced cellular damage, seeds have developed a detoxification mechanism.This detoxification system includes a number of antioxidant enzymes such as superoxide dismutase (SOD),catalase(CAT),ascorbateperoxidase(APX),monodehydroascorbatereductase (MDHAR),dehydroascorbatereductase(DHAR),glutathione peroxidase (GSHPx), and glutathione reductase (GSSGR).

Rajjou and Debeaujon (2008) suggested the contribution of testa to seed longevity for maintaining the weakest metabolic activity and protection against various environmental stresses. Free radical-counteracting process detoxification mechanisms are closely related to the control of the pro oxidant/antioxidant balance both during seed storage and germination. When the pro oxidant scavenging systems are saturated, detoxification mechanisms might be affected that irreparably will lead to seed death.

Cakmak *et al.* (2010) reported that long term storage (42 years) reduced the germination capability and caused delay in the germination of alfalfa seeds. In addition, antioxidant enzymes activities of catalase (CAT), peroxidase (POX), and superoxide dismutase (SOD) were also low and total phenolic matter content and lipid peroxidation were high in the aged dry seeds. Demirkaya *et al.* (2010) reported that inactivation of free radical scavenging enzymes (*i.e.*, SOD and CAT) during ageing and showed a direct relationship with the germination efficiency of ageing onion seeds. Moreover, a high level of correlation was found between the loss of seed viability and the decreases that occurred in CAT and SOD activities, in the seeds. Khanahmadi *et al.* (2010) suggested that almost all organisms are well protected against free radical damage by antioxidant. When the mechanism of antioxidant protection becomes unbalanced by the deterioration of cell, oxidation can occur which result in accumulation of free radical. The antioxidant is important compounds found that prevent oxidation.

2.3. Seed enhancement with botanicals

In recent years, attempts have been made to replace synthetic pesticides with natural pesticides of plant origin which are cheaper, safer and eco-friendly, less persistent and more specific. Among the various methods followed, use of botanicals has been a traditional method and is being received much attention, to prevent the loss of seed during storage.

Earlier reports suggested that seeds treated with botanicals, both in dry and wet form protected seeds from fast deterioration, which had resulted in better maintenance of seed germinability and seedling vigour (Vadivelu *et al.*, 1985; Ravichandran, 1991; Umarani and Vanangamudi, 1999).

2.3.1. Antioxidants:

The secondary metabolites of plants are the potential source of natural antioxidants (Walton and Brown, 1999). In dry seeds, lipid soluble non-enzymic antioxidants (such as α tocopherol) act as potential mechanism of defense when enzyme systems are impaired at low seed water contents and in aged seeds decrease in the activity of lipid soluble antioxidants (Pukacka and Kuiper, 1988) have been observed. Both the enzymatic and non-enzymatic antioxidant compounds present in seeds prevents the oxidative damage by scavenging free radicals formed in the membranes or other seed components. Enzymic antioxidants (superoxide dimutase, catalase, glutathione peroxidase and other peroxidases) detoxifies hydrogen peroxide and dimutates O_2 to H_2O_2 (Oliver *et al.,* 1990 in maize; Smok *et al.,* 1993 in sunflower; Van pijlen *et al.,* 1995 in tomato; Sung, 1996 in soybean; Bailly *et al.,* 2004 in sunflower and Posmyk *et al.,* 2001 in soybean). The non-enzymic antioxidants like ascorbic acid (directly scavenges H_2O_2, OH^- and O_2) α tocoperol, glutathione (scavenges H_2O_2, OH^-), β careotene (scavenges OH^-, O_2^-) and peroxy radicals are also effective in controlling free radical formation (Woodstock *et al.,* 1983 in onion, McKersie and Stinson, 1985 in soybean; Pallanka and Smirnoff, 1999 in pea; De Gara *et al.,* 2000 in maize). Hence when seeds are primed they stimulate the activities of enzymes, *viz,* amylase, dehydrogenase, glucose 6-phosphate dehydrogenase and peroxidase in sweet corn (Smith and Cobb, 1992), tomato (Parera and Cantliffe, 1994) and carrot (ShanthaNagarajan *et al.,* 2003).

2.3.2. Sources of antioxidants

In the wake of identifying antioxidants rich natural sources, many medicinal plants are preferred for research, though seeds treated with inorganic sources of antioxidants *viz.,* benzoic acid, sodium hydrogen phosphate, tocopherol and ascorbic acid have been effective in prolonging the shelf life of the seeds (Mandal and Basu, 1983). The enzymic antioxidants *viz.,* catalase, peroxidase and superoxide dismutase and non-enzymic antioxidants *viz.,* vitamin C, α-tocopherol and glutathione have been identified in pepper species (Karthikeyan and Rani, 2003), *Phyllanthus* (Raphael *et al.,* 2000), Indian squill (Tripathi *et al.,* 2001), chicory (Saroja *et al.*, 2000), *Caesalpinia* (Padma *et al.*, 2000) and sweet basil (Gangrade *et al.*, 2001).

2.3.3. Antioxidant and nutritional properties of botanicals

Fenugreek powder

The seeds of fenugreek contain lysine and L-tryptophan rich proteins, mucilaginous fibre and other rare chemical constituents such as saponins, coumarin, fenugreekine, nicotinic acid, sapogenins, phytic acid, scopoletin and trigonelline (Billaud and Adrian, 2001).

Kaviarasan *et al.* (2007) reported that the extract of fenugreek seeds exhibit scavenging of hydroxyl radicals (OH) and inhibition of hydrogen peroxide-induced lipid peroxidation, these antioxidants properties protects the cellular structures from oxidative damage.

Bukhari *et al.* (2008) reported that fenugreek seed extract exhibit antioxidant activity that could act as potent source of antioxidant.

Subhashini *et al.* (2011) found that ethanol extract of fenugreek seed offered strong antioxidant activity in a concentration dependent manner.

De *et al.* (2003) suggested that, wheat seeds when treated with fenugreek seed powder and aspro showed better results in improving storability, yield and other yield attributes. De *et al.* (2004) reported that fenugreek seed powder at 1 g kg^{-1} of seed improved storability in wheat seeds.

Fenugreek seed powder and rhizome powder have been found to be very effective in the maintenance of vigour, viability and productivity of soybean and okra seeds (Mandal *et al.*, 2000 and Kapri *et al.*, 2003).

Kundagrami *et al.* (2008) suggested that dry dressing with fenugreek seed powder and aspirin were very effective for the improvement of storability and field performance of rice seeds.

According to Kapri *et al.* (2003) dry treatments showed better germinability than wet treatments when both were given as a pre-storage treatment. The invigoration effect of the dry treatments was particularly noticeable with fenugreek seed powder, periwinkle leaf powder, ibucon and celin in okra seeds.

Pal and Basu (1988) found that treating of high vigour seeds with fenugreek seed powder @ 2 g kg^{-1} of seed and pharmaceutical formulations like Aspro, Ibucon and Celin @ 100 mg kg^{-1} of seed significantly slowed down the deterioration of seeds under various ageing conditions.

Sathish and Bhaskaran (2014) revealed that blackgram seeds treated with fenugreek seed powder @ 3 g kg^{-1} of seed enhanced the seed germination and seedling vigour.

Hridya (2013) reported that treating of acceleratedly aged soybean seeds with fenugreek seed powder @ 2 g kg^{-1} resulted in recording higher dehydrogenase activity (661) compared to control (281).

Custard apple leaf powder:

Stem and leaf constituents include anonaine, roemerine, corydine, isocorydine, apoprine alkaloids (Brever, 1986).

Misra (2000) treated blackgram seeds with custard apple (*Anona reticulata*) leaf powder @ 3 g kg^{-1} of seed and found that it protected against oviposition and insect damage upto five months.

Blackgram seeds treated with custard apple leaf powder @ 4 g kg^{-1} of seed enhanced the seed germination and seedling vigour (Sathish and Bhaskaran, 2014).

Baskar *et al.* (2007) revealed that leaf extract of *Anona* possessed potent *in vitro* free radical scavenging of hydroxyl ions with moderate lipid peroxidation inhibition activity.

According to Chandrashekar and Kulkarni (2011) custard apple leaf powder has antioxidant properties which are comparable to that of synthetic antioxidant butylated hydroxyl anisole.

Mythili (2012) observed maximum percentage of field emergence at twelve days after sowing when seeds invigorated with custard apple leaf powder @ 2 g kg^{-1} of seeds in onion.

According to Bose *et al.* (2011) methanol extracts of custard apple leaf extract is a good free radical scavenger and had recorded the presence of terpenoids, glycosides and carbohydrates in the extract.

In mango, stones presoaked with custard apple leaf extract five per cent performed better in terms of all seed quality parameters (Dawale *et al.,* 2011).

Neem leaf powder:

According to Arati (2000), bengal gram seeds treated with neem leaf powder @ 5 g kg^{-1} of seed recorded higher germination and vigour index at the end of ten months of storage period.

Yadava and Bhatnagar (1987) revealed that neem leaf powder dry dressed @ 40 g maintained 73 per cent germination after five months of storage in cowpea.

Jharnasom *et al.* (1995) reported that in greengram seed treatment with neem leaf powder @ 40 g kg^{-1} improved the germination and vigour.

Banjo and Mabogunge (1999) expressed that this leaf powder exerted protection against bruchid.

Patil (2000) reported that seed treatment with neem leaf powder recorded higher germination (65 per cent) and vigour index (1212) compared to control (60 per cent and 1208 respectively) at the end of ten months of storage period in chickpea seeds.

Misra (2000) in black gram revealed that neem leaf powder @ 30 g exerted protection against oviposition and insects up to five months of storage. While in chickpea, Merwade (2000) reported that sweet flag, wood ash and neem leaf powder @ 10 g kg^{-1} of chick pea seeds, offered excellent protection over bruchid infestation for a storage period of ten months.

Buraimoh *et al.* (2000) in cowpea revealed that seed treatment with neem leaf powder @ 125 to 250 g kg^{-1} of seed controlled the oviposition and adult emergence.

In peas, Singh *et al.* (2001) reported that seed treatment @ 10 g kg^{-1} of seed minimized the bruchid damage by 2.66 per cent and reduced the loss in weight. Neem leaf powder @ 20 g maintained 90 per cent germination upto three months of storage in blackgram as per Tripathy *et al.,* (2001).

In pigeon pea seeds treated with neem leaf powder @ 50 g kg^{-1} of seeds maintained the germination up to 24 months of storage as reported by Parameswari (2002).

Maraddi (2002) observed that cowpea seeds treated with neem leaf powder @ 5 g kg^{-1} of seed recorded higher germination (71 per cent) and vigour index (1072) compared to control (34 per cent and 864, respectively) at the end of tenth month storage period.

Deshpande *et al.* (2004) observed that blackgram seeds treated with neem seed kernel powder recorded significantly higher germination, seedling vigour index (91 per cent and 2009, respectively) whereas control recorded the minimum (89 per cent and 1701, respectively).

Treating the black gram with neem leaf powder @ 5 g kg^{-1} of seed enhanced the germination and vigour index values as per Manimekalai (2006).

Oyekale *et al.* (2012) treated sesame seeds with neem leaf powder (NLP) @ 75 g kg^{-1} of seed and found that, it enhanced better seedling growth, vigour index (339) throughout the storage period of eighteen weeks. Neem leaf powder @ 5 g kg^{-1} of cowpea seeds recorded higher germination and vigour index after ten months of storage as observed by Maradi (2002).

Umarani and Vanangamudi (1999) reported that seeds treated with neem leaf powder protected seed from faster deterioration and resulted in better maintenance of seed germinability and seedling vigour in Casuarinas.

Maradi (2002) observed that, cowpea seeds recorded higher germination and vigour index after ten months of storage when treated with neem leaf powder @ 5 g kg^{-1} of seeds.

When pigeonpea seeds were treated with neem leaf powder @ 50 g kg^{-1} of seeds, they maintained germination even after twenty four months of storage (Parameswari 2002).

Channabasanagowda *et al.* (2008) in soybean treated seeds with neem seed kernel powder @ 5 g kg^{-1}, neem oil @ 5 ml kg^{-1}, nimbicidne @ 5 ml kg^{-1}, neem leaf powder @ 5 g kg^{-1} and sweet flag rhizome powder @ 5 g kg^{-1} of seed and stored in gunny bag recorded better germination percentage and seed quality characters at the end of tenth month of storage.

Khatun *et al.* (2011) reported that lentil seeds treated with leaf powder of neem (*Azadirachta indica*), bishkatali (*Polygonum hydropiper*) and dholkalmi (*Ipomea sepiara*) and @ 25 g/500 g showed higher seed quality parameters.

Dry dressed cowpea seeds with neem fruit dust @ 10 g kg^{-1} (w/w) protected the seeds from bruchids for four months and maintained germination (Tanzubii, 1989).

Nwachukwe *et al.* (2001) stated that African yam bean seeds treated with leaf extracts of neem leaf shows higher germination and seedling emergence

Seed invigoration with two per cent neem leaf extract or two per cent moringa leaf extract for four hours resulted in better morphological characters, yield components, shelling percentage and seed yield in black gram (Manimekalai 2006).

Pungam leaf powder:

Vyakaranahal *et al.* (2000) in sunflower inferred that seed treated with pungam leaf powder @ 4 g kg^{-1} of seed maintained significantly higher seed germination, root length, shoot length and vigour index compared to control after accelerated ageing at 45 ± 1°C temperature and 95 ± 1 per cent RH for four days.

In ragi, Punithavathi (1997) reported that seed fortification with one per cent pungam leaf extract for twelve hours improved the vigour index by 47 per cent and also the seed yield and it was followed by seeds hardened with one per cent prosopis leaf extract. In black gram, cv. CO 5 seeds hardened with leaf extract one per cent of *Pongamia pinnata* enhanced seed germination and seedling vigour as compared to control.

Renugadevi *et al.* (2008) in cluster bean concluded that seed fortification with pungam (*Pongamia pinnata*) leaf extract at one and two per cent concentrations for three hours expressed superior germination, vigour and field emergence.

Arappu leaf powder:

Vadivelu *et al.* (1985) reported that bengal gram seeds treated with arappu leaf powder @ 50 g kg^{-1} of seeds maintained germination up to two seasons.

According to De *et al.* (2003) wheat seeds treated with arappu leaf powder, showed better results in improving storability, yield and other yield attributes and also noticed that the treatments were equally effective in all seed sizes (large, medium and small) of the same seed lot.

Renugadevi *et al.* (2008) in cluster bean concluded that seed fortification with arappu *(Albizia amara)* leaf extract at one and two per cent concentrations for three hours expressed superior germination, vigour and field emergence.

Notchi leaf powder

Vadivelu *et al.* (1985) in bengal gram treated the seeds with notchi (*Vitex negundo*) leaf powder @ 50 g kg^{-1} of seed and found that it maintained the germination up to two seasons.

Sabir-ahamed (1989) in soybean and Paramasivam (1990) in pea seeds treated the seeds with notchi leaf powders in the ratio of 1:100 w/w and found that it maintained more than 70 per cent germination after eight months of storage.

In chickpea, seed treatment with notchi (*Vitex negundo*) leaf powder was most effective in reducing number of eggs laid, adult emergence of pulse beetle and seed weight loss during the ten months of storage period (Maih *et al.,* 1993).

Cowpea seeds treated with notchi leaf powder @ 50 g maintained 89 per cent germination after nine months of storage (Anandi, 2001).

Malarkodi (2003) reported that greengram seeds treated with notchi dry leaf powder @ 100 g kg^{-1} of seed maintained 88 per cent of germination after twenty one months of storage and protected the seeds from bruchids.

Catharanthus leaf powder

Mandal *et al.* (2000) confirmed that freshly harvested soybean seeds dry dressed with finely powdered *Catharanthus* leaf powder @ 2 g kg^{-1} of seed improved the germinability over control.

Kapri *et al.* (2003) found that dry treatments showed better germinability than wet treatments when both were given as a pre-storage treatment. The invigoration effect of the dry treatments was particularly noticeable with periwinkle leaf powder in okra seeds.

Datura leaf powder

Yadava and Bhatnagar (1987) revealed that cowpea seeds treated with *Datura* leaf powder @ 10 g kg^{-1} maintained 71 per cent germination up to five months of storage.

Misra (2000) treated blackgram seeds with datura (*Datura metel)* leaf powder @ five per cent and found it reduced oviposition and protected from bruchids up to five months.

Vasambu leaf powder

Malarkodi (2003) reported that greengram seeds treated with vasambu (*Acorus calamus*) rhizome powder at 100 g kg^{-1} of seed maintained 87 per cent of germination after twenty one months of storage and protected the seeds from bruchids.

In pulses, Anandi (2001) concluded that cowpea seeds treated with *Acorus calamus* rhizome powder were observed to be highly germinable with longer root and shoots, higher dry matter production, better cell membrane integrity and protein content as compared to untreated seed and other seed treatments.

Kokila (2012) in greengram treated seeds with *Acorus calamus* rhizome powder @ 3 g kg^{-1} of seed and found that it maintained the seed germination above the seed certification requirements up to nine months of storage period with minimum loss in vigour and seed health.

Sweet flag rhizome powder

Channabasanagowda *et al.* (2008) reported that seed treatment with sweet flag rhizome powder at 10 g kg^{-1} of seed improved storability of wheat seeds by recording higher germination percentage and vigour index with lower electrical conductivity than control at the end of ten months of storage.

Deshpande *et al.* (2004) observed that blackgram seeds treated with sweet flag rhizome powder recorded significantly higher germination, seedling vigour index (93 per cent and 2275, respectively).

Muskmelon seeds when treated with sweet flag rhizome powder @ 10 g kg^{-1} seeds recoded better germination, seedling dry weight and vigour index at the end of ten months of storage (Roopa, 2006).

Rhizome powder and have been found to be very effective in the maintenance of vigour, viability and productivity of wheat, soybean and okra seeds (De *et al.*, 2003; Mandal *et al.*, 2000 and Kapri *et al.*, 2003).

Holybasil powder

Banjo and Mabogunge (1999) revealed that cowpea seeds treated with *Ocimum gratissimum* @ 100 g kg^{-1} of seed reduced the seed damage and maintained the germination.

Odutayo *et al.* (2001) also revealed that cowpea seeds treated with *Ocimum gratissimum* leaf powder @ 50, 100 and 150 g kg^{-1} of seed protected the seed against bruchids.

Biskatali leaf powder

Rouf *et al.* (1996) dry dressed lentil seeds with *Polygonum hydropiper* leaf powder @ 80 g kg^{-1} of seed and found that it reduced oviposition and adult emergence of bruchids and maintained the germination.

Khatun *et al.* (2011) reported that lentil seeds treated with leaf powder of bishkatali (*Polygonum hydropiper*), dholkalmi (*Ipomea sepiara*) and neem (*Azadirachta indica*) @ 25 g/ 500 g showed higher seed quality parameters.

Red chilli fruit powder

In wheat, De *et al.* (2003) observed that finely powdered dry red chilli fruit @ 1 g kg^{-1} of seed improved the storability over control.

In pulses, Mandal *et al.* (2000) confirmed that freshly harvested soybean seeds dry dressed with finely powdered dry red chilli fruit @ 1 g kg^{-1} of seeds had improved the germination over control.

In onion, Sengupta *et al.* (2005) demonstrated on pre-storage dry seed invigouration treatments for high vigour seeds with red chilli powder and found it improved the storability of seed and field performance.

Layek *et al.* (2006) also observed that dry treatments in high vigour gram seeds with red chilli powder @ 1 g kg^{-1} of seed improved storability and field performance over control.

De *et al.* (2004) reported that powder of dry red chilli fruit @ 1 g kg^{-1} of seed improved storability in wheat seeds.

Other botanicals:-

Sabir-ahamed (1989) in soybean and Paramasivam (1990) in pea seeds treated seeds with sambangi leaf powder (*Polianthes tuberosa*) @ 1:100 w/w and found it maintained more than 70 per cent germination up to eight months of storage.

According to Dixit and Saxena (1990) pulses seeds treated with *Premina integrifolia* leaf powder @ 250, 300 and 500 g kg^{-1} arrested the oviposition in storage of seeds.

Okonkwo and Okoye (1992) treated castor (*Ricinus communis*) leaf powder @ 3 to 10 g kg^{-1} of cowpea seed and found that it protected the seeds from bruchids up to three months.

Greengram seeds treated with mangraila (*Nigella sativa*) leaf powders found to reduce egg laying, adult emergence and seed damage by Kumari and Singh (1998).

According to Banjo and Mabogunge (1999) cowpea seeds treated with jatropha (*Jatropha curcas*) leaf powder @ 100 g kg^{-1} of seed reduced the seed damage and maintained the germination in storage.

Misra (2000) revealed that black gram treated with begonia (*Begonia bicolor*) @ 3 g kg^{-1} of seed protected the seed against oviposition and insect damage upto five months.

Elhag (2000) treated gram seeds with *Rhazya stricta* leaf powder and found it restricted the oviposition to 82 per cent.

Tripathy *et al.* (2001) treated the blackgram seeds with 20 g of *Eupotorium sp.* leaf powder and found that it, maintained 90 per cent germination up to three months and have 50 per cent insect mortality, while the same seeds treated with 40 g of *Gladulosum sp.* leaf powders maintained 92 per cent germination after three months and have 67 per cent insect mortality. They also reported that black gram seeds treated with 20 g leaf powder of Vettukayapoondu (*Tridax procumbens*) maintained 90 per cent germination after three months and have 70 per cent insect mortality.

Lawal (2001) dry dressed cowpea seeds with clove (*Eugenia aromatica*) and *Dennethatri petala* @ 10, 20 & 30 g kg^{-1} of seed and found they discouraged oviposition and minimized the damage. But the seed viability and quality were unaffected.

Seed treatment of pea seeds with *Chenopodium ambrosioides* @ 0.4 per cent (w/w) was found to kill more than 60 per cent of bruchids two days after treatment as per Tapondjou *et al.* (2002).

Lopes *et al.* (2002) revealed that cowpea seeds treated with tobacco (*Nicotiana tabaccum*) leaf powder prevented bruchid infestation and maintained the physical and physiological quality of seed.

In sesame, Oyekale *et al.* (2012) treated seeds with dress force powder @ 5 g kg^{-1} (DFP) (synthetic), dry pepper powder @ 75 g kg^{-1} seed (DPP) and the observations showed that DPP treatments had better mean seed germination of 82 per cent compared to DFP (46 per cent) and control (80 per cent). They recommended that natural botanicals could be adopted for short and medium term storage of seeds for eighteen weeks.

Menaka (2003) reported that sorghum seeds soaked in ten per cent prosopis leaf extract for six hours excelled others in producing vigourous seedlings, which recorded maximum vigour index, plant height, panicle length and yield.

According to Manimekalai (2006) germination percentage and seedling vigour of one year old black gram seeds could be improved by soaking the seeds in two per cent prosopis leaf extract for four hours.

Gaurav *et al.* (2013) noted that maize and soybean seeds treated with 0.25 per cent of garlic and 0.5 per cent of turmeric extracts and *Trichoderma harzianum* in combination with kaolin @ 4 g kg^{-1} enhanced germination per cent.

According to Suma (2005) sesame seeds fortified with tamarind leaf extract at one and two per cent maximized seed germination by 88 and 85 per cent, respectively.

Lowell (2005) opined that seed treatment with juice from fresh moringa leaves increases yield by 25-30 per cent in onion, bell pepper, soya, maize, sorghum, coffee, tea, chili, melon and reported that moringa leaf juice contains cytokinin group hormone namely zeatin, which favours increased seed yield.

Nouman *et al.* (2012) reported that seed priming with moringa leaf extract (1:30) produced vigourous root in *Cenchrus ciliaris* and *Panicum antidotale* while it improved the number of leaves, number of tillers and shoot vigour in *Echinochloa crus-galli.*

Leaf extracts of moringa induced beans to germinate early and increased germination percentage of cowpea and hypocotyl length in groundnut (Phiri and Mbewe, 2010).

Manimekalai (2006) revealed that soaking black gram seeds in two per cent moringa leaf extract for four hours improved germination and seedling quality characters.

In cowpea, Seck *et al.* (1996) treated seeds with *Boscia senegalense* fruit powder @ 1.2 to 4.8 g kg^{-1} of seed and found that it reduced the adult emergence and completely inhibited the production of new generation.

In cowpea, seeds dry mixed (Banjo and Mabogunge, 1999) with pepper (*Piper nigrum*) seed powder found to prevent adult emergence.

2.4. Influence of seed treatment with nano size botanicals

Nanotechnology is a broad and interdisciplinary area of research and development growing at a rapid pace worldwide in the past few years. The main thrust of research in nanotechnology focuses on applications in the field of electronics (Feiner, 2006), energy (Hu and Chen., 2007), medicine and life sciences (Caruthers *et al.*, 2007). There are few research works on application of nano particles in seed science. Nano particles are utilized to improve germination in wheat, emergence and growth of seedlings (Zhang *et al.*, 2006). Impregnation of nano particles into seed had a positive impact on performance.

Onion seeds invigourated with nano size (one hour ball milling) leaf powder of custard apple @ 2 g kg^{-1} of seed and shaken for one hour enhanced germination and vigour reported by Mythili (2012).

Tomato seeds dry dressed with near nano size fenugreek seed powder with one hour ball milling @ 2 g kg^{-1} for two hours recorded higher seed quality parameters (Vijayalakshmi, 2012).

Recent studies on seed treatment with botanicals revealed that, dry dressing of seeds with nano size leaf powder of custard apple at 2 g kg^{-1} of seed and shaken for one hour enhanced germination, vigour and field emergence in onion (Mythili, 2012).

Hridya (2013) concluded that seed treated with botanicals *viz.*, fenugreek seed powder, ashwagandha leaf powder, tea leaf powder and noni leaf powder ball milled for two hours and treated @ 2 g kg^{-1} of seed to improved seedling quality characters in terms of root, shoot length, vigour index and dry matter production in soybean.

Krishnashyla (2014) reported that, the ball milled fenugreek seed powder @ 2 g kg^{-1} and custard apple leaf powder @ 3 g kg^{-1} of seed recorded higher germination and seedling vigour in groundnut.

2.5. Seed microflora

Christensen and Kaufmann (1969) suggested that the field fungi and other microorganisms are unable to grow under limited moisture conditions. Seed viability, seedling vigour and chemical composition of seeds were adversely affected by the storage fungi.

Crop	Organism observed	Reference
1. Chilli	*Colletotrichum capsici* *Curvularia lunata* *Rhizopus stolonifer* *Aspergillus flavus* *Fusarium moniliforme*	Alam *et al.* (2014)
	Alternaria sp *Fusarium* sp *Aspergillus* sp *Colletotrichum* sp	Kavitha (2007)
2. Paddy	*Curvularia* sp *Fusarium* sp *Heliminthosporium oryzae* *Nigrospora oryzae* *Pyricularia oryzae*	Neergard and Saad (1962)
	Curvularia sp *Drechslera* sp *Nigrospora* sp *Trichothecium* sp *Fusarium* sp *Aspergillus* sp *Penicillium* sp	Ali and Deka (1996)
	Chaetomium globosum *Fusarium moniliforme* *Aspergillus* sp *Drechslera* sp *Verticillium* sp *Rhizopus* sp	Babo and Lokesh (1996)

	Drechslera oryzae *Fusarium* sp *Curvularia* sp *Aspergillus* sp *Rhizopus* sp	Chaudhry and Sharma (1986)
3. Maize	*Fusarium moniliforme* *Ceplasporium acremonium* *Aspergillus* sp *Penicillium* sp *Rhizopus* sp	Yap and Kulshreshta (1975)
	Alternaria alternata *Aspergillus flavus* *Fusarium moniliforme* *Penicillium expansum* *Rhizopus nigricans* *Trichoderma viridae*	Paul and Mishra, 1994
4. Sorghum	*Alternaria alternata* *Aspergillus flavus* *A. niger* *A. sydowi* *A. terreus,* *Curvularia. lunata* C. *pallescens* *Penicillium isolicum* *P. perpurrogenum* *F. solani*	Bhadraiah and Ramarao (1987)
	A. alternata C. *lunata* C. *lunata* var. *aeria,* *Epicoccum purpurescens* Ehrenb. ex. Schlecht, *F. moniliforme* *F. semitectum*	Anahosur and Hegde (1979)

	Gonatobotrys simplex Corda *D. specifer* *P. sorghina* *T. roseum*	
	F. moniliforme *F. semitectum* *F. oxysporum*	Mahalinga (1982)
5. Sunflower	*Aspergillus flavus* *A. niger* *Alternaria alternata* *Curvularia lunata* *Fusarium moniliforme* *F. oxysporum* *F. semitectum* *Penicillum digitatum* *Stemphylium* sp *Trichoderma* sp	Wakil (2014)
	Plasmopara halstedii	Basavaraju *et al.* (2004)
	Aspergillus flavus *Aspergillus niger*	Saxena and Karan (1991)
6. Sesame	*Aspergillus flavus* *Aspergillus niger*	Saxena and Karan (1991)
7. Groundnut	*Aspergillus flavus* *Aspergillus niger* *Fusarium* sp *Penicillum* sp	Krishnappa *et al.* (2003)
8. Soybean	*Aspergillus* sp *Penicillium* sp *Rhizopus* sp *Nigricans* sp.	Krishnamurthy and Raveesha (1996)

Materials and Methods

3. MATERIALS AND METHODS

Extending the viability of seeds during storage is essential in any seed production programme. Seed treatments aid in prolonging the viability and vigour of seeds. An investigation intended to elucidate the effects of botanicals and comparing the efficacy of normal grade and nano size botanicals on seedling vigour in chilli was undertaken in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara, Thrissur during 2015 - 2016. The details of the materials used and techniques utilized during the course of the study are described hereunder:-

3.1. Location

The storage experiment was conducted under ambient conditions in the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Vellanikkara, Thrissur, during February 2015 - March 2016 (Table 1).

3.2. Experiment material

Freshly harvested chilli seeds of variety Anugraha and Ujwala obtained from the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Thrissur and Agricultural Research Station, Mannuthy, Thrissur respectively were used for the study. The seeds of variety Anugraha and Ujwala were dried to around 6 and 7 per cent moisture content, respectively. Initial seed quality parameters were recorded before commencement of treatment.

3.3. Experiment details

The present study consisted of three experiments using two varieties of chilli (Anugraha and Ujwala) as follows,

Experiment 1: Seed treatment with normal grade botanicals

Experiment 2: Seed treatment with nano size botanicals

Experiment 3: Field performance of seeds treated with botanicals

Table 1: Monthly meteorological data from February 2015 to March 2016

Months	Temperature		Relative humidity (%)	Rainfall (mm)	Rainy days
	Mean maximum	Mean minimum			
Feb-15	34.3	23	55	0	0
Mar-15	35.8	24.9	63	72	2
Apr-15	34	24.6	77	162.2	8
May-15	32.9	24.7	80	259	12
Jun-15	31	23.9	85	629.8	23
Jul-15	30.3	23.5	85	510.1	23
Aug-15	31	23.7	83	320.8	17
Sep-15	31.9	23.7	81	242.2	12
Oct-15	32.5	24.1	79	203.8	15
Nov-15	31.6	23.8	75	151.2	8
Dec-15	32.3	23.3	65	88.3	3
Jan-16	33.2	23	56	23.8	1
Feb-16	35.3	23.5	57	11.4	1
Mar-16	36.3	25.2	67	9.8	1

3.3.1. Experiment 1: Seed treatment with normal grade botanicals

3.3.1.1. Treatment details

The study involved five commonly used botanicals namely *viz.*, arappu (*Albizia amara*), fenugreek (*Trigonella foenum-graecum*), pungam (*Pongamia glabra*), custard apple (*Anona squamosa)* and neem (*Azadirachta indica*).

3.3.1.2. Seed treatment procedure

The fresh leaves of botanicals collected from different sources were shade dried and then dried in hot air oven at 60°C. The dried samples were ground in mixer grinder and sieved through wire mesh sieve of 0.1 mm size. These powders were referred to as 'normal grade powders' and they were used for seed treatment in Experiment 1 (Plate 1).

3.3.1.3. Method of storage

Chilli seeds were pre-treated with each of the normal grade botanicals as detailed in table 2. The treated seeds along with the control were packed in 400 gauge polyethylene bags. The polyethylene bags were heat sealed and stored under ambient conditions and observations recorded at monthly intervals for a period of fourteen months.

3.3.2. Experiment 2: Seed treatment with nano size botanicals

3.3.2.1. Treatment details

The five botanicals used in the previous experiment (as 3.3.1.1) were utilized in this experiment.

3.3.2.2. Seed treatment procedure

The fresh leaves of botanicals collected from different sources were shade dried and then dried in hot air oven maintaining at 60°C. The dried samples were ground in mixer grinder and sieved through wire mesh sieve of 0.1 mm size. These powders which were referred to as 'normal grade powders' were further ball milled using FRITSCH, PULVERISETTE 7 HIGH ENERGY BALLMILL (Plate 2) at 600 rpm with 15 min on-off cycle for three hours to reduce the particle size to nano dimension. These powders were referred to as 'nanopowders'. In order to ensure their nano size they were characterized further in Particle Size Analyser and they were used for seed treatment in Experiment 2.

Plate 1: Normal grade leaf powders of botanicals

Arappu leaf powder

Fenugreek leaf powder

Pungam leaf powder

Custard apple leaf powder

Neem leaf powder

Table 2: Treatment details of normal grade botanicals

Treatments	Name of the botanical	Abbreviations used
T_1: Control	Untreated	-
T_2 : ALP@ 0.5g kg^{-1}	Arappu leaf powder	ALP
T_3 : ALP@ 1g kg^{-1}	Arappu leaf powder	ALP
T_4 : ALP@ 2g kg^{-1}	Arappu leaf powder	ALP
T_5 : FLP@ 0.5g kg^{-1}	Fenugreek leaf powder	FLP
T_6 : FLP@ 1g kg^{-1}	Fenugreek leaf powder	FLP
T_7 : FLP@ 2g kg^{-1}	Fenugreek leaf powder	FLP
T_8 : PLP@ 0.5g kg^{-1}	Pungam leaf powder	PLP
T_9 : PLP@ 1g kg^{-1}	Pungam leaf powder	PLP
T_{10} : PLP@ 2g kg^{-1}	Pungam leaf powder	PLP
T_{11} : CLP@ 0.5g kg^{-1}	Custard apple leaf powder	CLP
T_{12} : CLP@ 1g kg^{-1}	Custard apple leaf powder	CLP
T_{13} : CLP@ 2g kg^{-1}	Custard apple leaf powder	CLP
T_{14} : NLP@ 0.5g kg^{-1}	Neem leaf powder	NLP
T_{15} : NLP@ 1g kg^{-1}	Neem leaf powder	NLP
T_{16} : NLP@ 2g kg^{-1}	Neem leaf powder	NLP

Table 3: Treatment details of nano size botanicals

Treatments	Name of the botanical	Abbreviations used
T_1: Control	Untreated	-
T_2 : ALP@ 0.5g kg^{-1}	Arappu leaf powder	ALP
T_3 : ALP@ 1g kg^{-1}	Arappu leaf powder	ALP
T_4 : ALP@ 2g kg^{-1}	Arappu leaf powder	ALP
T_5 : FLP@ 0.5g kg^{-1}	Fenugreek leaf powder	FLP
T_6 : FLP@ 1g kg^{-1}	Fenugreek leaf powder	FLP
T_7 : FLP@ 2g kg^{-1}	Fenugreek leaf powder	FLP
T_8 : PLP@ 0.5g kg^{-1}	Pungam leaf powder	PLP
T_9 : PLP@ 1g kg^{-1}	Pungam leaf powder	PLP
T_{10} : PLP@ 2g kg^{-1}	Pungam leaf powder	PLP
T_{11} : CLP@ 0.5g kg^{-1}	Custard apple leaf powder	CLP
T_{12} : CLP@ 1g kg^{-1}	Custard apple leaf powder	CLP
T_{13} : CLP@ 2g kg^{-1}	Custard apple leaf powder	CLP
T_{14} : NLP@ 0.5g kg^{-1}	Neem leaf powder	NLP
T_{15} : NLP@ 1g kg^{-1}	Neem leaf powder	NLP
T_{16} : NLP@ 2g kg^{-1}	Neem leaf powder	NLP

3.3.2.2.1. Ball milling

Principle

The ball mill, a key piece of equipment for grinding crushed materials, is a cylindrical device, which rotates around horizontal axis partially filled with the material to be ground along with the grinding medium. The grinding works on the principle of critical speed. The critical speed can be understood as that speed after which the steel balls (which responsible for the grinding of particles) starts rotating along the direction of the cylindrical device; thus causing no further grinding. The grinding balls in the grinding jars are made up of steel, lined with high carbon steel plate, porcelain or silica rocks which are subjected to super imposed rotational movements, called coriolis forces. For medium and fine reduction of abrasive materials, ball mills are used. In a ball mill, size reduction is achieved by impact of the balls. The difference in speed between the balls and grinding jars produces an interaction between the frictional and impact forces, which releases high dynamic energies. The interplay between these forces produces high and very effective degree of size reduction of the sample (Sahay and Singh, 2001).

3.3.2.2.2. Particle size analyzer (PSA)

Particle size and the distribution pattern of synthesized sample suspensions were determined using Horiba Scientific Nanoparticle SZ-100 (Nanoparticle analyser), Japan. Accurately, 0.5 mg sample was dispersed in 20 ml distilled water, sonicated for 15 min and the suspension was analyzed under dynamic light scattering method using 90° or 173° at 25°C (Plate 2).

3.3.2.2.3. Scanning Electron Microscope (SEM)

SEM FEI QUANTA 250 was used to characterize the size and morphology of the nanoparticles. Sample of test nanoparticles (0.5 to 1.0 mg) was dusted on one side of the double sided adhesive carbon conducting tape and mounted on the 12 mm dia aluminum stub. Sample surface was observed at different magnifications and the images were recorded.

Plate 2: Instruments used for synthesis of nanopowders

Fritsch, Pulverisette 7 High Energy Ball mill

Horiba Scientific Nanoparticle SZ-100 (Nanoparticle analyser)

3.3.2.3. Method of storage

Chilli seeds were pre-treated with each of the nano sized botanicals as detailed in table 3. The treated seeds along with the control were packed in 400 gauge polyethylene bags. The polyethylene bags were heat sealed and stored under ambient conditions and observations recorded at monthly intervals for a period of fourteen months.

3.3.3. Experiment 3: Field performance of seeds treated with botanicals

3.3.3.1. Treatment details

All the treatments of Experiment 1 (as 3.3.1) and Experiment 2 (as 3.3.2) were raised in the field to study the effect of the botanical seed treatments on field performance. The treated chilli seeds of Anugraha and Ujwala were raised in nursery and transplanted after 30 days of sowing.

Season	September – October
Plot size	2 x 1.5 m
Spacing	60 x 45 cm
Replication	3
Design	RBD

The crop was raised with the recommended package of practices of Kerala Agricultural University and observations on the following characters were recorded on five random plants of each replication.

3.4. Observations

3.4.1 Germination (%)

In each treatment, 400 seeds per replication were randomly sampled from each replication and used to conduct standard germination test as per procedure advocated by ISTA for rolled paper towel method. Germination test through between papers was conducted at 25 ± 2^{0}C and 90 ± 3 per cent relative humidity in the presence of light (ISTA, 1999). On 14th day, the total number of normal seedlings were counted and expressed in per cent.

3.4.2. Seedling shoot length (cm)

Ten normal seedlings were selected randomly from each replication of the treatment at the end of the germination test and the shoot length was measured from the base of primary leaf to the collar region. The mean shoot length was expressed in centimetre.

3.4.3. Seedling root length (cm)

Ten seedlings used for measuring the shoot length were used to record the root length. The root length of each seedling was measured from collar region to the tip of primary root. The mean root length was expressed in centimetre.

3.4.4. Seedling dry weight (mg)

Ten seedlings used for measuring shoot and root length, were placed in a butter paper cover dried in a hot air oven maintained at 85 ± 1°C for 24 hours as per ISTA (2007). Then the seedlings were removed and allowed to cool in desiccators for 30 minutes before weighing in digital balance and expressed in milligram.

3.4.5. Vigour index I

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

Vigour index I = Germination (%) x Seedling length (cm)

3.4.6. Vigour index II

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

Vigour index II = Germination (%) x Seedling dry weight (mg)

3.4.7. Electrical conductivity of seed leachate (dSm^{-1})

The observation on electrical conductivity of seed leachate (EC) was recorded using five gram seeds of each replication, weighed up to two decimal places. The seeds were treated with mercuric chloride (0.1 per cent) for half a minute and were thoroughly washed in distilled water two to three times. The seeds were soaked in 25 ml distilled water. The containers were placed in an incubator maintained at constant temperature of $25^0C \pm 1^0C$ for 24 hours. After incubation, leachate was collected in a beaker. The EC of the seed leachate was measured in the EUTECH CON-510 digital conductivity meter with a cell constant of 0.1 and recorded as desi Siemons per meter (dSm^{-1}) (Presley, 1958).

3.4.8. Dehydrogenase activity (OD value)

Four replicates of twenty five seeds from each replication of the treatment were soaked in water for eighteen hours. Ten embryos were separated and incubated in darkness with 5 ml of 0.2 per cent Tetrazolium chloride for four hours. After incubation, the excess solution was decanted and the embryos were thoroughly washed with distilled water and surface dried with blotters. The Formazon was eluted by soaking the stained embryos in 5 ml of Methyl cellosolve (2 methoxy ethanol) overnight and the optical density was measured using spectrophotometer at 470 nm (Kittock and Law, 1968).

3.4.9. Seed moisture content (%)

Five gram of seed material from two replication were taken for determining the moisture content through low constant temperature method as per procedure advocated by ISTA (1993). The seeds were ground to coarse powder using grinding 42 mill. The powdered seed material was placed in a weighed airtight aluminium cup with lid. The seed material was placed in hot air oven maintained at 103 ± 2°C and allowed to dry for 17 ± 1 hour after removing the lid. Then, the lid was replaced after the drying period and so the contents were cooled in a dessicator for thirty minutes and weighed in an electronic balance. The moisture content was worked out using the following formula and expressed as per cent (ISTA, 1999).

$$\text{Moisture content (\%)} = \frac{M2 - M3}{M2 - M1} \times 100$$

where,

M1 = weight of the aluminium cup with lid alone

M2 = weight of the aluminium cup with lid + sample before drying

M3 = weight of the aluminium cup with lid + sample after drying

3.4.10. Seed microflora (%)

3.4.10.1. Blotter method

Storage fungi present on seeds were detected using Blotter method as prescribed by ISTA (1999). Twenty five seeds were placed equidistantly on three layered moistened blotter taken in sterilized petriplates. Four replications were kept for each treatment. They were incubated at 20°C for seven days with an alternate cycle of twelve hour near ultra violet range and for remaining twelve hours in dark. On the 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 percentage. The slides were prepared using the fungal growth on seeds and observed under light microscope for identification.

3.4.10.2. Agar plate method

Four replications of ten seeds each per treatment was used in the agar plate method. Seeds were surface sterilized using 0.1 per cent mercuric chloride and placed in a Potato Dextrose Agar media equidistantly under the laminar airflow chamber. The petriplates are packed in a polyethylene cover and kept under the bell jar for incubation. The fungal growth was examined under the stereo binocular microscope.

3.4.11. Plant height (cm)

The height of the plant was measured from the ground level to the tip of the main stem at 120 days after transplanting and expressed in centimetre.

3.4.12. Days to flowering

The number of days taken for 50 per cent flowering in five randomly selected plants from the date of sowing were counted and expressed as whole number.

3.4.13. Number of fruits per plant

Total number of fruits harvested per plant in each of the picking was counted and expressed in number.

3.4.14. Fruit length (cm)

In the randomly selected plants, fruits were collected and their length were measured and expressed in centimetre.

3.4.15. Fruit girth (cm)

In the randomly selected plants, fruits were collected and their girth were measured and expressed in centimetre.

3.4.16. Fruit weight per plant (g)

The fruits were collected from randomly selected plants and were weighed and expressed in gram.

3.4.17. Fruit yield per plant (g)

In the randomly selected plants, fruit yield per plant were found based on the total number of fruits and weight of fruit and expressed in gram.

3.6. Statistical analysis

Statistical analysis of the data on various seed quality parameters was performed using Web Agri Stat Package (WASP) developed by Indian Council of Agricultural Research for completely randomized design and significant test by Duncan's Multiple Range Test (DMRT). The treatment efficacy criteria expressed as per cent and the numbers having low counts and zero values were transformed to square root of (x + 0.5) before analysis of variance (ANOVA). Data obtained were subjected to analysis of variance (ANOVA).

3.6.1. ANOVA for completely randomized design

The data recorded in each observation were analyzed using ANOVA so as to test the differences among two or more independent groups.

Source of variation	Degree of freedom (df)	Sum of squares(SS)	Mean square MS = SS/df	Computed F
Treatment	t – 1	SST	MST	MST/MSE
Error	n – t	SSE	MSE	
Total	N – 1	SSTO		

where,

t – treatments

MSE – error sum of squares

MST – treatment sum of squares

n – number of observations

3.6.2. Pair wise comparison using DMRT test

Duncan's multiple range test (DMRT) is used for experiments that require the evaluation of all possible pairs of treatment means, especially when the total number of treatments is large.

Computation of numerical boundaries that allow for the classification of difference between any two treatments or means as significant or non-significant is done. However, unlike the LSD test in which only a single value is required for any pair comparison at a prescribed level of significance, the DMRT requires computation of a series of values, each corresponding to a specific series, of pair comparisons. The following steps are followed for ranking the data (Gomez and Gomez, 1976).

Step 1: Rank all the treatment means in decreasing (or increasing) order. It is customary to rank the treatment means according to the order of preference.

Step 2: Compute the s_d value following the appropriate procedure.

Step 3: Compute the (t-1) values of the shortest significant ranges as:

$$s_d = \frac{\sqrt{2s^2}}{r}$$

Step 3: Compute the (t - 1) values of the short

$R_p = (r_p)(s_d)$

for p = 2,3,......,t

where,'t' is the total number of treatments,'s' is the standard error of the mean difference computed in step 2, 'r' values are the tabular values of the significant ranges, and 'p' is the distance in rank between the pairs of treatment means to be compared (i.e., p = 2 for the two means with consecutive rankings and p = t for the highest and lowest means).

Step 4: Identify and group together all treatment means that do not differ significantly from each other.

Step 5: Use the alphabet notation according to the ranking to present the test results.

Results

4. RESULTS

Results obtained from laboratory and field studies conducted on application of normal grade and nano size botanicals on seed quality improvement in chilli seeds are presented in this chapter. The data obtained were statistically analyzed and presented below.

4.1. Characterization of nano size powders

The normal grade botanical leaf powders of arappu leaf powder (ALP), fenugreek leaf powder (FLP), pungam leaf powder (PLP), custard apple leaf powder (CLP), and neem leaf powder (NLP) were synthesized into nano size powders using top-down approach by employing high energy ball milling for three hours at the rate of 600 rpm.

4.1.1. Particle size analyzer

The particle size analyzer was used to analyze the size of the particle using dynamic light scattering principle for estimating the average particle size and distribution pattern for nano powders. The particle sizes of arappu leaf powder (ALP), fenugreek leaf powder (FLP), pungam leaf powder (PLP), custard apple leaf powder (CLP), and neem leaf powder (NLP) were analysed as 273 nm, 275 nm, 218 nm, 263 nm and 317 nm, respectively (Figures 1-5).

4.1.2. Scanning Electron Microscope (SEM)

The surface morphology of arappu leaf powder (ALP), fenugreek leaf powder (FLP), pungam leaf powder (PLP), custard apple leaf powder (CLP), and neem leaf powder (NLP) were irregular in shape. After ball milling, the particle size of ALP, FLP, PLP, CLP and NLP were reduced from bulk particle to nano particle (Plate 3).

4.2. Effect of seed treatment with normal grade botanicals on seed quality parameters

4.2.1. Analysis of variance

The analysis of variance on observations recorded at monthly intervals for fourteen months of storage revealed that, significant differences existed among the normal grade treatments on seed qualities like germination per cent, seedling shoot and root length, seedling dry weight, seedling vigour indices, electrical conductivity of seed leachate, dehydrogenase activity and seed infection per cent in both Anugraha and Ujwala.

4.2.2. Germination (%)

In variety Anugraha, the germination of seeds with normal grade botanicals showed significant differences among the treatments and over the period of storage (Table 4). There

Particle size and distribution of nanopowders

Fig 1: Particle size distribution of arappu leaf powder

Z-Average: 27652.1 nm **Peak: 273.5 nm**
PI: 19.974

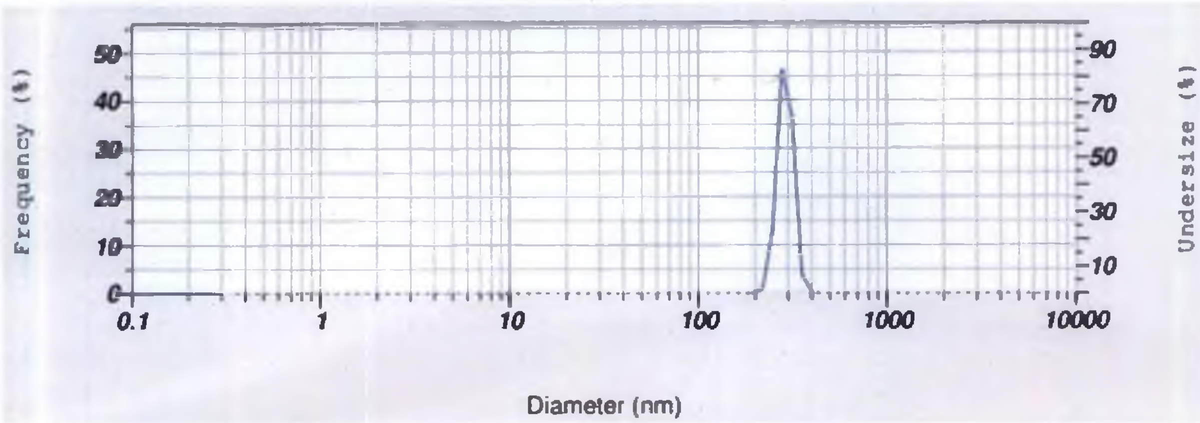


Fig 2: Particle size distribution of fenugreek leaf powder

Z-Average: 31989.6 nm **Peak: 263.2 nm**
PI: 17.039

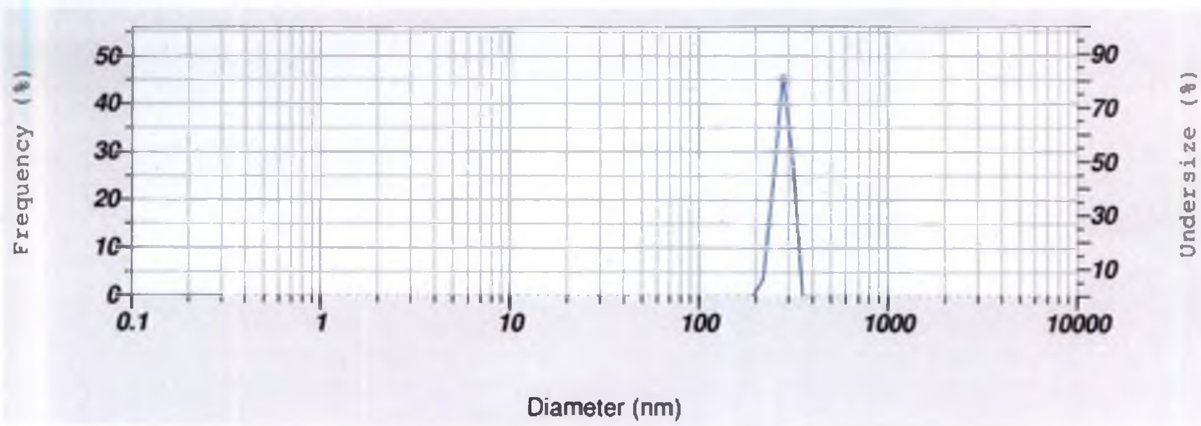


Fig 3: Particle size distribution of pungam leaf powder

Z-Average: 6694.7 nm **Peak: 217.5 nm**
PI: 4.604

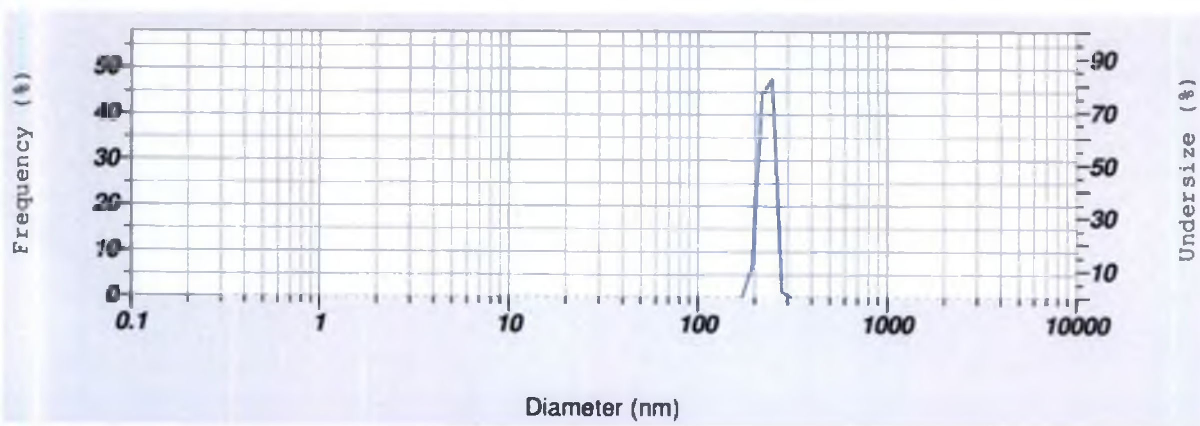


Fig 4: Particle size distribution of custard apple leaf powder

Z-Average: 14959.2 nm **Peak: 317.2 nm**
PI: 20.041

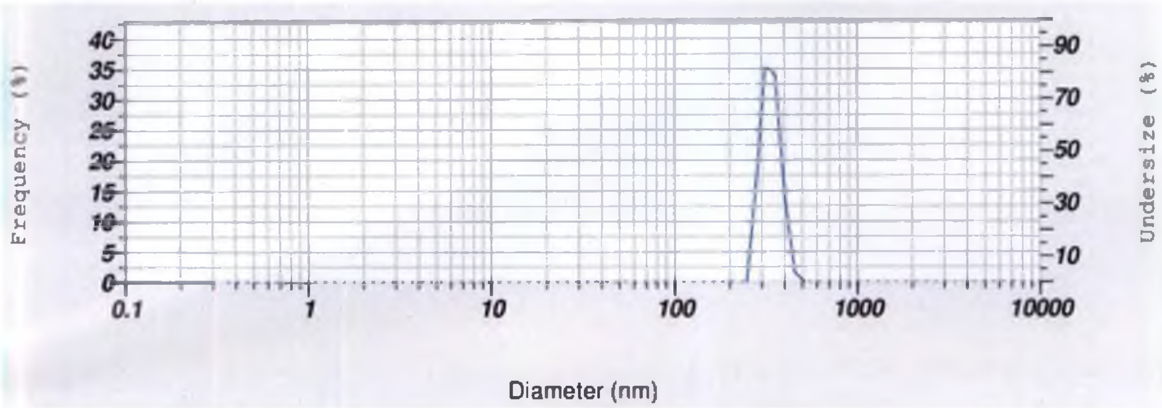


Fig 5: Particle size distribution of neem leaf powder

Z-Average: 21582.3 nm **Peak: 275.1 nm**
PI: 21.993

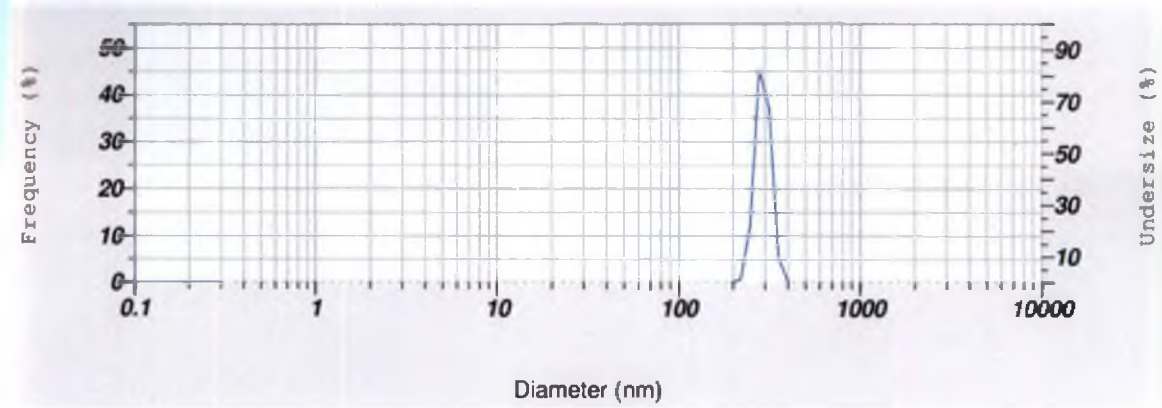
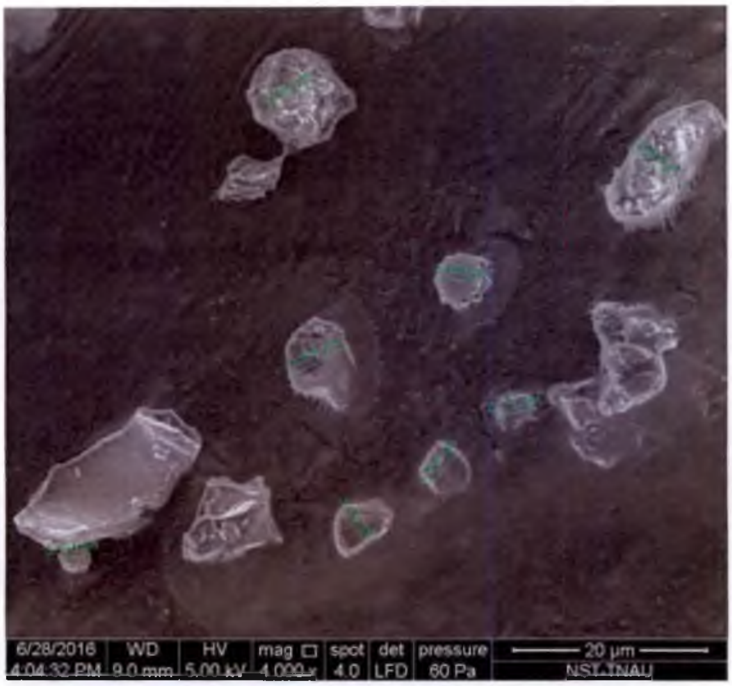
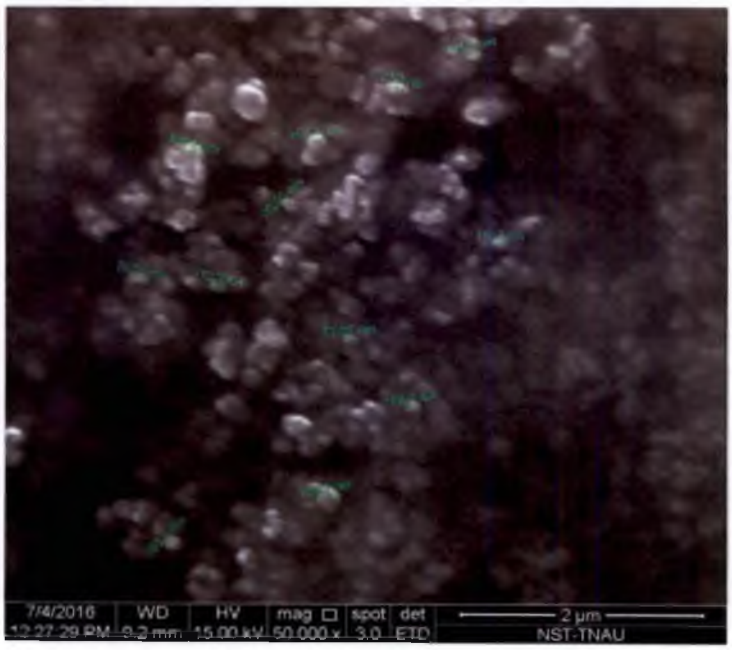


Plate 3: Scanning electron microscope image of leaf powders

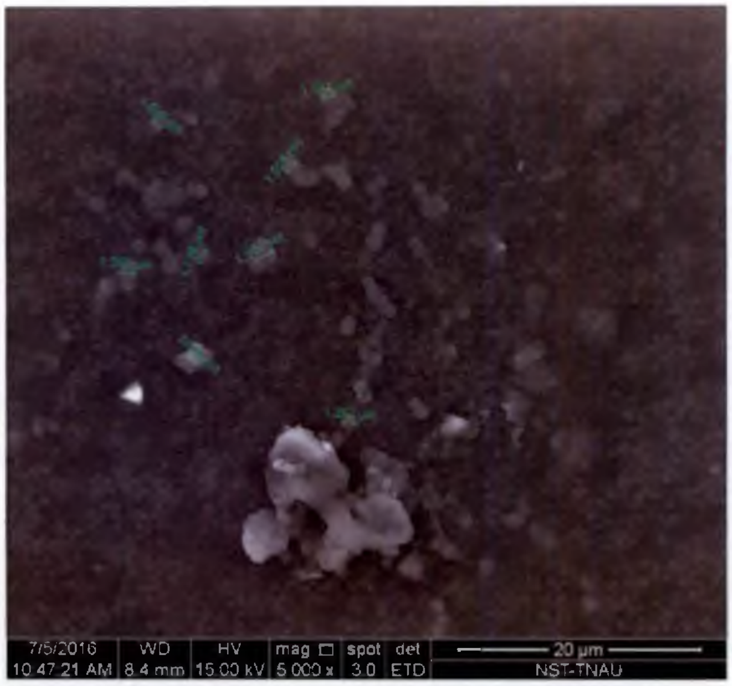


Arappu leaf powder before ball milling

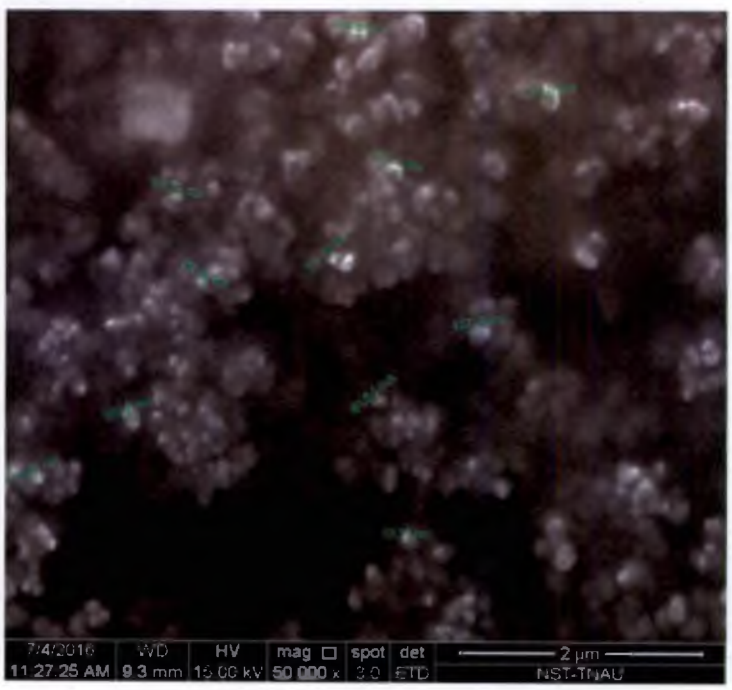


Arappu leaf powder after ball milling

Plate 3 (contd)



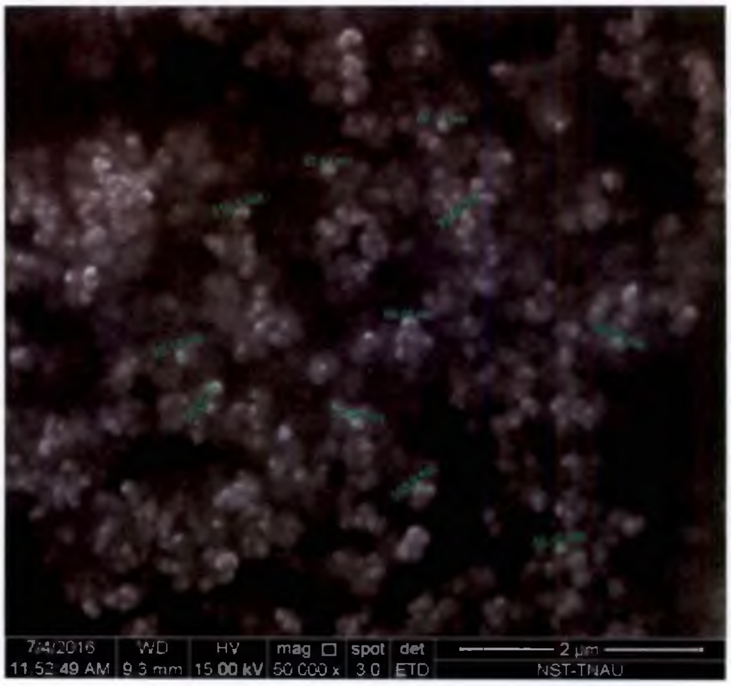
Fenugreek leaf powder before ball milling



Fenugreek leaf powder after ball milling

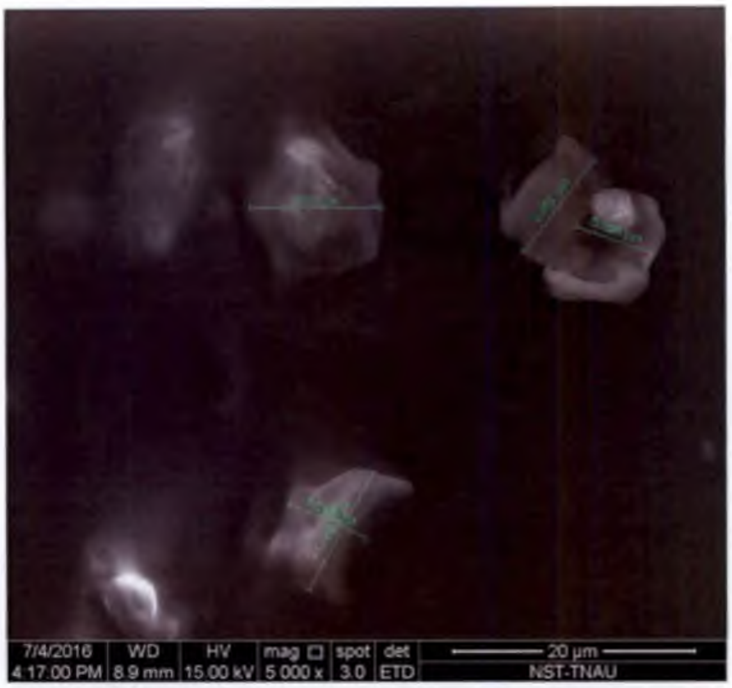
Plate 3 (contd)

Pungam leaf powder before ball milling

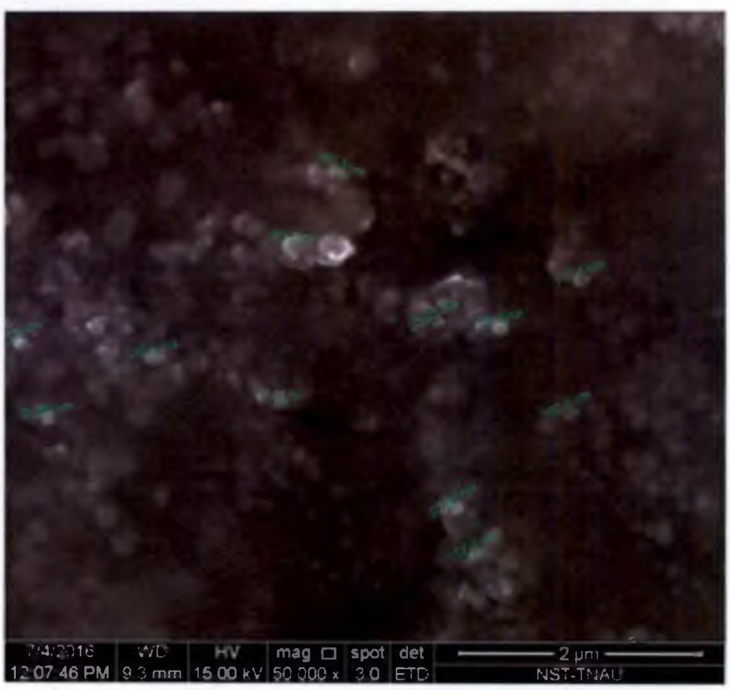


Pungam leaf powder after ball milling

Plate 3 (contd)



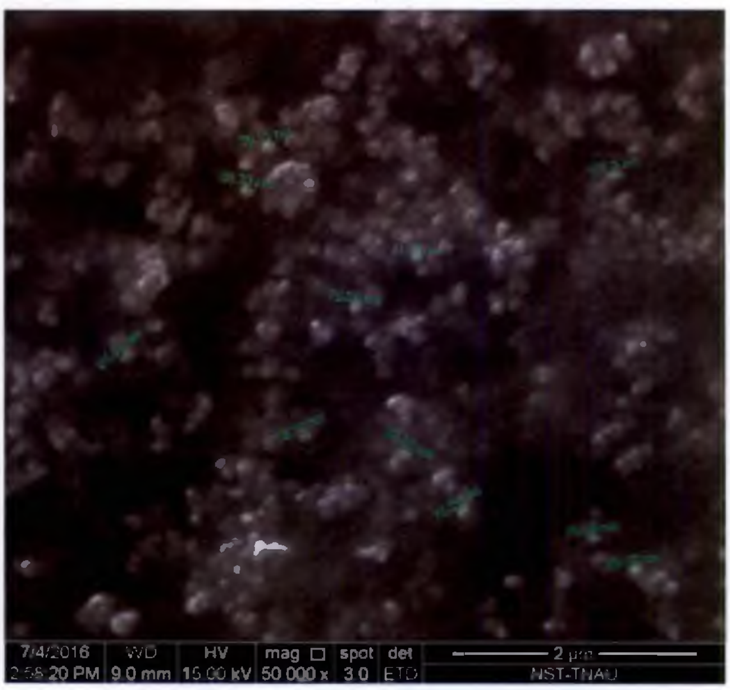
Custard apple leaf powder before ball milling



Custard apple leaf powder after ball milling

Plate 3 (contd)

Neem leaf powder before ball milling



Neem leaf powder after ball milling

Table 4: Effect of normal grade botanicals on germination (%) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	93.33 (9.69)	90.88 (9.56)	85.80 (9.29)	83.50 (9.16)	78.30^{d} (8.88)	75.09^{e} (8.69)	71.72^{d} (8.50)	67.09^{e} (8.22)	64.32^{d} (8.05)	59.48^{e} (7.86)	44.50^{g} (7.51)	36.30^{g} (7.09)	0.00 (0.71)	0.00 (0.71)	60.74 (8.11)
ALP @ 0.5gKg^{-1}	92.80 (9.66)	91.76 (9.60)	90.60 (9.54)	89.28 (9.47)	87.50^{ab} (9.38)	85.09^{ab} (9.25)	80.56^{abc} (9.00)	77.52^{abc} (8.83)	73.66^{bc} (8.61)	70.78^{abc} (8.44)	67.81^{abcd} (8.18)	63.58^{abcd} (8.00)	60.89^{abcd} (7.83)	57.83^{bc} (7.64)	77.83 (8.82)
ALP @ 1gKg^{-1}	92.29 (9.63)	90.80 (9.55)	89.54 (9.49)	89.00 (9.46)	86.18^{abc} (9.31)	82.66^{bcd} (9.12)	80.60^{abc} (9.00)	77.78^{ab} (8.84)	73.40^{bc} (8.59)	68.79^{bcd} (8.32)	64.39^{cdef} (8.05)	61.59^{cde} (7.88)	59.56^{bcde} (7.75)	57.80^{bc} (7.63)	76.74 (8.76)
ALP @ 2gKg^{-1}	93.97 (9.72)	92.95 (9.66)	92.54 (9.64)	90.88 (9.56)	88.89^{a} (9.45)	86.88^{ab} (9.34)	83.93^{a} (9.18)	81.87^{a} (9.07)	78.80^{ab} (8.90)	76.62^{a} (8.78)	72.80^{a} (8.56)	69.58^{a} (8.37)	66.90^{a} (8.20)	64.38^{a} (8.05)	81.5 (9.03)
FLP @ 0.5gKg^{-1}	93.02 (9.67)	92.48 (9.64)	91.69 (9.60)	90.86 (9.56)	89.01^{a} (9.46)	88.77^{a} (9.45)	85.92^{a} (9.29)	82.39^{a} (9.10)	79.97^{a} (8.97)	74.83^{ab} (8.68)	70.89^{ab} (8.45)	66.80^{abc} (8.20)	63.91^{abc} (8.02)	61.67^{ab} (7.88)	80.87 (9.00)
FLP @ 1gKg^{-1}	92.37 (9.64)	90.18 (9.52)	89.80 (9.50)	88.25 (9.42)	86.20^{abc} (9.31)	83.33^{abc} (9.15)	80.50^{abc} (9.00)	76.54^{abcd} (8.78)	73.52^{bc} (8.60)	68.79^{bcd} (8.32)	65.09^{bcde} (8.10)	62.00^{bcde} (7.90)	60.68^{abcd} (7.82)	57.76^{bc} (7.63)	76.79 (8.76)
FLP @ 2gKg^{-1}	92.77 (9.66)	91.98 (9.62)	91.89 (9.61)	90.83 (9.56)	89.11^{a} (9.47)	87.64^{ab} (9.39)	84.41^{a} (9.18)	81.92^{a} (9.08)	78.88^{ab} (8.91)	75.67^{a} (8.73)	71.55^{a} (8.49)	67.91^{ab} (8.27)	65.85^{ab} (8.14)	62.49^{ab} (7.94)	80.92 (9.00)
PLP @ 0.5gKg^{-1}	91.58 (9.60)	90.16 (9.52)	88.24 (9.42)	85.54 (9.28)	82.30^{bcd} (9.10)	78.60^{cde} (8.89)	74.80^{cd} (8.68)	71.63^{cde} (8.49)	67.02^{d} (8.22)	64.91^{cde} (8.09)	61.80^{defg} (7.89)	56.90^{ef} (7.57)	54.77^{defg} (7.43)	51.99^{cd} (7.24)	72.87 (8.53)
PLP @ 1gKg^{-1}	92.80 (9.66)	91.76 (9.60)	90.73 (9.55)	89.37 (9.48)	87.45^{ab} (9.38)	84.88^{ab} (9.24)	81.89^{ab} (9.08)	77.80^{ab} (8.85)	74.80^{ab} (8.68)	71.95^{ab} (8.51)	68.20^{abcd} (8.29)	64.10^{abc} (8.04)	61.86^{abc} (7.90)	57.67^{bc} (7.62)	78.23 (8.85)
PLP @ 2gKg^{-1}	91.76 (9.60)	89.56 (9.49)	87.33 (9.37)	85.16 (9.16)	82.28^{bcd} (9.10)	77.38^{de} (8.82)	74.20^{d} (8.64)	71.55^{cde} (8.49)	68.20^{cd} (8.29)	63.81^{de} (8.02)	58.10^{fg} (7.65)	53.89^{fg} (7.37)	51.44^{g} (7.21)	48.89^{d} (7.03)	71.68 (8.45)
CLP @ 0.5gKg^{-1}	92.80 (9.66)	91.76 (9.43)	90.58 (9.54)	89.20 (9.47)	88.89^{abc} (9.28)	86.91^{abc} (9.17)	83.56^{a} (9.17)	79.44^{a} (8.94)	75.82^{ab} (8.73)	72.67^{ab} (8.55)	68.77^{abc} (8.32)	64.68^{abc} (8.07)	61.90^{abc} (7.90)	57.79^{bc} (7.63)	78.91 (8.85)
CLP @ 1gKg^{-1}	92.47 (9.64)	91.89 (9.61)	88.40 (9.43)	85.47 (9.27)	82.41^{bcd} (9.10)	77.39^{de} (8.82)	73.69^{d} (8.61)	70.84^{de} (8.45)	66.69^{d} (8.20)	63.68^{de} (8.01)	59.80^{efg} (7.76)	56.55^{ef} (7.55)	53.69^{efg} (7.36)	51.47^{cd} (7.21)	72.46 (8.50)
CLP @ 2gKg^{-1}	91.82 (9.43)	89.07 (9.46)	89.48 (9.48)	88.46 (9.25)	85.30^{abc} (9.26)	82.66^{bcd} (9.12)	80.66^{bcd} (8.82)	78.39^{a} (8.88)	74.90^{ab} (8.68)	68.98^{bcd} (8.33)	64.91^{bcde} (8.09)	60.79^{cde} (7.83)	57.93^{cdef} (7.64)	54.39^{cd} (7.41)	76.27 (8.69)
NLP @ 0.5gKg^{-1}	91.76 (9.61)	89.56 (9.49)	87.53 (9.38)	85.16 (9.25)	83.20^{abcd} (9.15)	77.40^{de} (8.83)	73.66^{d} (8.61)	71.74^{bcde} (8.50)	68.44^{cd} (8.30)	64.30^{de} (8.05)	57.74^{g} (7.63)	53.97^{fg} (7.38)	51.66^{fg} (7.22)	49.54^{d} (7.07)	71.83 (8.46)
NLP @ 1gKg^{-1}	91.82 (9.61)	89.07 (9.46)	88.69 (9.44)	85.84 (9.11)	82.39^{bcd} (9.07)	78.63^{e} (8.71)	74.89^{cd} (8.68)	71.75^{bcde} (8.50)	68.22^{cd} (8.29)	65.14^{cde} (8.10)	61.86^{defg} (7.89)	57.60^{def} (7.62)	54.79^{defg} (7.43)	51.90^{cd} (7.24)	73.04 (8.51)
NLP @ 2gKg^{-1}	91.85 (9.61)	90.00 (9.51)	87.20 (9.36)	84.59 (9.22)	80.68^{cd} (9.01)	76.40^{e} (8.77)	71.46^{d} (8.48)	67.08^{e} (8.22)	64.97^{d} (8.09)	61.09^{e} (7.84)	56.48^{g} (7.55)	52.71^{fg} (7.29)	50.87^{g} (7.16)	48.98^{d} (7.03)	70.31 (8.37)
SEM±	0.17	0.31	0.48	0.62	0.85	1.14	1.23	1.28	1.29	1.27	1.38	1.47	1.98	2.20	1.06
CD (0.01)	NS	NS	NS	NS	NS	0.408	0.451	0.469	0.475	0.507	0.539	0.524	0.552	0.564	
CD (0.05)	NS	NS	NS	NS	0.328	0.304	0.336	0.349	0.353	0.377	0.401	0.390	0.411	0.420	

Values in parentheses are square root transformation values

was no significant difference observed in germination per cent till the fifth month of storage. However, it was seen that, seeds treated with normal grade powders resulted in higher germination compared to control. Treated seeds maintained more than 60 percent (minimum seed certification standards), till twelfth month (60.84) of storage whereas the untreated control could retain MSCS only upto ninth month (64.32). Among the treatments, maximum germination per cent was recorded by T_4: ALP @ 2 g kg^{-1} (69.58) followed by T_7: FLP @ 2 g kg^{-1} (67.91) and T_5: FLP @ 0.5 g kg^{-1} (66.80), T_{11}: CLP @ 0.5 g kg^{-1} (64.68), T_9: PLP @ 1 g kg^{-1} (64.10) which were on par with each other compared to control seeds (36.30) at twelfth month of storage. It was seen that, T_{16}: NLP @ 2 g kg^{-1} (52.71) produced least germination among the treated seeds at the twelfth month of storage (Fig 8).

In Ujwala, the germination percent of seeds with normal grade botanicals showed significant differences among the treatments and over the period of storage (Table 5).There was no significant difference in germination per cent till third month of storage. However, it was seen that, seeds treated with normal grade powders resulted in higher germination compared to control. The germination per cent as per the minimum seed certification standards was retained till ninth month (61.68) of storage for treated seeds, whereas, it was only upto fifth month (63.80) for untreated seeds. Among the normal powder treatments, maximum germination per cent was recorded in seeds treated with T_2: ALP @ 0.5 g kg^{-1} (64.10), T_7: FLP @ 2 g kg^{-1} (63.89) followed by T_{16}: FLP @ 1 g kg^{-1} (63.52) and T_{11}: CLP @ 0.5 g kg^{-1} (63.40) were on par with each other compared to control (32.56) at ninth month of storage. It was seen that, T_{15}: NLP @ 1 g kg^{-1} (62.98) produced least germination among the treated seeds (Fig 9).

In both the varieties, irrespective of the concentration of botanicals, least germination per cent was found in neem next to control.

4.2.3. Shoot length (cm)

Effect of seed treatments and storage period were found to be significant in influencing seedling shoot length. Seeds treated with normal grade powders had higher shoot length compared to control.

In Anugraha, among the treatments (Table 6), seeds treated with T_4: ALP @ 2 g kg^{-1} (5.91 cm), T_7: FLP @ 2 g kg^{-1} (5.86 cm) which were on par with each other and T_5: FLP @ 0.5 g kg^{-1} (5.84 cm), T_9: PLP @ 1 g kg^{-1} (5.79 cm), T_2: ALP @ 0.5 g kg^{-1} (5.71 cm), T_3: ALP @ 1 g kg^{-1} (5.69 cm), T_6: FLP @ 1 g kg^{-1} (5.68 cm) which were on par with each other, produced longer shoots than control (4.23 cm) at the twelfth month of storage.

Fig 8: Effect of normal grade botanicals on germination (%) in Anugraha

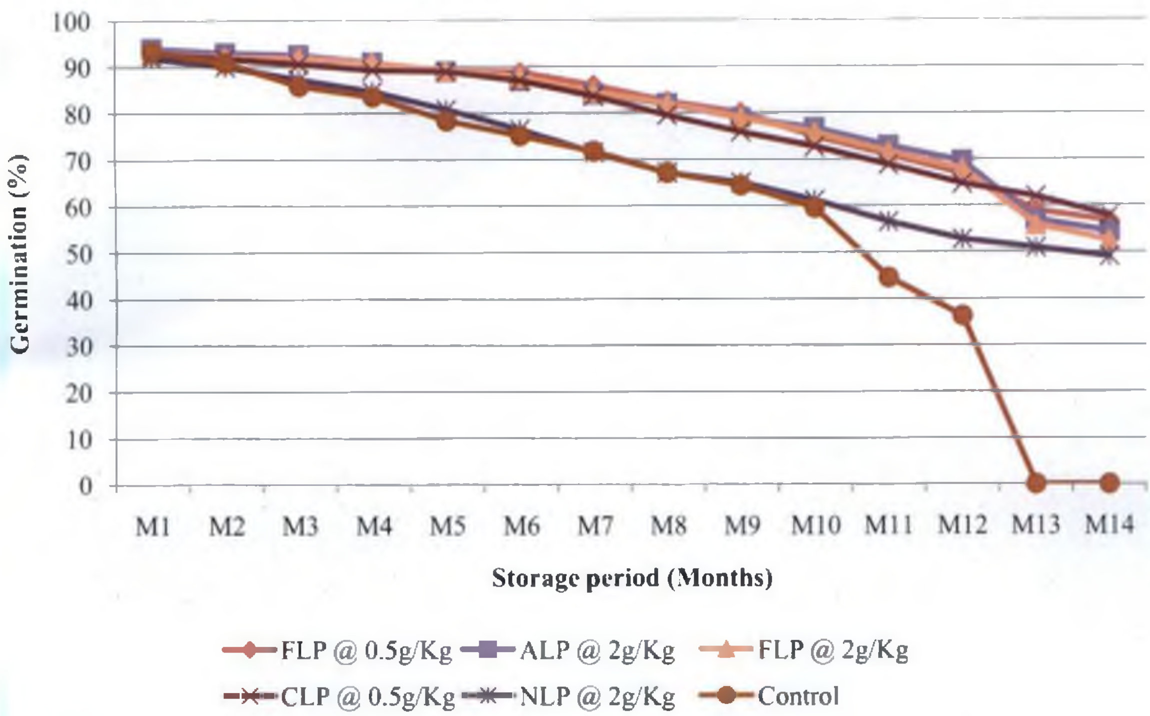


Fig 9: Effect of normal grade botanicals on germination (%) in Ujwala

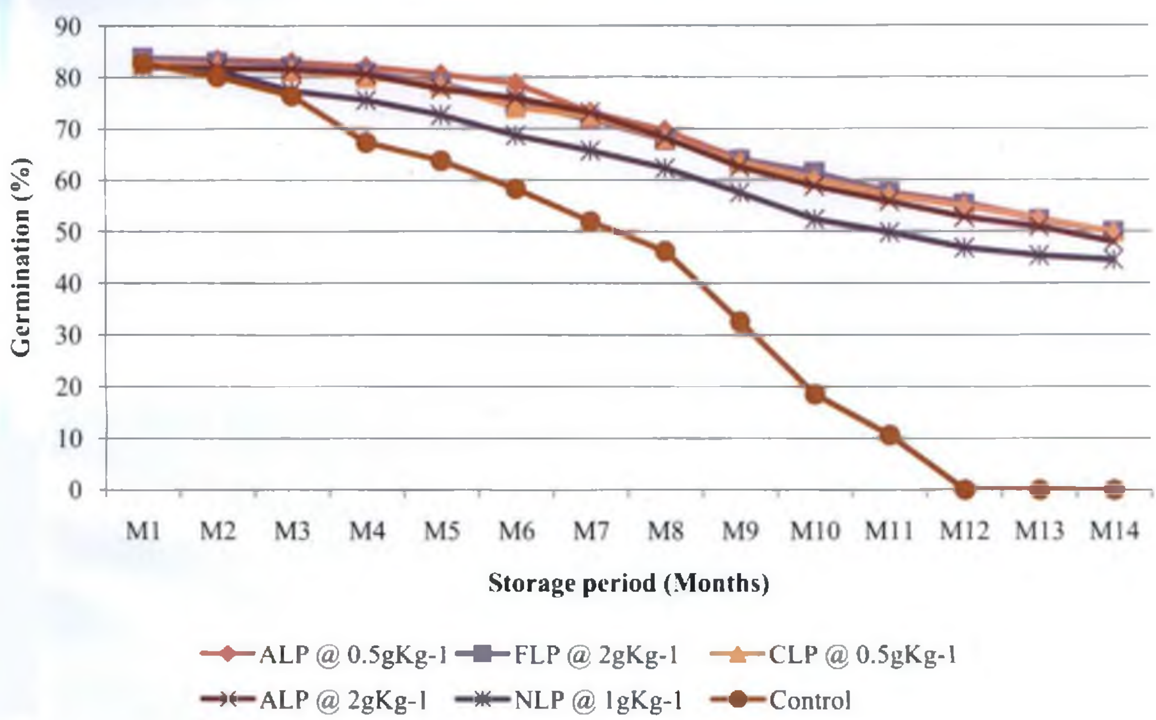


Table 5: Effect of normal grade botanicals on germination (%) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	82.67 (9.12)	80.10 (8.98)	76.40 (8.76)	67.33^{g} (8.23)	63.80^{g} (8.01)	58.30^{e} (7.67)	51.90^{d} (7.24)	46.13^{e} (6.83)	32.56^{f} (5.74)	18.50^{e} (4.35)	10.60^{e} (3.31)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	42.02 (6.10)
ALP @ 0.5gKg^{-1}	83.76 (9.17)	83.45 (9.16)	82.94 (9.13)	82.00^{a} (9.08)	80.56^{a} (9.00)	78.80^{a} (8.90)	73.20^{a} (8.58)	69.66^{a} (8.37)	64.10^{a} (8.07)	61.44^{abc} (7.87)	57.69^{abc} (7.62)	55.59^{ab} (7.48)	52.49^{a} (7.27)	49.80^{a} (7.32)	69.71 (8.36)
ALP @ 1gKg^{-1}	82.89 (9.13)	82.51 (9.11)	80.09 (8.94)	78.40^{bcde} (8.88)	75.98^{bcde} (8.74)	73.81^{abcd} (8.62)	70.08^{abc} (8.40)	66.20^{abc} (8.16)	62.30^{abcd} (7.92)	57.58^{ab} (7.62)	54.88^{ab} (7.44)	52.77^{a} (7.30)	50.47^{ab} (7.14)	48.79^{abc} (7.02)	66.91 (8.17)
ALP @ 2gKg^{-1}	82.00 (9.08)	81.70 (9.07)	81.48 (9.05)	80.60^{ab} (9.01)	77.71^{abcd} (8.84)	76.00^{ab} (8.75)	73.12^{a} (8.58)	68.20^{ab} (8.29)	62.55^{abcd} (7.94)	58.77^{abc} (7.70)	55.80^{abc} (7.50)	52.73^{ab} (7.29)	50.87^{ab} (7.17)	47.95^{abc} (6.96)	67.82 (8.23)
FLP @ 0.5gKg^{-1}	82.96 (9.13)	81.98 (9.08)	79.17 (8.92)	78.67^{bcde} (8.90)	76.80^{bcd} (8.80)	73.48^{abcd} (8.60)	69.39^{abc} (8.36)	66.00^{bc} (8.15)	62.83^{abcd} (7.96)	56.62^{abcd} (7.56)	53.69^{abcd} (7.36)	51.58^{ab} (7.21)	49.70^{ab} (7.08)	48.91^{abc} (7.03)	66.56 (8.15)
FLP @ 1gKg^{-1}	82.84 (9.13)	81.68 (9.06)	79.88 (8.96)	79.05^{bcde} (8.91)	76.42^{bcd} (8.77)	74.90^{abc} (8.68)	71.31^{abc} (8.47)	67.70^{abc} (8.26)	63.52^{abc} (8.04)	56.23^{cd} (7.53)	54.57^{cd} (7.42)	52.47^{b} (7.28)	50.15^{ab} (7.12)	48.87^{abc} (7.02)	67.11 (8.19)
FLP @ 2gKg^{-1}	83.81 (9.18)	82.92 (9.13)	81.99 (9.08)	80.80^{ab} (9.01)	78.80^{ab} (8.90)	74.98^{abcd} (8.63)	71.83^{ab} (8.50)	67.80^{abc} (8.26)	63.89^{abc} (8.07)	61.45^{d} (7.85)	57.44^{d} (7.61)	55.27^{b} (7.46)	52.19^{a} (7.26)	49.90^{ab} (7.09)	68.84 (8.29)
PLP @ 0.5gKg^{-1}	82.89 (9.13)	82.51 (9.11)	81.20 (9.04)	77.40^{cdef} (8.82)	75.80^{cdef} (8.66)	73.21^{abcd} (8.58)	70.53^{abc} (8.43)	64.80^{bcd} (8.08)	60.99^{de} (7.84)	55.80^{cd} (7.50)	53.70^{bcd} (7.36)	51.67^{ab} (7.22)	50.09^{ab} (7.11)	48.66^{abc} (7.00)	66.38 (8.13)
PLP @ 1gKg^{-1}	82.70 (9.12)	82.30 (9.10)	80.09 (8.98)	77.20^{def} (8.81)	72.75^{ef} (8.56)	70.09^{cd} (8.36)	67.01^{bc} (8.21)	65.77^{bcd} (8.14)	60.23^{abcd} (7.79)	55.76^{a} (7.50)	53.58^{a} (7.35)	50.48^{a} (7.14)	48.80^{ab} (7.02)	46.57^{bc} (6.86)	65.24 (8.07)
PLP @ 2gKg^{-1}	82.80 (9.13)	82.20 (9.09)	81.19 (9.04)	80.10^{abc} (8.98)	78.00^{ab} (8.86)	76.10^{ab} (8.75)	72.51^{ab} (8.54)	68.02^{abc} (8.28)	63.31^{abcd} (7.99)	58.82^{abcd} (7.70)	55.77^{abcd} (7.50)	52.69^{ab} (7.29)	49.68^{ab} (7.08)	46.89^{bc} (6.88)	67.72 (8.22)
CLP @ 0.5gKg^{-1}	82.80 (9.13)	82.22 (9.09)	81.22 (9.04)	80.00^{abc} (8.97)	78.53^{ab} (8.89)	74.12^{abcd} (8.64)	72.45^{ab} (8.54)	68.00^{abc} (8.28)	63.40^{abc} (7.99)	60.20^{abc} (7.79)	56.96^{abc} (7.58)	54.89^{ab} (7.44)	52.46^{a} (7.27)	49.88^{ab} (7.10)	68.37 (8.27)
CLP @ 1gKg^{-1}	82.70 (9.12)	82.94 (9.13)	80.33 (8.99)	80.12^{abc} (8.98)	76.00^{bcde} (8.74)	74.40^{abc} (8.65)	70.92^{abc} (8.45)	66.80^{abc} (8.20)	61.27^{abcd} (7.86)	55.80^{abcd} (7.50)	52.80^{abcd} (7.30)	49.94^{ab} (7.10)	47.25^{ab} (6.91)	46.90^{c} (8.48)	66.30 (8.24)
CLP @ 2gKg^{-1}	82.80 (9.13)	82.20 (9.09)	80.05 (8.97)	79.82^{abcd} (8.96)	77.75^{abc} (8.84)	75.67^{ab} (8.73)	73.01^{a} (8.57)	66.90^{abc} (8.21)	61.70^{abcd} (7.89)	56.67^{abcd} (7.56)	53.42^{abcd} (7.34)	50.01^{ab} (7.10)	47.84^{ab} (6.95)	45.80^{bc} (6.80)	66.69 (8.15)
NLP @ 0.5gKg^{-1}	82.40 (9.10)	81.80 (9.07)	78.58 (8.89)	77.03^{bcde} (8.92)	76.55^{bcd} (8.77)	73.27^{abcd} (8.59)	69.17^{abc} (8.35)	64.47^{cd} (8.06)	59.28^{cde} (7.73)	54.33^{ab} (7.40)	50.86^{a} (7.16)	48.67^{a} (7.01)	45.83^{b} (6.80)	44.75^{bc} (6.72)	64.79 (8.04)
NLP @ 1gKg^{-1}	82.10 (9.09)	81.30 (9.04)	77.33 (8.82)	75.56^{f} (8.72)	72.66^{f} (8.55)	68.70^{d} (8.32)	65.72^{c} (8.13)	62.29^{d} (7.92)	57.48^{e} (7.61)	52.30^{bcd} (7.26)	49.76^{abcd} (7.09)	46.80^{ab} (6.88)	45.30^{b} (6.77)	44.48^{bc} (6.71)	62.98 (7.92)
NLP @ 2gKg^{-1}	82.33 (9.10)	81.77 (9.07)	78.90 (8.91)	76.40^{ef} (8.77)	74.43^{def} (8.65)	71.68^{bcd} (8.49)	68.10^{abc} (8.28)	64.67^{bcd} (8.07)	58.37^{cde} (7.67)	53.52^{bcd} (7.35)	51.46^{abcd} (7.21)	49.80^{ab} (7.09)	47.20^{ab} (6.90)	44.56^{bc} (6.71)	64.51 (8.02)
SEM±	0.12	0.19	0.42	0.85	0.95	1.15	1.29	1.35	1.90	2.50	2.78	3.29	3.13	3.01	1.60
CD (0.01)	NS	NS	NS	0.208	0.255	0.447	0.484	0.304	0.355	0.526	0.600	0.562	0.578	0.534	
CD (0.05	NS	NS	NS	0.154	0.190	0.333	0.360	0.226	0.264	0.391	0.446	0.418	0.430	0.397	

Values in parentheses are square root transformation values

Table 6: Effect of normal grade botanicals on seedling shoot length (cm) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.89^{a} (2.72)	6.66^{a} (2.67)	6.29^{a} (2.60)	6.11^{a} (2.57)	5.91^{e} (2.53)	5.73^{e} (2.49)	5.42^{e} (2.43)	5.27^{d} (2.40)	4.98^{d} (2.34)	4.79^{e} (2.30)	4.56^{d} (2.25)	4.23^{e} (2.17)	0.00 (0.71)	0.00 (0.71)	4.77 (2.21)
ALP @ 0.5gKg^{-1}	7.18^{a} (2.77)	7.14^{a} (2.76)	6.92^{a} (2.72)	6.81^{a} (2.70)	6.70^{abc} (2.68)	6.42^{abcd} (2.63)	6.36^{abcd} (2.62)	6.19^{abc} (2.59)	6.12^{ab} (2.57)	5.96^{abc} (2.54)	5.80^{ab} (2.51)	5.71^{ab} (2.49)	5.68^{ab} (2.49)	5.54^{ab} (2.46)	6.32 (2.61)
ALP @ 1gKg^{-1}	7.19^{a} (2.77)	7.16^{a} (2.77)	7.00^{a} (2.74)	7.06^{a} (2.75)	6.81^{ab} (2.70)	6.71^{ab} (2.68)	6.52^{abc} (2.65)	6.29^{abc} (2.60)	6.16^{ab} (2.58)	5.90^{abc} (2.53)	5.81^{ab} (2.51)	5.69^{ab} (2.49)	5.66^{ab} (2.48)	5.57^{ab} (2.46)	6.40 (2.62)
ALP @ 2gKg^{-1}	7.15^{a} (2.77)	7.20^{a} (2.77)	7.15^{a} (2.77)	7.10^{a} (2.76)	7.04^{a} (2.75)	6.92^{a} (2.72)	6.83^{a} (2.71)	6.72^{a} (2.69)	6.52^{a} (2.65)	6.39^{a} (2.62)	5.99^{a} (2.55)	5.91^{a} (2.53)	5.89^{a} (2.53)	5.78^{a} (2.51)	6.61 (2.66)
FLP @ 0.5gKg^{-1}	7.21^{a} (2.78)	7.19^{a} (2.77)	7.14^{a} (2.76)	7.10^{a} (2.76)	7.02^{a} (2.74)	6.89^{a} (2.72)	6.78^{ab} (2.70)	6.57^{ab} (2.66)	6.31^{ab} (2.61)	6.17^{ab} (2.58)	5.93^{ab} (2.53)	5.84^{ab} (2.52)	5.79^{ab} (2.51)	5.68^{ab} (2.48)	6.54 (2.65)
FLP @ 1gKg^{-1}	7.13^{a} (2.76)	6.93^{a} (2.72)	6.86^{a} (2.71)	6.78^{a} (2.70)	6.66^{abcd} (2.68)	6.39^{abcd} (2.62)	6.31^{abcd} (2.61)	6.18^{abc} (2.58)	6.09^{ab} (2.57)	5.81^{abcd} (2.51)	5.72^{ab} (2.49)	5.68^{ab} (2.48)	5.59^{ab} (2.47)	5.48^{ab} (2.44)	6.26 (2.60)
FLP @ 2gKg^{-1}	7.19^{a} (2.77)	7.15^{a} (2.77)	7.12^{a} (2.76)	7.10^{a} (2.76)	7.00^{a} (2.74)	6.91^{a} (2.72)	6.80^{ab} (2.70)	6.69^{a} (2.68)	6.48^{a} (2.64)	6.28^{a} (2.60)	6.00^{a} (2.55)	5.86^{a} (2.52)	5.80^{ab} (2.51)	5.77^{a} (2.50)	6.58 (2.66)
PLP @ 0.5gKg^{-1}	7.19^{a} (2.77)	7.10^{a} (2.76)	6.54^{a} (2.65)	6.48^{a} (2.64)	6.22^{bcde} (2.59)	6.15^{bcde} (2.58)	5.99^{cde} (2.55)	5.84^{bcd} (2.52)	5.61^{bcd} (2.47)	5.39^{cde} (2.43)	5.26^{abcd} (2.40)	5.11^{bcde} (2.37)	5.07^{bcd} (2.36)	4.95^{bcd} (2.33)	5.92 (2.53)
PLP @ 1gKg^{-1}	7.25^{a} (2.78)	7.16^{a} (2.77)	6.98^{a} (2.73)	6.82^{a} (2.70)	6.73^{abc} (2.69)	6.51^{abc} (2.65)	6.43^{abc} (2.63)	6.29^{abc} (2.60)	6.13^{ab} (2.57)	5.98^{abc} (2.54)	5.86^{ab} (2.52)	5.79^{ab} (2.51)	5.68^{ab} (2.48)	5.59^{ab} (2.47)	6.37 (2.62)
PLP @ 2gKg^{-1}	7.11^{a} (2.76)	6.94^{a} (2.73)	6.78^{a} (2.70)	6.60^{a} (2.66)	6.47^{abcde} (2.64)	6.20^{bcde} (2.59)	5.92^{cde} (2.53)	5.80^{cd} (2.51)	5.63^{bcd} (2.48)	5.46^{bcde} (2.44)	5.21^{bcd} (2.39)	4.89^{cde} (2.32)	4.76^{cde} (2.29)	4.66^{cde} (2.27)	5.89 (2.52)
CLP @ 0.5gKg^{-1}	6.97^{a} (2.73)	6.89^{a} (2.72)	6.72^{a} (2.69)	6.50^{a} (2.65)	6.23^{bcde} (2.59)	6.20^{bcde} (2.59)	6.00^{cde} (2.55)	5.89^{bcd} (2.53)	5.78^{abc} (2.51)	5.67^{abcd} (2.48)	5.50^{abc} (2.45)	5.44^{abcd} (2.44)	5.30^{abcd} (2.41)	5.24^{abcd} (2.40)	6.02 (2.55)
CLP @ 1gKg^{-1}	6.93^{a} (2.72)	6.84^{a} (2.71)	6.63^{a} (2.67)	6.46^{a} (2.64)	6.20^{cde} (2.59)	6.16^{bcde} (2.58)	5.96^{cde} (2.54)	5.87^{bcd} (2.52)	5.69^{bcd} (2.49)	5.53^{bcde} (2.45)	5.43^{abc} (2.43)	5.39^{abcd} (2.43)	5.26^{abcd} (2.40)	5.19^{abcd} (2.38)	5.97 (2.54)
CLP @ 2gKg^{-1}	7.06^{a} (2.75)	6.99^{a} (2.74)	6.80^{a} (2.70)	6.61^{a} (2.67)	6.39^{bcde} (2.62)	6.16^{bcde} (2.58)	6.06^{bcde} (2.56)	5.92^{bcd} (2.53)	5.82^{abc} (2.51)	5.70^{abcd} (2.49)	5.69^{ab} (2.49)	5.60^{abc} (2.47)	5.55^{ab} (2.46)	5.47^{ab} (2.44)	6.13 (2.57)
NLP @ 0.5gKg^{-1}	6.99^{a} (2.74)	6.70^{a} (2.68)	6.59^{a} (2.66)	6.37^{a} (2.62)	6.17^{cde} (2.58)	6.06^{cde} (2.56)	5.89^{cde} (2.53)	5.79^{cd} (2.51)	5.62^{bcd} (2.47)	5.53^{bcde} (2.45)	5.46^{abc} (2.44)	5.23^{abcd} (2.39)	5.19^{abcd} (2.38)	5.08^{abcd} (2.36)	5.91 (2.53)
NLP @ 1gKg^{-1}	7.15^{a} (2.77)	6.92^{a} (2.72)	6.85^{a} (2.71)	6.71^{a} (2.68)	6.52^{abcd} (2.65)	6.21^{bcde} (2.59)	6.18^{abcd} (2.58)	6.09^{abc} (2.57)	5.89^{abc} (2.53)	5.71^{abcd} (2.49)	5.66^{ab} (2.48)	5.58^{abc} (2.47)	5.49^{abc} (2.45)	5.37^{abc} (2.42)	6.17 (2.58)
NLP @ 2gKg^{-1}	6.99^{a} (2.74)	6.77^{a} (2.70)	6.44^{a} (2.63)	6.22^{a} (2.59)	6.06^{de} (2.56)	5.83^{de} (2.52)	5.64^{de} (2.48)	5.55^{cd} (2.46)	5.33^{cd} (2.41)	5.14^{de} (2.37)	4.86^{cd} (2.31)	4.77^{de} (2.29)	4.66^{de} (2.27)	4.57^{de} (2.25)	5.63 (2.47)
SEM±	0.03	0.05	0.06	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.12	0.12	0.09
CD (0.01)	NS	NS	NS	NS	0.154	0.156	0.194	0.196	0.201	0.200	0.202	0.206	0.192	0.193	
CD (0.05)	NS	NS	NS	NS	0.114	0.116	0.144	0.146	0.149	0.148	0.150	0.153	0.143	0.144	

Values in parentheses are square root transformation values

In Ujwala, among the treatments (Table 7), seeds treated with T_2: ALP @ 0.5 g kg^{-1} (5.88 cm) which were on par with T_{11}: CLP @ 0.5 g kg^{-1} (5.71 cm) and T_7: FLP @ 2 g kg^{-1} (5.69 cm) followed by T_4: ALP @ 2 g kg^{-1} (5.62 cm), T_{10}: PLP @ 2 g kg^{-1} (5.59 cm), T_{13}: CLP @ 2 g kg^{-1} (5.49 cm) which were on par with each other, produced longer shoots than control (4.37 cm) at ninth month of storage.

4.2.4. Root Length (cm)

Seed treatment with normal grade powders had a pronounced effect on seedling root length. It was seen that, treated seeds had higher root length compared to control.

In Anugraha, among the treatments (Table 8), seeds treated with T_4: ALP @ 2 g kg^{-1} (7.89 cm), T_7: FLP @ 2 g kg^{-1} (7.80 cm) which were on par with each other followed by T_5: FLP @ 2 g kg^{-1} (7.66 cm) and T_2: ALP @ 0.5 g kg^{-1} (7.31 cm) produced longer roots than control (5.33 cm) at twelfth month of storage.

In Ujwala, among the treatments (Table 9), maximum root length was observed in seeds treated with T_2: ALP @ 0.5 g kg^{-1} (7.47 cm), T_7: FLP @ 2 g kg^{-1} (7.46 cm), T_{11}: CLP @ 0.5 g kg^{-1} (7.38 cm) were on par with each other followed by T_{10}: PLP @ 2 g kg^{-1} (7.27 cm) produced longer roots compare to control (5.28 cm) at ninth month of storage.

4.2.5. Dry weight (mg)

Significant variation was observed for seedling dry weight due to treatment with botanicals over the period of storage.

In Anugraha, among the seeds treated with normal grade powders (Table 10), treatments such as T_7: FLP @ 2 g kg^{-1} (20.49 mg) followed by T_4: ALP @ 2 g kg^{-1} (20.38 mg) and T_5: FLP @ 0.5 g kg^{-1} (19.74 mg) produced maximum dry weight whereas, control recorded a dry weight of 12.80 mg at twelfth month of storage.

In Ujwala, among the seeds treated with normal grade powders (Table 11), treatments such as T_2: ALP @ 0.5 g kg^{-1} (17.43 mg), T_7: FLP @ 2 g kg^{-1} (17.27 mg) and T_4: ALP @ 2 g kg^{-1} (15.67 mg) which were on par with T_3: ALP @ 1 g kg^{-1} (15.64 mg) and T_6: FLP @ 1 g kg^{-1} (15.54 mg) produced maximum dry weight whereas, the untreated seeds recorded the least value (11.66 mg) at ninth month of storage.

4.2.6. Vigour index I

Vigour index I of seeds treated with normal grade powders revealed significant differences among the treatments and over the period of storage. Treated seeds had higher

Table 7: Effect of normal grade botanicals on seedling shoot length (cm) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	5.58^{d} (2.47)	5.23^{e} (2.39)	5.10^{e} (2.37)	5.04^{e} (2.35)	5.00^{g} (2.34)	4.96^{f} (2.34)	4.61^{e} (2.26)	4.56^{e} (2.25)	4.37^{f} (2.21)	4.12^{e} (2.15)	3.88^{f} (2.09)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	4.03 (1.95)
ALP @ 0.5gKg^{-1}	7.03^{a} (2.74)	6.90^{a} (2.71)	6.83^{a} (2.69)	6.71^{a} (2.68)	6.66^{a} (2.68)	6.49^{a} (2.64)	6.33^{a} (2.61)	5.94^{a} (2.54)	5.88^{a} (2.53)	5.61^{a} (2.47)	5.55^{a} (2.46)	5.48^{a} (2.44)	5.37^{a} (2.42)	5.28^{a} (2.40)	6.14 (2.57)
ALP @ 1gKg^{-1}	6.78^{abc} (2.70)	6.67^{abc} (2.68)	6.51^{abc} (2.65)	6.38^{abc} (2.62)	6.18^{abcde} (2.58)	5.71^{cde} (2.49)	5.58^{bcd} (2.47)	5.43^{abcd} (2.43)	5.32^{abcde} (2.41)	5.30^{abcd} (2.41)	5.21^{abcd} (2.39)	5.14^{abc} (2.37)	5.03^{abcd} (2.35)	4.97^{abc} (2.34)	5.73 (2.49)
ALP @ 2gKg^{-1}	6.86^{ab} (2.71)	6.73^{abc} (2.69)	6.64^{ab} (2.67)	6.59^{ab} (2.66)	6.46^{abc} (2.64)	6.30^{abcd} (2.61)	5.96^{abc} (2.54)	5.78^{abc} (2.51)	5.62^{abc} (2.47)	5.43^{ab} (2.43)	5.37^{ab} (2.42)	5.28^{ab} (2.40)	5.18^{a} (2.38)	5.06^{a} (2.36)	5.95 (2.54)
FLP @ 0.5gKg^{-1}	6.66^{abc} (2.68)	6.50^{abcd} (2.65)	6.41^{abc} (2.63)	6.37^{abc} (2.62)	6.18^{abcde} (2.58)	5.78^{bcde} (2.51)	5.63^{abcd} (2.48)	5.49^{abcd} (2.45)	5.40^{abcd} (2.43)	5.32^{abc} (2.41)	5.24^{abc} (2.40)	5.17^{abc} (2.38)	5.08^{abc} (2.36)	4.90^{abcd} (2.32)	5.72 (2.49)
FLP @ 1gKg^{-1}	6.67^{abc} (2.68)	6.50^{abcd} (2.64)	6.42^{abc} (2.63)	6.31^{abc} (2.61)	6.13^{abcdef} (2.57)	5.69^{cde} (2.49)	5.42^{cd} (2.43)	5.21^{bcde} (2.39)	4.94^{cdef} (2.33)	4.66^{cde} (2.27)	4.57^{cdef} (2.25)	4.48^{cde} (2.23)	4.37^{de} (2.20)	4.29^{cde} (2.19)	5.40 (2.42)
FLP @ 2gKg^{-1}	6.98^{a} (2.73)	6.84^{ab} (2.71)	6.76^{ab} (2.69)	6.67^{ab} (2.68)	6.46^{abc} (2.64)	6.36^{abc} (2.62)	6.30^{a} (2.61)	5.80^{abc} (2.51)	5.69^{ab} (2.49)	5.59^{a} (2.47)	5.50^{a} (2.45)	5.47^{a} (2.44)	5.34^{a} (2.41)	5.30^{a} (2.41)	6.08 (2.56)
PLP @ 0.5gKg^{-1}	6.49^{abc} (2.64)	6.41^{abcd} (2.63)	6.26^{abcd} (2.60)	6.09^{abcd} (2.57)	5.81^{bcdef} (2.51)	5.67^{cde} (2.48)	5.43^{cd} (2.43)	5.21^{bcde} (2.39)	5.03^{bcdef} (2.35)	4.77^{bcde} (2.29)	4.68^{bcde} (2.27)	4.59^{bcde} (2.25)	4.45^{bcde} (2.22)	4.36^{bcde} (2.20)	5.38 (2.42)
PLP @ 1gKg^{-1}	6.49^{abc} (2.64)	6.37^{abcd} (2.62)	6.26^{abcd} (2.60)	6.13^{abcd} (2.57)	5.72^{def} (2.49)	5.61^{def} (2.47)	5.48^{cd} (2.45)	5.23^{bcde} (2.39)	5.02^{bcdef} (2.35)	4.61^{de} (2.26)	4.59^{cde} (2.26)	4.48^{cde} (2.23)	4.39^{cde} (2.21)	4.27^{de} (2.18)	5.33 (2.41)
PLP @ 2gKg^{-1}	6.81^{ab} (2.70)	6.73^{abc} (2.69)	6.64^{ab} (2.67)	6.55^{ab} (2.65)	6.39^{abcd} (2.62)	6.31^{abcd} (2.61)	5.89^{abcd} (2.53)	5.66^{abcd} (2.48)	5.59^{abc} (2.47)	5.44^{ab} (2.44)	5.37^{ab} (2.42)	5.29^{a} (2.41)	5.18^{a} (2.38)	5.05^{ab} (2.36)	5.92 (2.53)
CLP @ 0.5gKg^{-1}	6.99^{a} (2.74)	6.82^{ab} (2.71)	6.73^{ab} (2.69)	6.53^{ab} (2.65)	6.49^{ab} (2.64)	6.42^{ab} (2.63)	6.21^{ab} (2.59)	5.88^{ab} (2.53)	5.71^{ab} (2.49)	5.62^{a} (2.47)	5.58^{a} (2.47)	5.47^{a} (2.44)	5.30^{a} (2.41)	5.21^{a} (2.39)	6.07 (2.56)
CLP @ 1gKg^{-1}	6.54^{abc} (2.65)	6.43^{abcd} (2.63)	6.26^{abcd} (2.60)	6.13^{abcd} (2.57)	5.78^{cdef} (2.51)	5.69^{cde} (2.49)	5.55^{bcd} (2.46)	5.49^{abcd} (2.45)	5.31^{abcde} (2.41)	5.20^{abcd} (2.39)	5.11^{abcd} (2.37)	4.98^{abcd} (2.34)	4.88^{abcd} (2.32)	4.76^{abcd} (2.29)	5.58 (2.46)
CLP @ 2gKg^{-1}	6.80^{ab} (2.70)	6.73^{abc} (2.69)	6.60^{ab} (2.66)	6.49^{ab} (2.64)	6.29^{abcde} (2.60)	5.89^{abcde} (2.53)	5.71^{abcd} (2.49)	5.60^{abcd} (2.47)	5.49^{abc} (2.45)	5.40^{ab} (2.43)	5.33^{ab} (2.41)	5.24^{ab} (2.39)	5.17^{a} (2.38)	5.06^{a} (2.36)	5.84 (2.51)
NLP @ 0.5gKg^{-1}	6.18^{bcd} (2.58)	6.07^{cd} (2.56)	5.86^{cd} (2.52)	5.75^{cd} (2.50)	5.66^{efg} (2.48)	5.44^{ef} (2.44)	5.23^{de} (2.39)	5.12^{cde} (2.37)	4.78^{def} (2.30)	5.41^{ab} (2.43)	5.32^{ab} (2.41)	5.23^{ab} (2.39)	5.14^{ab} (2.37)	5.06^{a} (2.36)	5.45 (2.44)
NLP @ 1gKg^{-1}	6.09^{cd} (2.57)	5.89^{de} (2.53)	5.66^{de} (2.48)	5.54^{de} (2.46)	5.46^{fg} (2.44)	5.32^{ef} (2.41)	5.20^{de} (2.39)	5.02^{de} (2.35)	4.68^{ef} (2.27)	4.40^{e} (2.21)	4.31^{ef} (2.19)	4.23^{e} (2.17)	4.15^{e} (2.15)	4.05^{e} (2.13)	5.00 (2.34)
NLP @ 2gKg^{-1}	6.26^{bcd} (2.60)	6.19^{bcd} (2.59)	6.10^{bcd} (2.57)	6.00^{bcd} (2.55)	5.69^{defg} (2.49)	5.51^{ef} (2.45)	5.42^{cd} (2.43)	5.32^{abcd} (2.41)	5.13^{bcde} (2.37)	4.63^{cde} (2.26)	4.51^{def} (2.24)	4.44^{de} (2.22)	4.38^{de} (2.21)	4.26^{de} (2.18)	5.27 (2.40)
SEM±	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.18	0.42	0.41	0.40	0.18
CD (0.01)	0.170	0.179	0.180	0.182	0.182	0.186	0.191	0.192	0.194	0.198	0.200	0.200	0.201	0.202	
CD (0.05)	0.127	0.134	0.134	0.135	0.136	0.139	0.142	0.144	0.145	0.147	0.149	0.149	0.150	0.150	

Values in parentheses are square root transformation values

Table 8: Effect of normal grade botanicals on seedling root length (cm) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	7.40^{gh} (2.77)	7.31^{ij} (2.76)	7.22^{gh} (2.74)	7.00^{j} (2.72)	6.88^{j} (2.72)	6.60^{j} (2.66)	6.43^{h} (2.63)	6.25^{h} (2.60)	6.11^{f} (2.57)	5.97^{g} (2.54)	5.73^{g} (2.50)	5.33^{g} (2.41)	0.00 (0.71)	0.00 (0.71)	6.36 (2.36)
ALP @ 0.5gKg^{-1}	8.44^{cd} (2.99)	8.41^{de} (2.98)	8.39^{d} (2.98)	8.36^{cd} (2.98)	8.20^{de} (2.95)	8.00^{de} (2.92)	7.90^{cd} (2.90)	7.84^{b} (2.89)	7.73^{b} (2.87)	7.59^{c} (2.84)	7.48^{b} (2.82)	7.31^{bc} (2.79)	7.20^{bc} (2.77)	7.10^{bc} (2.76)	7.85 (2.89)
ALP @ 1gKg^{-1}	9.04^{b} (3.09)	8.89^{bc} (3.06)	8.80^{bc} (3.05)	8.73^{bc} (3.04)	8.51^{cd} (3.00)	8.38^{cd} (2.98)	8.18^{bc} (2.95)	7.80^{b} (2.88)	7.53^{bc} (2.83)	7.39^{cd} (2.81)	7.20^{bc} (2.77)	7.07^{cd} (2.75)	6.97^{cde} (2.73)	6.88^{cd} (2.72)	7.96 (2.90)
ALP @ 2gKg^{-1}	9.54^{a} (3.17)	9.51^{a} (3.16)	9.44^{a} (3.15)	9.32^{a} (3.13)	9.20^{a} (3.11)	8.93^{a} (3.07)	8.81^{a} (3.05)	8.72^{a} (3.04)	8.52^{a} (3.00)	8.51^{a} (3.00)	8.11^{a} (2.93)	7.89^{a} (2.90)	7.74^{a} (2.87)	7.67^{a} (2.86)	8.71 (3.03)
FLP @ 0.5gKg^{-1}	9.01^{b} (3.08)	8.85^{bc} (3.06)	8.83^{b} (3.05)	8.72^{bc} (3.04)	8.64^{bc} (3.02)	8.52^{bc} (3.00)	8.48^{ab} (3.00)	8.33^{a} (2.97)	8.26^{a} (2.96)	8.01^{b} (2.92)	7.90^{a} (2.90)	7.80^{a} (2.88)	7.77^{a} (2.88)	7.68^{a} (2.86)	8.34 (2.97)
FLP @ 1gKg^{-1}	8.10^{de} (2.93)	8.02^{ef} (2.92)	8.09^{de} (2.93)	8.00^{de} (2.92)	7.83^{ef} (2.89)	7.72^{ef} (2.87)	7.63^{d} (2.85)	7.59^{bc} (2.84)	7.46^{bc} (2.82)	7.39^{cd} (2.81)	7.36^{b} (2.80)	7.21^{cd} (2.78)	7.17^{cd} (2.77)	7.02^{cd} (2.74)	7.61 (2.85)
FLP @ 2gKg^{-1}	9.20^{ab} (3.11)	9.20^{ab} (3.11)	9.16^{ab} (3.11)	9.09^{ab} (3.10)	9.00^{ab} (3.08)	8.87^{ab} (3.06)	8.79^{a} (3.05)	8.55^{a} (3.01)	8.36^{a} (2.98)	8.29^{ab} (2.96)	8.00^{a} (2.92)	7.66^{ab} (2.86)	7.59^{ab} (2.84)	7.47^{ab} (2.82)	8.52 (3.00)
PLP @ 0.5gKg^{-1}	7.58^{fgh} (2.84)	7.52^{ghij} (2.83)	7.49^{fgh} (2.83)	7.40^{ghi} (2.81)	7.33^{ghi} (2.80)	7.15^{hi} (2.77)	7.01^{fg} (2.74)	6.84^{efg} (2.71)	6.70^{e} (2.68)	6.67^{f} (2.68)	6.60^{def} (2.66)	6.51^{ef} (2.65)	6.47^{fgh} (2.64)	6.31^{ef} (2.61)	6.97 (2.73)
PLP @ 1gKg^{-1}	8.60^{c} (3.02)	8.51^{cd} (3.00)	8.43^{cd} (2.99)	8.24^{d} (2.96)	7.13^{hij} (2.76)	7.89^{e} (2.90)	7.83^{cd} (2.89)	7.76^{bc} (2.87)	7.69^{b} (2.86)	7.52^{cd} (2.83)	7.44^{b} (2.82)	7.37^{bc} (2.81)	7.24^{bc} (2.78)	7.11^{bc} (2.76)	7.77 (2.87)
PLP @ 2gKg^{-1}	7.22^{h} (2.78)	7.18^{j} (2.77)	7.11^{h} (2.76)	7.03^{ij} (2.74)	6.99^{ij} (2.74)	6.86^{ij} (2.71)	6.76^{gh} (2.69)	6.69^{fg} (2.68)	6.57^{e} (2.66)	6.56^{f} (2.66)	6.50^{ef} (2.65)	6.39^{f} (2.62)	6.28^{gh} (2.60)	6.16^{f} (2.58)	6.74 (2.69)
CLP @ 0.5gKg^{-1}	7.78^{efg} (2.88)	7.77^{fgh} (2.88)	7.61^{fg} (2.85)	7.53^{fgh} (2.83)	7.49^{fgh} (2.83)	7.29^{gh} (2.79)	7.09^{fg} (2.75)	7.06^{def} (2.75)	6.86^{de} (2.71)	6.76^{f} (2.69)	6.70^{def} (2.68)	6.63^{ef} (2.67)	6.55^{fgh} (2.65)	6.48^{ef} (2.64)	7.11 (2.76)
CLP @ 1gKg^{-1}	7.78^{efg} (2.88)	7.63^{fghi} (2.85)	7.53^{fg} (2.83)	7.41^{fghi} (2.81)	7.32^{ghi} (2.80)	7.14^{hi} (2.76)	7.00^{fg} (2.74)	6.83^{efg} (2.71)	6.71^{e} (2.69)	6.63^{f} (2.67)	6.60^{def} (2.66)	6.49^{ef} (2.64)	6.37^{gh} (2.62)	6.26^{ef} (2.60)	6.98 (2.73)
CLP @ 2gKg^{-1}	7.82^{ef} (2.88)	7.80^{fg} (2.88)	7.76^{ef} (2.87)	7.69^{efg} (2.86)	7.53^{fg} (2.83)	7.39^{fgh} (2.81)	7.23^{ef} (2.78)	7.10^{de} (2.76)	6.89^{de} (2.72)	6.79^{ef} (2.70)	6.73^{de} (2.69)	6.62^{ef} (2.67)	6.58^{efg} (2.66)	6.41^{ef} (2.63)	7.17 (2.77)
NLP @ 0.5gKg^{-1}	7.58^{fgh} (2.84)	7.40^{hij} (2.81)	7.27^{gh} (2.79)	7.18^{hij} (2.77)	7.10^{hij} (2.76)	7.06^{hi} (2.75)	6.83^{g} (2.71)	6.76^{efg} (2.69)	6.74^{e} (2.69)	6.66^{f} (2.68)	6.53^{def} (2.65)	6.40^{f} (2.63)	6.36^{gh} (2.62)	6.28^{ef} (2.60)	6.87 (2.71)
NLP @ 1gKg^{-1}	8.10^{de} (2.93)	8.02^{ef} (2.92)	7.86^{ef} (2.89)	7.80^{ef} (2.88)	7.74^{f} (2.87)	7.64^{efg} (2.85)	7.53^{de} (2.83)	7.40^{cd} (2.81)	7.21^{cd} (2.78)	7.18^{de} (2.77)	6.92^{cd} (2.72)	6.83^{de} (2.71)	6.78^{def} (2.70)	6.64^{de} (2.67)	7.40 (2.81)
NLP @ 2gKg^{-1}	7.50^{fgh} (2.83)	7.48^{ghij} (2.82)	7.33^{gh} (2.80)	7.13^{ij} (2.76)	7.00^{ij} (2.74)	6.89^{ij} (2.72)	6.71^{gh} (2.68)	6.63^{gh} (2.67)	6.50^{ef} (2.65)	6.44^{f} (2.63)	6.31^{f} (2.61)	6.29^{f} (2.61)	6.18^{h} (2.58)	6.11^{f} (2.57)	6.75 (2.69)
SEM±	0.18	0.18	0.18	0.19	0.19	0.18	0.19	0.18	0.18	0.18	0.16	0.15	0.17	0.17	0.17
CD (0.01)	0.100	0.100	0.102	0.103	0.105	0.104	0.105	0.107	0.166	0.207	0.211	0.195	0.196	0.198	
CD (0.05)	0.074	0.074	0.076	0.077	0.078	0.078	0.078	0.080	0.123	0.154	0.157	0.145	0.146	0.148	

Values in parentheses are square root transformation values

Table 9: Effect of normal grade botanicals on seedling root length (cm) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.94^{f} (2.73)	6.62^{g} (2.67)	6.55^{e} (2.65)	6.49^{e} (2.64)	6.38^{f} (2.62)	6.15^{g} (2.58)	5.88^{f} (2.53)	5.62^{f} (2.47)	5.28^{g} (2.40)	5.15^{f} (2.38)	4.71^{f} (2.28)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	4.70 (2.16)
ALP @ 0.5gKg^{-1}	8.10^{a} (2.93)	8.02^{a} (2.92)	7.90^{a} (2.90)	7.83^{a} (2.89)	7.70^{a} (2.86)	7.67^{a} (2.86)	7.65^{a} (2.85)	7.53^{a} (2.83)	7.47^{a} (2.82)	7.38^{a} (2.81)	7.24^{a} (2.78)	7.14^{a} (2.76)	7.02^{a} (2.74)	6.88^{a} (2.72)	7.54 (2.83)
ALP @ 1gKg^{-1}	7.65^{abcde} (2.85)	7.58^{abcde} (2.84)	7.50^{abc} (2.83)	7.32^{abcd} (2.80)	7.22^{abcde} (2.78)	7.16^{abcde} (2.77)	7.02^{abcd} (2.74)	6.82^{bcd} (2.70)	6.79^{abc} (2.70)	6.59^{bc} (2.66)	6.44^{bc} (2.63)	6.37^{bc} (2.62)	6.25^{bcd} (2.60)	6.19^{abc} (2.59)	6.92 (2.72)
ALP @ 2gKg^{-1}	7.80^{abcd} (2.88)	7.76^{abc} (2.87)	7.60^{ab} (2.85)	7.52^{ab} (2.83)	7.48^{abc} (2.82)	7.33^{abcd} (2.80)	7.27^{abc} (2.79)	7.18^{abc} (2.77)	7.08^{abc} (2.75)	6.78^{abc} (2.70)	6.67^{abc} (2.68)	6.59^{abc} (2.66)	6.47^{abcd} (2.64)	6.33^{abc} (2.61)	7.13 (2.76)
FLP @ 0.5gKg^{-1}	7.49^{abcdef} (2.83)	7.37^{abcdef} (2.80)	7.21^{abcde} (2.78)	7.14^{abcde} (2.76)	6.96^{bcdef} (2.73)	6.82^{cdefg} (2.70)	6.78^{bcde} (2.70)	6.62^{cd} (2.67)	6.58^{bcd} (2.66)	6.42^{cd} (2.63)	6.38^{cd} (2.62)	6.26^{bcd} (2.60)	6.18^{cde} (2.58)	6.07^{bcd} (2.56)	6.73 (2.69)
FLP @ 1gKg^{-1}	7.64^{abcdef} (2.85)	7.57^{abcde} (2.84)	7.43^{abcd} (2.81)	7.26^{abcd} (2.78)	6.99^{bcdef} (2.74)	6.87^{bcdef} (2.71)	6.76^{cde} (2.69)	6.63^{cd} (2.67)	6.50^{cde} (2.64)	6.42^{cd} (2.63)	6.37^{cd} (2.62)	6.24^{bcd} (2.59)	6.13^{cde} (2.57)	6.02^{bcd} (2.55)	6.77 (2.69)
FLP @ 2gKg^{-1}	7.98^{ab} (2.91)	7.81^{ab} (2.88)	7.73^{ab} (2.87)	7.67^{a} (2.86)	7.60^{ab} (2.84)	7.55^{ab} (2.84)	7.54^{a} (2.83)	7.47^{ab} (2.82)	7.46^{a} (2.82)	7.36^{a} (2.80)	7.25^{a} (2.78)	7.11^{a} (2.76)	6.95^{a} (2.73)	6.84^{a} (2.71)	7.45 (2.82)
PLP @ 0.5gKg^{-1}	7.32^{bcdef} (2.80)	7.20^{bcdefg} (2.77)	7.11^{bcde} (2.76)	6.93^{bcde} (2.72)	6.81^{cdef} (2.70)	6.76^{defg} (2.69)	6.69^{cde} (2.68)	6.58^{cde} (2.66)	6.44^{cdef} (2.63)	6.30^{cde} (2.61)	6.22^{cde} (2.59)	6.19^{cde} (2.58)	6.00^{def} (2.55)	5.87^{cde} (2.52)	6.60 (2.66)
PLP @ 1gKg^{-1}	7.09^{ef} (2.75)	6.86^{fg} (2.71)	6.78^{de} (2.70)	6.63^{de} (2.67)	6.53^{ef} (2.65)	6.36^{fg} (2.62)	6.22^{ef} (2.59)	5.91^{ef} (2.53)	5.81^{efg} (2.51)	5.66^{ef} (2.48)	5.56^{e} (2.46)	5.45^{f} (2.44)	5.34^{fg} (2.42)	5.28^{e} (2.40)	6.11 (2.57)
PLP @ 2gKg^{-1}	7.86^{abc} (2.89)	7.76^{abc} (2.87)	7.64^{ab} (2.85)	7.54^{ab} (2.84)	7.51^{abc} (2.83)	7.48^{abc} (2.82)	7.47^{ab} (2.82)	7.38^{ab} (2.81)	7.27^{ab} (2.79)	7.18^{ab} (2.77)	7.09^{ab} (2.75)	6.89^{ab} (2.72)	6.77^{abc} (2.70)	6.68^{ab} (2.68)	7.32 (2.80)
CLP @ 0.5gKg^{-1}	8.03^{a} (2.92)	7.92^{a} (2.90)	7.87^{a} (2.89)	7.72^{a} (2.87)	7.66^{ab} (2.86)	7.58^{a} (2.84)	7.49^{a} (2.83)	7.44^{ab} (2.82)	7.38^{a} (2.81)	7.29^{ab} (2.79)	7.14^{ab} (2.76)	7.08^{a} (2.75)	6.89^{ab} (2.72)	6.79^{a} (2.70)	7.45 (2.82)
CLP @ 1gKg^{-1}	7.18^{cdef} (2.77)	7.09^{cdefg} (2.75)	6.78^{de} (2.70)	6.75^{cde} (2.69)	6.54^{ef} (2.65)	6.36^{fg} (2.62)	6.23^{ef} (2.59)	5.83^{f} (2.51)	5.91^{defg} (2.53)	5.80^{def} (2.51)	5.72^{de} (2.49)	5.63^{def} (2.47)	5.50^{efg} (2.45)	5.47^{de} (2.44)	6.20 (2.59)
CLP @ 2gKg^{-1}	7.73^{abcde} (2.87)	7.64^{abcd} (2.85)	7.51^{abc} (2.83)	7.44^{abc} (2.82)	7.38^{abcd} (2.81)	7.27^{abcd} (2.79)	7.20^{abc} (2.77)	7.09^{abc} (2.75)	6.79^{abc} (2.70)	6.68^{abc} (2.68)	6.60^{abc} (2.66)	6.51^{abc} (2.65)	6.44^{abcd} (2.63)	6.34^{abc} (2.61)	7.04 (2.74)
NLP @ 0.5gKg^{-1}	7.11^{def} (2.76)	6.86^{fg} (2.71)	6.74^{de} (2.69)	6.65^{de} (2.67)	6.57^{ef} (2.66)	6.41^{fg} (2.63)	6.26^{ef} (2.60)	6.19^{def} (2.59)	5.90^{defg} (2.53)	5.81^{def} (2.51)	5.70^{de} (2.49)	5.61^{def} (2.47)	5.54^{efg} (2.46)	5.40^{de} (2.43)	6.20 (2.58)
NLP @ 1gKg^{-1}	7.09^{ef} (2.75)	6.90^{efg} (2.72)	6.82^{cde} (2.70)	6.71^{de} (2.68)	6.68^{def} (2.68)	6.47^{efg} (2.64)	6.36^{def} (2.62)	6.12^{def} (2.57)	5.77^{fg} (2.50)	5.67^{ef} (2.48)	5.58^{e} (2.46)	5.42^{f} (2.43)	5.30^{g} (2.41)	5.21^{e} (2.39)	6.15 (2.57)
NLP @ 2gKg^{-1}	7.10^{def} (2.76)	6.97^{defg} (2.73)	6.88^{cde} (2.72)	6.72^{de} (2.69)	6.55^{ef} (2.65)	6.44^{fg} (2.63)	6.30^{ef} (2.61)	6.18^{def} (2.58)	5.96^{defg} (2.54)	5.73^{def} (2.49)	5.66^{e} (2.48)	5.54^{ef} (2.46)	5.40^{fg} (2.43)	5.28^{e} (2.40)	6.19 (2.58)
SEM±	0.10	0.11	0.11	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.18	0.42	0.41	0.40	0.18
CD (0.01)	NS	0.167	0.170	0.171	0.173	0.173	0.174	0.175	0.178	0.180	0.182	0.178	0.179	0.183	
CD (0.05)	0.124	0.124	0.126	0.127	0.129	0.128	0.129	0.130	0.133	0.134	0.135	0.133	0.133	0.136	

Values in parentheses are square root transformation values

Table 10: Effect of normal grade botanicals on seedling dry weight (mg) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	22.10^{f} (4.75)	21.18^{g} (4.66)	20.50^{f} (4.58)	19.58^{f} (4.48)	19.43^{d} (4.46)	18.54^{c} (4.36)	18.33^{h} (4.34)	17.78^{h} (4.28)	17.53^{f} (4.25)	16.54^{i} (4.13)	14.75^{f} (3.90)	12.80^{f} (3.65)	0.00 (0.71)	0.00 (0.71)	15.65 (3.80)
ALP @ 0.5gKg^{-1}	23.43^{bcde} (4.89)	23.30^{abcde} (4.88)	22.61^{bcd} (4.81)	22.57^{abc} (4.80)	21.57^{b} (4.70)	20.60^{b} (4.59)	20.58^{def} (4.59)	19.71^{def} (4.50)	19.82^{b} (4.51)	18.50^{gh} (4.36)	18.38^{bcde} (4.34)	17.50^{de} (4.24)	17.38^{bc} (4.23)	17.31^{bcd} (4.22)	20.23 (4.55)
ALP @ 1gKg^{-1}	23.66^{abc} (4.91)	23.57^{ab} (4.91)	22.58^{cd} (4.80)	21.63^{e} (4.70)	21.54^{b} (4.69)	20.70^{b} (4.60)	20.66^{de} (4.60)	19.55^{de} (4.48)	19.47^{bcd} (4.47)	19.40^{cdef} (4.46)	18.66^{b} (4.38)	18.56^{c} (4.37)	17.48^{b} (4.24)	17.40^{b} (4.23)	20.35 (4.56)
ALP @ 2gKg^{-1}	24.22^{a} (4.97)	23.42^{abcd} (4.89)	23.33^{ab} (4.88)	23.23^{a} (4.87)	22.81^{a} (4.83)	22.78^{a} (4.82)	21.74^{b} (4.72)	21.63^{b} (4.70)	21.58^{a} (4.70)	21.50^{a} (4.69)	20.49^{a} (4.58)	20.38^{ab} (4.57)	19.73^{a} (4.50)	19.65^{a} (4.49)	21.89 (4.73)
FLP @ 0.5gKg^{-1}	24.24^{a} (4.97)	23.30^{abcde} (4.88)	23.24^{abc} (4.87)	23.19^{ab} (4.87)	22.65^{a} (4.81)	22.60^{a} (4.81)	22.54^{a} (4.80)	21.57^{a} (4.70)	21.46^{a} (4.69)	20.67^{b} (4.60)	20.55^{a} (4.59)	19.74^{b} (4.50)	19.69^{a} (4.49)	19.58^{a} (4.48)	21.79 (4.72)
FLP @ 1gKg^{-1}	23.50^{abcd} (4.90)	23.41^{abcd} (4.89)	22.60^{bcd} (4.81)	22.55^{abc} (4.80)	21.60^{b} (4.70)	20.67^{b} (4.60)	20.61^{def} (4.59)	20.50^{def} (4.58)	19.49^{bc} (4.47)	19.42^{cdef} (4.46)	18.50^{bcd} (4.36)	17.47^{de} (4.24)	17.40^{bc} (4.23)	17.34^{bc} (4.22)	20.36 (4.56)
FLP @ 2gKg^{-1}	23.81^{ab} (4.93)	23.70^{a} (4.92)	23.66^{a} (4.92)	22.76^{abc} (4.82)	22.67^{a} (4.81)	22.56^{a} (4.80)	21.60^{bc} (4.70)	21.55^{bc} (4.70)	21.45^{a} (4.68)	20.66^{b} (4.60)	20.56^{a} (4.59)	20.49^{a} (4.58)	19.77^{a} (4.50)	19.66^{a} (4.49)	21.78 (4.72)
PLP @ 0.5gKg^{-1}	22.88^{de} (4.84)	22.80^{cdef} (4.83)	21.72^{e} (4.71)	21.64^{de} (4.71)	20.59^{c} (4.59)	20.50^{b} (4.58)	19.99^{efg} (4.53)	19.90^{efg} (4.52)	18.88^{cde} (4.40)	18.76^{defg} (4.39)	17.83^{de} (4.28)	17.79^{d} (4.28)	17.66^{b} (4.26)	16.90^{bcde} (4.17)	19.85 (4.51)
PLP @ 1gKg^{-1}	22.77^{def} (4.82)	22.70^{def} (4.82)	21.74^{e} (4.72)	21.60^{e} (4.70)	20.64^{c} (4.60)	20.59^{b} (4.59)	19.89^{fg} (4.52)	19.80^{fg} (4.51)	19.65^{b} (4.49)	18.75^{efg} (4.39)	17.84^{cde} (4.28)	17.76^{d} (4.27)	17.62^{b} (4.26)	16.92^{bcde} (4.17)	19.88 (4.51)
PLP @ 2gKg^{-1}	23.12^{bcde} (4.86)	22.50^{f} (4.80)	22.43^{de} (4.79)	21.53^{e} (4.69)	21.42^{b} (4.68)	20.60^{b} (4.59)	20.55^{def} (4.59)	19.70^{def} (4.49)	18.53^{e} (4.36)	17.78^{h} (4.28)	17.70^{e} (4.27)	16.80^{e} (4.16)	16.73^{cd} (4.15)	16.69^{cde} (4.15)	19.72 (4.49)
CLP @ 0.5gKg^{-1}	22.98^{cde} (4.85)	22.86^{bcdef} (4.83)	22.79^{bcd} (4.83)	22.67^{abc} (4.81)	21.59^{b} (4.70)	20.96^{b} (4.63)	20.89^{cd} (4.62)	19.85^{cd} (4.51)	19.80^{b} (4.51)	19.74^{c} (4.50)	18.60^{b} (4.37)	17.70^{d} (4.27)	17.65^{b} (4.26)	16.85^{bcde} (4.17)	20.35 (4.56)
CLP @ 1gKg^{-1}	23.72^{abc} (4.92)	23.45^{abc} (4.89)	22.78^{bcd} (4.82)	22.64^{abc} (4.81)	21.67^{b} (4.71)	20.79^{b} (4.61)	20.68^{de} (4.60)	20.55^{de} (4.59)	19.60^{bc} (4.48)	19.46^{cde} (4.47)	18.60^{b} (4.37)	17.54^{de} (4.25)	17.40^{bc} (4.23)	17.33^{bc} (4.22)	20.44 (4.57)
CLP @ 2gKg^{-1}	23.50^{abcd} (4.90)	23.33^{abcde} (4.88)	22.75^{bcd} (4.82)	22.60^{abc} (4.81)	21.70^{b} (4.71)	20.84^{b} (4.62)	20.70^{de} (4.60)	20.60^{de} (4.59)	19.64^{b} (4.49)	19.50^{cd} (4.47)	18.58^{bc} (4.37)	17.58^{d} (4.25)	17.45^{b} (4.24)	17.36^{bc} (4.23)	20.44 (4.57)
NLP @ 0.5gKg^{-1}	22.76^{def} (4.82)	22.66^{ef} (4.81)	22.50^{cd} (4.80)	22.38^{cd} (4.78)	21.42^{b} (4.68)	20.81^{b} (4.62)	19.58^{g} (4.48)	19.50^{g} (4.47)	18.68^{e} (4.38)	18.60^{g} (4.37)	17.69^{e} (4.26)	17.58^{d} (4.25)	16.67^{d} (4.14)	16.59^{e} (4.13)	19.82 (4.50)
NLP @ 1gKg^{-1}	22.83^{def} (4.83)	22.66^{ef} (4.81)	22.59^{bcd} (4.81)	22.48^{bc} (4.79)	21.43^{b} (4.68)	20.78^{b} (4.61)	20.68^{de} (4.60)	19.77^{de} (4.50)	18.74^{de} (4.39)	18.69^{fg} (4.38)	17.73^{e} (4.27)	17.67^{d} (4.26)	16.74^{cd} (4.15)	16.62^{de} (4.14)	19.96 (4.52)
NLP @ 2gKg^{-1}	22.69^{ef} (4.82)	22.54^{f} (4.80)	22.46^{de} (4.79)	21.34^{e} (4.67)	20.44^{c} (4.58)	20.24^{b} (4.55)	19.89^{fg} (4.52)	19.78^{fg} (4.50)	18.64^{e} (4.37)	18.57^{g} (4.37)	17.67^{e} (4.26)	17.56^{d} (4.25)	16.62^{d} (4.14)	16.56^{e} (4.13)	19.64 (4.48)
SEM±	0.15	0.16	0.18	0.23	0.22	0.26	0.24	0.24	0.28	0.3	0.35	0.43	1.14	1.13	0.35
CD (0.01)	0.054	0.051	0.053	0.054	0.052	0.052	0.053	0.051	0.053	0.053	0.052	0.054	0.053	0.054	
CD (0.05)	0.040	0.037	0.039	0.040	0.038	0.039	0.039	0.037	0.039	0.039	0.038	0.040	0.039	0.040	

Values in parentheses are square root transformation values

Table 11: Effect of normal grade botanicals on seedling dry weight (mg) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	17.19^{g} (4.21)	17.09^{h} (4.19)	16.42^{h} (4.11)	16.21^{g} (4.09)	16.08^{h} (4.07)	15.27^{d} (3.97)	15.17^{e} (3.96)	13.89^{f} (3.79)	11.66^{g} (3.49)	9.74^{f} (3.20)	5.43^{f} (2.43)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	11.01 (3.12)
ALP @ 0.5gKg^{-1}	18.49^{a} (4.36)	18.37^{a} (4.34)	18.20^{a} (4.32)	18.09^{a} (4.31)	17.84^{a} (4.28)	17.76^{a} (4.27)	17.65^{a} (4.26)	17.54^{a} (4.25)	17.43^{a} (4.23)	17.31^{a} (4.22)	17.18^{a} (4.20)	17.08^{a} (4.19)	16.89^{a} (4.17)	16.72^{a} (4.15)	17.61 (4.26)
ALP @ 1gKg^{-1}	17.74^{cdef} (4.27)	17.66^{cdef} (4.26)	17.20^{ef} (4.21)	17.07^{de} (4.19)	16.45^{efgh} (4.12)	16.33^{bc} (4.10)	16.29^{b} (4.10)	15.70^{c} (4.02)	15.64^{bc} (4.02)	15.52^{b} (4.00)	15.44^{b} (3.99)	15.34^{b} (3.98)	15.25^{bc} (3.97)	15.19^{b} (3.96)	16.20 (4.09)
ALP @ 2gKg^{-1}	18.08^{bcd} (4.31)	17.87^{bcd} (4.29)	17.76^{bc} (4.27)	17.54^{bc} (4.25)	17.38^{bc} (4.23)	16.39^{bc} (4.11)	16.22^{b} (4.09)	16.18^{b} (4.08)	15.67^{b} (4.02)	15.50^{b} (4.00)	15.43^{b} (3.99)	15.37^{b} (3.98)	15.29^{b} (3.97)	15.20^{b} (3.96)	16.42 (4.11)
FLP @ 0.5gKg^{-1}	17.63^{ef} (4.26)	17.54^{defg} (4.25)	17.41^{cde} (4.23)	17.28^{cd} (4.22)	16.66^{def} (4.14)	16.38^{bc} (4.11)	16.23^{b} (4.09)	15.50^{cd} (4.00)	15.39^{bcd} (3.99)	15.24^{bcd} (3.97)	15.15^{bc} (3.96)	15.09^{bc} (3.95)	14.88^{cde} (3.92)	14.77^{cd} (3.91)	16.08 (4.07)
FLP @ 1gKg^{-1}	17.59^{ef} (4.25)	17.42^{efgh} (4.23)	17.23^{ef} (4.21)	17.18^{cd} (4.20)	16.57^{efg} (4.13)	16.42^{bc} (4.11)	16.27^{b} (4.10)	15.66^{c} (4.02)	15.54^{bc} (4.00)	15.30^{bc} (3.97)	15.24^{b} (3.97)	15.18^{bc} (3.96)	15.00^{bcd} (3.94)	14.87^{bc} (3.92)	16.11 (4.07)
FLP @ 2gKg^{-1}	18.15^{ab} (4.32)	18.08^{ab} (4.31)	17.85^{ab} (4.28)	17.77^{ab} (4.27)	17.64^{ab} (4.26)	17.51^{a} (4.24)	17.44^{a} (4.24)	17.36^{a} (4.23)	17.27^{a} (4.22)	17.12^{a} (4.20)	17.06^{a} (4.19)	16.90^{a} (4.17)	16.84^{a} (4.16)	16.71^{a} (4.15)	17.41 (4.23)
PLP @ 0.5gKg^{-1}	17.77^{bcdef} (4.27)	17.60^{defg} (4.25)	17.54^{bcde} (4.25)	16.77^{ef} (4.16)	16.45^{efgh} (4.12)	16.37^{bc} (4.11)	15.47^{cde} (4.00)	15.38^{cd} (3.98)	15.14^{de} (3.95)	14.92^{cde} (3.93)	14.82^{cde} (3.91)	14.70^{de} (3.90)	14.61^{ef} (3.89)	14.53^{cde} (3.88)	15.86 (4.04)
PLP @ 1gKg^{-1}	17.66^{ef} (4.26)	17.50^{defg} (4.24)	17.44^{cde} (4.24)	16.41^{fg} (4.11)	16.33^{fgh} (4.10)	16.24^{c} (4.09)	15.57^{cd} (4.01)	15.48^{cd} (4.00)	15.27^{cd} (3.97)	15.17^{bcd} (3.96)	15.09^{bcd} (3.95)	14.91^{cd} (3.93)	14.82^{de} (3.91)	14.73^{cd} (3.90)	15.90 (4.05)
PLP @ 2gKg^{-1}	17.69^{def} (4.26)	17.52^{defg} (4.24)	16.88^{fg} (4.17)	16.77^{ef} (4.16)	16.61^{ef} (4.14)	16.54^{bc} (4.13)	15.76^{c} (4.03)	15.59^{c} (4.01)	15.41^{bcd} (3.99)	15.33^{b} (3.98)	15.21^{bc} (3.96)	15.14^{bc} (3.95)	15.09^{bcd} (3.95)	14.82^{bc} (3.91)	16.03 (4.06)
CLP @ 0.5gKg^{-1}	18.10^{abc} (4.31)	18.00^{abc} (4.30)	17.86^{ab} (4.28)	17.76^{ab} (4.27)	17.61^{ab} (4.26)	17.54^{a} (4.25)	17.40^{a} (4.23)	17.32^{a} (4.22)	17.25^{a} (4.21)	17.03^{a} (4.19)	16.90^{a} (4.17)	16.79^{a} (4.16)	16.64^{a} (4.14)	16.54^{a} (4.13)	17.34 (4.22)
CLP @ 1gKg^{-1}	17.88^{bcde} (4.29)	17.71^{bcdef} (4.27)	17.68^{bc} (4.26)	17.52^{bc} (4.24)	16.77^{de} (4.16)	16.54^{bc} (4.13)	16.37^{b} (4.11)	15.67^{c} (4.02)	15.49^{bcd} (4.00)	15.33^{b} (3.98)	15.20^{bc} (3.96)	15.12^{bc} (3.95)	15.02^{bcd} (3.94)	14.82^{bc} (3.91)	16.22 (4.09)
CLP @ 2gKg^{-1}	17.81^{bcde} (4.28)	17.77^{bcde} (4.27)	17.65^{bcd} (4.26)	17.52^{bc} (4.24)	16.77^{de} (4.16)	16.58^{bc} (4.13)	16.32^{b} (4.10)	15.60^{c} (4.01)	15.37^{bcd} (3.98)	15.29^{bc} (3.97)	15.16^{bc} (3.96)	15.02^{bcd} (3.94)	14.89^{cde} (3.92)	14.71^{cd} (3.90)	16.18 (4.08)
NLP @ 0.5gKg^{-1}	17.40^{fg} (4.23)	17.37^{fgh} (4.23)	17.27^{def} (4.22)	16.50^{fg} (4.12)	16.28^{fgh} (4.10)	15.40^{d} (3.99)	15.20^{de} (3.96)	15.13^{de} (3.95)	14.70^{f} (3.90)	14.55^{e} (3.88)	14.44^{e} (3.87)	14.32^{e} (3.85)	14.22^{g} (3.84)	14.17^{e} (3.83)	15.50 (4.00)
NLP @ 1gKg^{-1}	17.58^{efg} (4.25)	17.22^{gh} (4.21)	16.50^{gh} (4.12)	16.37^{g} (4.11)	16.20^{gh} (4.09)	15.37^{d} (3.98)	15.20^{de} (3.96)	14.80^{e} (3.91)	14.78^{ef} (3.91)	14.64^{e} (3.89)	14.56^{e} (3.88)	14.45^{e} (3.87)	14.35^{fg} (3.85)	14.21^{e} (3.84)	15.45 (3.99)
NLP @ 2gKg^{-1}	17.66^{ef} (4.26)	17.57^{defg} (4.25)	17.49^{bcde} (4.24)	17.20^{cd} (4.21)	17.01^{cd} (4.18)	16.67^{b} (4.14)	16.59^{b} (4.13)	15.46^{cd} (3.99)	15.11^{de} (3.95)	14.88^{de} (3.92)	14.71^{de} (3.90)	14.64^{de} (3.89)	14.51^{efg} (3.87)	14.40^{de} (3.86)	15.99 (4.06)
SEM±	0.08	0.08	0.12	0.14	0.14	0.18	0.20	0.24	0.33	0.42	0.66	0.98	0.97	0.97	0.39
CD (0.01)	0.096	0.093	0.095	0.096	0.094	0.094	0.095	0.093	0.095	0.095	0.094	0.096	0.095	0.096	
CD (0.05)	0.061	0.058	0.060	0.061	0.059	0.060	0.060	0.058	0.060	0.060	0.059	0.061	0.060	0.061	

Values in parentheses are square root transformation values

vigour index I compared to control. However, seedling vigour index declined progressively throughout the storage period, there was no significant difference among the treatments upto third month of storage.

In Anugraha, among the normal grade powder treatments (Table 12), maximum vigour index I was observed in seeds treated with T_4: ALP @ 2 g kg^{-1} (961) followed by T_7: FLP @ 2 g kg^{-1} (917) and T_5: FLP @ 0.5 g kg^{-1} (914) and T_9: PLP @ 1 g kg^{-1} (844) while minimum vigour index I was observed in T_{16}: NLP @ 2 g kg^{-1} (584) and control recorded a vigour index I (349) at twelfth month of storage.

In Ujwala, among the normal grade powder treatments (Table 13), maximum vigour index I observed was in seeds treated with T_2: ALP @ 0.5 g kg^{-1} (863), T_7: FLP @ 2 g kg^{-1} (849) were on par with T_{11}: CLP @ 0.5 g kg^{-1} (830), T_{10}: PLP @ 2 g kg^{-1} (815) and T_4: ALP @ 2 g kg^{-1} (793) while minimum vigour index was observed in T_{15}: NLP @ 1 g kg^{-1} (600) compared to control (315) at ninth month of storage.

In both the varieties, irrespective of the concentration, the least performing botanical was neem among the treated seeds.

4.2.7. Vigour index II

Vigour index II of seeds treated with normal grade powders revealed significant differences among the treatments and over the period of storage. Treated seeds had higher vigour index II compared to control. However, seedling vigour index declined progressively throughout the storage period, there was no significant difference among the treatments upto third month of storage.

In Anugraha, among normal powder treatments (Table 14), maximum vigour index II was observed in seeds treated with T_4: ALP @ 2 g kg^{-1} (1419), T_7: FLP @ 2 g kg^{-1} (1391), T_5: FLP @ 0.5 g kg^{-1} (1320) which were on par with each other and T_{11}: CLP @ 0.5 g kg^{-1} (1145), T_3: ALP @ 1 g kg^{-1} (1144) were also on par. Vigour index II was minimum in T_{16}: NLP @ 2 g kg^{-1} (926) whereas control recorded a vigour index II of 466 at twelfth month of storage.

In Ujwala, among the normal grade powder treatments (Table 15), maximum vigour index II was observed in seeds treated with T_7: FLP @ 2 g kg^{-1} (1093) which was on par with T_2: ALP @ 0.5 g kg^{-1} (1075) followed by T_6: FLP @ 1 g kg^{-1} (997) which was on par with T_4: ALP @ 2 g kg^{-1} (980). Minimum vigour index II was observed in T_{15}: NLP @ 1 g kg^{-1} (850) compared to control (380) at ninth month of storage.

Table 12: Effect of normal grade botanicals on vigour index I during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1335^{c}	1271^{g}	1160^{g}	1097^{h}	1003^{h}	928^{f}	852^{f}	774^{e}	715^{g}	624^{i}	460^{h}	349^{i}	0	0	755
ALP @ 0.5gKg^{-1}	1449^{abcde}	1426^{abcdef}	1387^{abcde}	1354^{abcd}	1303^{bcd}	1227^{cd}	1149^{bc}	1087^{c}	1019^{bc}	958^{cde}	882^{bc}	827^{bcd}	784^{bcde}	731^{bc}	1113
ALP @ 1gKg^{-1}	1499^{abcd}	1458^{abcd}	1415^{abcd}	1406^{abc}	1321^{abc}	1248^{bc}	1185^{ab}	1097^{bc}	1006^{bc}	915^{def}	838^{cde}	787^{cde}	752^{cdef}	721^{bc}	1118
ALP @ 2gKg^{-1}	1569^{a}	1554^{a}	1537^{a}	1493^{a}	1445^{a}	1378^{a}	1314^{a}	1265^{a}	1186^{a}	1143^{a}	1028^{a}	961^{a}	914^{a}	868^{a}	1261
FLP @ 0.5gKg^{-1}	1511^{abc}	1485^{abc}	1467^{abc}	1440^{ab}	1396^{ab}	1369^{ab}	1314^{a}	1230^{ab}	1168^{a}	1063^{abc}	983^{ab}	914^{ab}	869^{abc}	827^{ab}	1217
FLP @ 1gKg^{-1}	1408^{abcde}	1350^{bcdefg}	1345^{bcdef}	1306^{bcdef}	1250^{cde}	1177^{cd}	1124^{bc}	1055^{c}	998^{bc}	910^{def}	853^{cd}	801^{bcd}	776^{bcde}	724^{bc}	1077
FLP @ 2gKg^{-1}	1520^{ab}	1503^{ab}	1495^{ab}	1469^{a}	1425^{ab}	1382^{a}	1304^{a}	1247^{a}	1170^{a}	1101^{ab}	1001^{ab}	917^{ab}	881^{ab}	827^{ab}	1232
PLP @ 0.5gKg^{-1}	1353^{cde}	1318^{defg}	1239^{efg}	1187^{fgh}	1115^{efgh}	1046^{ef}	973^{def}	909de	825^{efg}	783^{fghi}	733^{defg}	662^{fgh}	632^{fghij}	586^{def}	954
PLP @ 1gKg^{-1}	1471^{abcde}	1438^{abcde}	1399^{abcde}	1346^{abcde}	1212^{cdef}	1223^{cd}	1168^{abc}	1094^{bc}	1034^{b}	996^{bcd}	907^{abc}	844^{abc}	800^{abcd}	733^{bc}	1119
PLP @ 2gKg^{-1}	1315^{e}	1265^{g}	1214^{fg}	1139^{gh}	1108^{fgh}	1011^{ef}	941^{ef}	895de	833^{defg}	768^{ghi}	681^{fgh}	609^{ghi}	568^{ij}	530^{ef}	920
CLP @ 0.5gKg^{-1}	1370^{bcde}	1296^{efg}	1299^{defg}	1253^{cdefg}	1174^{defg}	1127^{cde}	1095^{bcd}	1030^{cd}	959^{bcd}	904^{def}	840^{cde}	782^{cde}	735^{defg}	678^{cd}	1039
CLP @ 1gKg^{-1}	1359^{bcde}	1329^{defg}	1251^{efg}	1184^{fgh}	1113^{efgh}	1028^{ef}	954^{def}	899de	826^{defg}	794^{fghi}	719^{efg}	671^{efgh}	624^{ghij}	589^{def}	953
CLP @ 2gKg^{-1}	1318^{e}	1316^{defg}	1302^{defg}	1218^{defgh}	1187^{cdefg}	1120de	1029^{cde}	1020^{cd}	952^{bcde}	845^{efg}	806^{cdef}	742^{cdef}	702^{defgh}	645^{cde}	1014
NLP @ 0.5gKg^{-1}	1337de	1262^{g}	1213^{fg}	1153^{fgh}	1104^{fgh}	1015^{ef}	936^{ef}	900de	845^{defg}	784^{fghi}	692^{fgh}	627^{fghi}	596^{hij}	562^{def}	930
NLP @ 1gKg^{-1}	1402^{bcde}	1332^{cdefg}	1306^{cdefg}	1197^{efgh}	1166^{defg}	1042^{ef}	1028^{cde}	969^{cd}	895^{cdef}	841^{efgh}	780^{cdef}	716^{defg}	674^{efghi}	625^{cdef}	998
NLP @ 2gKg^{-1}	1332^{e}	1283^{fg}	1202^{fg}	1130^{gh}	1055^{gh}	973^{f}	883^{ef}	818^{e}	770^{fg}	708^{hi}	632^{gh}	584^{hi}	552^{j}	524^{f}	889
SEM±	20.72	23.71	28.40	32.52	33.51	37.18	38.11	37.30	36.23	35.96	37.17	38.49	53.13	50.01	34.38
CD (0.01)	NS	NS	NS	2.184	2.321	1.897	2.846	2.314	1.468	2.743	2.713	2.813	2.821	2.148	
CD (0.05)	NS	NS	2.353	1.750	1.852	1.537	2.243	1.846	1.217	2.166	2.143	2.218	2.224	1.723	

Table 13: Effect of normal grade botanicals on vigour index I during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1034	950	892^{e}	777^{g}	726^{f}	648^{h}	544^{f}	471^{e}	315^{g}	173^{h}	92^{h}	0	0	0	473
ALP @ 0.5gKg^{-1}	1265	1243	1218^{a}	1193^{a}	1158^{a}	1116^{a}	1024^{a}	939^{a}	863^{a}	799^{a}	745^{a}	705^{a}	654^{a}	655^{a}	970
ALP @ 1gKg^{-1}	1196	1177	1114^{abcd}	1075^{abcde}	1019^{bcd}	948^{bcde}	883^{abcde}	811^{bcd}	754^{bcd}	686^{abcde}	645^{abcde}	609^{abc}	571^{abcde}	554^{bcd}	860
ALP @ 2gKg^{-1}	1203	1185	1162^{abc}	1138^{ab}	1084^{ab}	1035^{ab}	968^{abc}	885^{ab}	793^{abc}	719^{abcd}	677^{abcd}	627^{ab}	594^{abcd}	555^{bcd}	902
FLP @ 0.5gKg^{-1}	1174	1138	1080^{abcd}	1064^{abcde}	1012^{bcde}	925^{cdef}	861^{bcde}	800^{bcd}	752^{bcd}	666^{bcdef}	629^{bcdef}	591^{abc}	561^{abcde}	545^{bcde}	843
FLP @ 1gKg^{-1}	1186	1151	1110^{abcd}	1073^{abcde}	1005^{bcde}	943^{bcde}	869^{bcde}	803^{bcd}	732^{cd}	625^{cdefg}	579^{cdefg}	563^{bcd}	528^{bcdef}	524^{cdef}	835
FLP @ 2gKg^{-1}	1256	1216	1186^{ab}	1158^{ab}	1107^{ab}	1028^{abc}	997^{ab}	901^{ab}	849^{a}	790^{a}	714^{ab}	696^{a}	642^{ab}	626^{ab}	941
PLP @ 0.5gKg^{-1}	1146	1124	1084^{abcd}	1007^{cdef}	939^{cde}	911^{defg}	857^{bcde}	764^{cd}	697de	617^{defg}	568^{defg}	558^{bcd}	525^{cdef}	518^{cdef}	808
PLP @ 1gKg^{-1}	1124	1089	1045^{bcde}	985^{def}	891de	832^{fg}	785^{e}	733^{cd}	652^{ef}	573^{efg}	537^{efg}	502^{cd}	475^{ef}	453^{fg}	763
PLP @ 2gKg^{-1}	1214	1191	1159^{abc}	1128^{abc}	1083^{ab}	1049^{ab}	968^{abc}	887^{ab}	815^{ab}	741^{abc}	687^{abc}	642^{ab}	594^{abcd}	558^{bcd}	908
CLP @ 0.5gKg^{-1}	1245	1211	1186^{ab}	1140^{ab}	1112^{ab}	1038^{ab}	994^{ab}	905^{ab}	830^{ab}	777^{ab}	717^{ab}	689^{a}	639^{abc}	606^{abc}	935
CLP @ 1gKg^{-1}	1137	1123	1048^{abcde}	1032^{bcdef}	937^{cde}	894^{defg}	838^{cde}	757^{cd}	686de	615^{defg}	571^{defg}	531^{bcd}	492^{def}	438^{fg}	793
CLP @ 2gKg^{-1}	1204	1183	1131^{abcd}	1113^{abcd}	1064^{abc}	996^{bcd}	944^{abcd}	850^{abc}	757^{bcd}	687^{abcde}	639^{abcde}	590^{abc}	558^{abcde}	513^{def}	873
NLP @ 0.5gKg^{-1}	1096	1057	992^{cde}	980^{ef}	937^{cde}	867^{efg}	795de	728^{d}	632^{ef}	611^{defg}	558^{efg}	527^{bcd}	488^{def}	457^{efg}	766
NLP @ 1gKg^{-1}	1084	1040	967de	927^{f}	883^{e}	809^{g}	761^{e}	694^{d}	600^{f}	528^{g}	491^{g}	452^{d}	428^{f}	402^{g}	719
NLP @ 2gKg^{-1}	1101	1077	1027^{bcde}	973^{ef}	912de	853^{efg}	800de	744^{cd}	646^{ef}	557^{fg}	522^{fg}	498^{cd}	462^{ef}	415^{g}	756
SEM±	16.70	19.29	22.30	26.32	27.82	28.96	30.08	28.34	33.14	37.21	37.96	41.04	38.13	37.45	29.69
CD (0.01)	NS	NS	NS	2.808	2.945	2.521	3.470	2.938	2.092	3.367	3.337	3.437	3.445	2.772	
CD (0.05)	NS	NS	2.665	2.062	2.164	1.849	2.555	2.158	1.529	2.478	2.455	2.530	2.536	2.035	

Table 14: Effect of normal grade botanicals on vigour index II during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	2064	1926	1760^{d}	1636^{e}	1523^{g}	1394^{f}	1316^{h}	1218^{g}	1129^{e}	928^{g}	658^{e}	466^{g}	0	0	1144
ALP @ $0.5gKg^{-1}$	2174	2137	2048^{abc}	2015^{abc}	1887^{abcd}	1753^{b}	1658^{cde}	1528^{bcde}	1459^{b}	1309^{cde}	1221^{bc}	1112^{bcd}	1058^{bc}	1001^{b}	1597
ALP @ $1gKg^{-1}$	2184	2141	2022^{abc}	1926^{bcd}	1857^{cd}	1712^{bcd}	1666^{cde}	1521^{bcde}	1430^{bc}	1335^{cde}	1202^{bc}	1144^{bc}	1041^{bcd}	1007^{b}	1585
ALP @ $2gKg^{-1}$	2277	2177	2160^{a}	2112^{a}	2029^{a}	1980^{a}	1825^{ab}	1771^{a}	1701^{a}	1648^{a}	1493^{a}	1419^{a}	1321^{a}	1266^{a}	1798
FLP @ $0.5gKg^{-1}$	2256	2156	2133^{ab}	2109^{a}	2018^{abc}	2007^{a}	1938^{a}	1778^{a}	1718^{a}	1549^{ab}	1459^{a}	1320^{a}	1260^{a}	1209^{a}	1779
FLP @ $1gKg^{-1}$	2172	2112	2031^{abc}	1991^{abc}	1862^{bcd}	1724^{bcd}	1660^{cde}	1570^{bcd}	1434^{bc}	1337^{cde}	1205^{bc}	1084^{bcd}	1057^{bc}	1003^{b}	1589
FLP @ $2gKg^{-1}$	2208	2179	2173^{a}	2066^{ab}	2019^{ab}	1976^{a}	1808^{abc}	1764^{a}	1691^{a}	1562^{ab}	1471^{a}	1391^{a}	1301^{a}	1228^{a}	1774
PLP @ $0.5gKg^{-1}$	2095	2056	1917^{cd}	1851^{cd}	1695^{ef}	1612^{bcde}	1496^{fg}	1425^{cdef}	1266^{de}	1218^{def}	1102^{cd}	1012^{cdef}	967^{bcde}	879^{bcd}	1471
PLP @ $1gKg^{-1}$	2113	2083	1973^{bc}	1931^{bcd}	1805^{def}	1748^{bc}	1629^{def}	1567^{bcd}	1470^{b}	1349^{cd}	1217^{bc}	1139^{bc}	1090^{b}	976^{bc}	1578
PLP @ $2gKg^{-1}$	2122	2015	1959^{bc}	1798^{de}	1763^{def}	1594^{de}	1525^{efg}	1410^{ef}	1264^{de}	1135^{fg}	1029^{d}	906^{f}	861^{e}	816^{d}	1443
CLP @ $0.5gKg^{-1}$	2133	2021	2065^{abc}	2023^{ab}	1847^{de}	1752^{bc}	1746^{bcd}	1577^{bc}	1502^{b}	1435^{bc}	1280^{b}	1145^{b}	1093^{b}	974^{bc}	1614
CLP @ $1gKg^{-1}$	2193	2154	2013^{abc}	1934^{bcd}	1785^{def}	1608^{cde}	1523^{efg}	1478^{bcdef}	1307^{cd}	1239^{def}	1112^{cd}	991^{def}	934^{cde}	892^{bcd}	1512
CLP @ $2gKg^{-1}$	2080	2077	2035^{abc}	1924^{bcd}	1851^{de}	1722^{bcd}	1601^{def}	1596^{b}	1471^{b}	1345^{cde}	1206^{bc}	1068^{bcde}	1011^{bcd}	944^{bcd}	1567
NLP @ $0.5gKg^{-1}$	2088	2029	1969^{bc}	1906^{bcd}	1782^{def}	1610^{bcde}	1442^{gh}	1399^{ef}	1278^{d}	1196^{ef}	1021^{d}	948^{ef}	861^{e}	821^{d}	1454
NLP @ $1gKg^{-1}$	2097	2019	2004^{abc}	1854^{cd}	1752^{def}	1564^{e}	1550^{efg}	1419^{def}	1279^{d}	1218^{def}	1098^{cd}	1019^{bcdef}	918^{de}	863^{cd}	1475
NLP @ $2gKg^{-1}$	2084	2029	1959^{bc}	1806^{d}	1650^{fg}	1547^{e}	1422^{gh}	1327^{fg}	1212^{de}	1135^{fg}	998^{d}	926^{f}	846^{e}	812^{d}	1411
SEM±	16.23	18.2	24.94	31.28	33.88	42.25	40.91	39.76	44.88	45.52	51.85	55.7	75.06	71.01	40.46
CD (0.01)	NS	NS	NS	1.399	1.559	2.262	2.294	1.586	1.611	2.471	2.494	2.473	2.524	2.354	
CD (0.05)	NS	NS	1.896	1.029	1.147	1.671	1.694	1.167	1.186	1.826	1.843	1.827	1.865	1.739	

Table 15: Effect of normal grade botanicals on vigour index II during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1421	1369	1255^{d}	1092^{j}	1026^{h}	890^{f}	787^{f}	641^{g}	380^{g}	181^{e}	58^{e}	0	0	0	650
ALP @ 0.5gKg^{-1}	1529	1518	1503^{ab}	1446^{abc}	1332^{bcd}	1376^{a}	1273^{a}	1198^{a}	1075^{abc}	1012^{a}	945^{a}	907^{a}	852^{a}	859^{a}	1202
ALP @ 1gKg^{-1}	1471	1457	1366^{bcd}	1338^{fg}	1250^{def}	1205^{bcd}	1142^{cd}	1039^{cd}	974^{bcd}	894^{b}	848^{bc}	810^{b}	770^{b}	741^{b}	1093
ALP @ 2gKg^{-1}	1483	1460	1447^{ab}	1414^{bcd}	1351^{bc}	1245^{bc}	1187^{bc}	1104^{b}	980^{bc}	911^{b}	861^{b}	811^{b}	778^{b}	729^{bc}	1126
FLP @ 0.5gKg^{-1}	1462	1438	1378^{bcd}	1359^{cdefg}	1281^{cde}	1204^{bcd}	1126^{cd}	1023^{cde}	967^{bcd}	863^{bc}	813^{bcd}	778^{bc}	739^{bc}	722^{bcd}	1082
FLP @ 1gKg^{-1}	1457	1423	1377^{bcd}	1358^{defg}	1266de	1230^{bc}	1160^{bc}	1061^{bc}	997^{b}	861^{bc}	832^{bc}	797^{b}	753^{b}	727^{bc}	1093
FLP @ 2gKg^{-1}	1499	1479	1451^{ab}	1421^{bc}	1383^{ab}	1300^{ab}	1261^{ab}	1177^{a}	1093^{a}	1026^{a}	962^{a}	922^{a}	872^{a}	825^{a}	1191
PLP @ 0.5gKg^{-1}	1473	1452	1425^{ab}	1298^{ghi}	1225^{efg}	1199^{bcd}	1091^{cde}	996de	924^{cde}	833^{bcd}	795^{bcd}	759^{bcd}	731^{bc}	706^{bcde}	1065
PLP @ 1gKg^{-1}	1461	1440	1397^{abc}	1267^{hi}	1188^{fg}	1128de	1044de	1018^{cde}	919de	846^{bcd}	809^{bcd}	753^{bcd}	723^{bc}	686^{bcde}	1049
PLP @ 2gKg^{-1}	1504	1487	1419^{abcd}	1384^{cde}	1283^{d}	1243^{bc}	1116^{def}	1041^{ef}	994^{ef}	866^{cdef}	816^{bcde}	766^{bcd}	719^{cdefg}	672^{ef}	1094
CLP @ 0.5gKg^{-1}	1465	1440	1371^{bcd}	1343^{efg}	1296^{cd}	1259^{bc}	1143^{cd}	1060^{bc}	975^{bcd}	902^{b}	848^{bc}	797^{b}	749^{b}	694^{bcde}	1096
CLP @ 1gKg^{-1}	1479	1469	1420^{ab}	1404^{bcde}	1274de	1231^{bc}	1161^{bc}	1047^{bcd}	949^{bcd}	855^{bcd}	802^{bcd}	755^{bcd}	709^{bc}	651^{cde}	1086
CLP @ 2gKg^{-1}	1475	1461	1413^{ab}	1399^{bcdef}	1304^{cd}	1255^{bc}	1192^{abc}	1044^{bcd}	948^{bcd}	867^{bc}	811^{bcd}	752^{bcd}	713^{bc}	675^{bcde}	1094
NLP @ 0.5gKg^{-1}	1434	1420	1358^{bcd}	1304^{gh}	1246^{defg}	1128de	1052de	975^{ef}	871^{ef}	791^{cd}	734^{d}	696^{cd}	651^{c}	633^{e}	1021
NLP @ 1gKg^{-1}	1443	1400	1276^{cd}	1237^{i}	1177^{g}	1056^{e}	998^{e}	922^{f}	850^{f}	766^{d}	725^{d}	677^{d}	650^{c}	632^{e}	986
NLP @ 2gKg^{-1}	1453	1437	1380^{bcd}	1314^{gh}	1266de	1195^{cd}	1129^{cd}	1000^{cde}	882^{ef}	796^{cd}	757^{cd}	730^{bcd}	685^{bc}	642de	1048
SEM±	7.88	9.52	16.20	23.39	24.28	28.58	30.10	32.65	42.16	49.38	52.65	53.47	40.42	48.63	32.44
CD (0.01)	NS	NS	NS	0.887	1.047	1.75	1.782	1.074	1.099	1.959	1.982	1.961	2.012	1.842	
CD (0.05)	NS	NS	1.540	0.673	0.791	1.315	1.338	0.811	0.830	1.470	1.487	1.471	1.509	1.383	

In both the varieties, irrespective of the concentration, the least performing botanical was neem following untreated (control).

4.2.8. Electrical conductivity (dSm^{-1})

Effect of seed treatments on electrical conductivity were found to be significant throughout the storage period. The results revealed that, electrical conductivity of seeds increased with increase in storage period. At the end of the storage period, electrical conductivity of treated seeds was less than the control.

In Anugraha, among the normal grade powder seed treatments (Table 16), T_4: ALP @ 2 g kg^{-1} (0.834 dSm^{-1}) followed by T_7: FLP @ 2 g kg^{-1} (0.880 dSm^{-1}) and T_5: FLP @ 0.5 g kg^{-1} (1.040 dSm^{-1}) had lower electrical conductivity when compared with control (1.795 dSm^{-1}). Among the treated seeds, higher electrical conductivity was observed in T_{16}: NLP @ 2 g kg^{-1} (1.259 dSm^{-1}) at twelfth month of storage.

In Ujwala, the normal grade powder treatments (Table 17) such as T_2: ALP @ 0.5 g kg^{-1} (0.149 dSm^{-1}) followed by T_7: FLP @ 2 g kg^{-1} (0.197 dSm^{-1}) and T_4: ALP @ 2 g kg^{-1} (0.197 dSm^{-1}) which were on par with T_{11}: CLP @ 0.5 g kg^{-1} (0.220 dSm^{-1}) had lower electrical conductivity values compared to control (0.423 dSm^{-1}). Among the treated seeds, higher electrical conductivity was observed in T_{15}: NLP @ 1 g kg^{-1} (0.318 dSm^{-1}) at ninth month of storage.

4.2.9. Dehydrogenase activity (OD value)

Seeds treated with normal grade powder treatments on dehydrogenase enzyme activity recorded significant differences after four and three months of storage in Anugraha and Ujwala respectively. Reduction in dehydrogenase activity of seeds was observed at the end of storage period.

In Anugraha, the normal grade powder treatments (Table 18), maximum dehydrogenase activity was recorded in seeds treated with T_4: ALP @ 2 g kg^{-1} (0.068) followed by T_6: FLP @ 1 g kg^{-1} (0.059), T_7: FLP @ 2 g kg^{-1} (0.058), T_{11}: CLP @ 0.5 g kg^{-1} (0.057), T_5: FLP @ 0.5 g kg^{-1} (0.054) while minimum dehydrogenase activity was seen in T_{16}: NLP @ 2 g kg^{-1} (0.023). The control recorded a value of 0.020 at twelfth month of storage.

In Ujwala, maximum dehydrogenase activity was recorded by the seeds treated with normal grade powders (Table 19) such as T_2: ALP @ 0.5 g kg^{-1} (0.092) was on par with T_7:

Table 16: Effect of normal grade botanicals on electrical conductivity of seed leachate (dSm^{-1}) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.593^{e}	0.680^{a}	0.764^{a}	0.841^{a}	0.853^{a}	0.979^{a}	1.025^{a}	1.125^{a}	1.138^{a}	1.456^{a}	1.628^{a}	1.795^{a}	1.827^{a}	1.994^{a}	1.193
ALP @ 0.5gKg^{-1}	0.335^{ij}	0.455^{ef}	0.570^{f}	0.647^{f}	0.677^{hi}	0.738^{ef}	0.778^{fg}	0.837^{f}	0.850^{fg}	0.876^{g}	0.938^{g}	1.054^{fg}	1.070^{hi}	1.178^{h}	0.786
ALP @ 1gKg^{-1}	0.377^{gh}	0.540^{b}	0.675^{bcd}	0.689^{de}	0.719^{fg}	0.730^{ef}	0.821^{e}	0.844^{ef}	0.900^{de}	0.927^{ef}	0.975^{fg}	1.034^{g}	1.176^{fg}	1.250^{g}	0.833
ALP @ 2gKg^{-1}	0.300^{j}	0.439^{f}	0.500^{g}	0.567^{h}	0.640^{i}	0.650^{g}	0.672^{h}	0.700^{h}	0.747^{h}	0.762^{i}	0.810^{i}	0.834^{i}	0.907^{j}	1.044^{j}	0.684
FLP @ 0.5gKg^{-1}	0.329^{ij}	0.448^{ef}	0.549^{f}	0.620^{fg}	0.657^{i}	0.729^{f}	0.748^{g}	0.837^{ef}	0.844^{g}	0.865^{g}	0.890^{h}	1.040^{g}	1.044^{i}	1.118^{i}	0.766
FLP @ 1gKg^{-1}	0.353^{hi}	0.487^{de}	0.580^{f}	0.639^{fg}	0.701^{gh}	0.729^{f}	0.810^{ef}	0.871^{cdef}	0.921^{cd}	0.896^{fg}	0.984^{f}	1.055^{fg}	1.085^{h}	1.240^{g}	0.811
FLP @ 2gKg^{-1}	0.310^{j}	0.440^{f}	0.557^{f}	0.600^{gh}	0.637^{i}	0.687^{g}	0.700^{h}	0.747^{g}	0.780^{h}	0.810^{h}	0.841^{i}	0.880^{h}	0.940^{j}	1.100^{i}	0.716
PLP @ 0.5gKg^{-1}	0.438^{cde}	0.520^{bcd}	0.649^{cde}	0.760^{b}	0.784^{cd}	0.809^{c}	0.829^{de}	0.877^{cde}	0.889^{def}	0.945^{de}	1.035^{de}	1.178^{c}	1.358^{c}	1.490^{d}	0.897
PLP @ 1gKg^{-1}	0.444^{cd}	0.511^{bcd}	0.642^{de}	0.750^{b}	0.809^{bc}	0.875^{b}	0.886^{b}	0.890^{cd}	0.927^{cd}	0.950^{de}	1.043^{cd}	1.155^{cd}	1.280^{d}	1.480^{de}	0.903
PLP @ 2gKg^{-1}	0.489^{b}	0.540^{b}	0.687^{bc}	0.754^{b}	0.833^{ab}	0.839^{bc}	0.867^{bcd}	0.899^{c}	0.942^{bc}	1.059^{b}	1.157^{b}	1.237^{b}	1.478^{b}	1.571^{c}	0.954
CLP @ 0.5gKg^{-1}	0.400^{efg}	0.529^{bc}	0.641^{de}	0.710^{cd}	0.754^{def}	0.769^{de}	0.831^{de}	0.867^{cdef}	0.880^{efg}	0.927^{ef}	1.080^{c}	1.120^{de}	1.210^{ef}	1.440^{e}	0.868
CLP @ 1gKg^{-1}	0.420^{def}	0.527^{bc}	0.647^{cde}	0.733^{bc}	0.760^{de}	0.800^{cd}	0.824^{e}	0.857^{def}	0.873^{efg}	0.946^{de}	1.029^{de}	1.150^{cd}	1.243^{de}	1.457^{de}	0.876
CLP @ 2gKg^{-1}	0.387^{fgh}	0.500^{cd}	0.637^{de}	0.658^{ef}	0.732^{efg}	0.741^{ef}	0.810^{ef}	0.854^{def}	0.921^{cd}	0.940^{de}	0.997^{ef}	1.084^{ef}	1.152^{g}	1.380^{f}	0.842
NLP @ 0.5gKg^{-1}	0.467^{bc}	0.509^{bcd}	0.633^{e}	0.710^{cd}	0.820^{abc}	0.875^{b}	0.899^{b}	0.947^{b}	0.975^{b}	0.996^{c}	1.058^{cd}	1.180^{c}	1.277^{d}	1.486^{d}	0.917
NLP @ 1gKg^{-1}	0.477^{bc}	0.527^{bc}	0.654^{bcde}	0.720^{bcd}	0.784^{cd}	0.812^{c}	0.837^{cde}	0.885^{cd}	0.873^{efg}	0.973^{cd}	1.066^{cd}	1.159^{cd}	1.370^{c}	1.548^{c}	0.906
NLP @ 2gKg^{-1}	0.488^{b}	0.531^{bc}	0.689^{b}	0.757^{b}	0.840^{ab}	0.866^{b}	0.874^{bc}	0.941^{b}	0.973^{b}	1.097^{b}	1.174^{b}	1.259^{b}	1.375^{c}	1.612^{b}	0.963
SEM±	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05	0.06	0.06	0.03
CD (0.01)	0.053	0.055	0.059	0.062	0.063	0.066	0.066	0.069	0.077	0.078	0.080	0.081	0.085	0.087	
CD (0.05)	0.040	0.041	0.044	0.047	0.047	0.048	0.049	0.051	0.056	0.056	0.057	0.058	0.060	0.061	

Table 17: Effect of normal grade botanicals on electrical conductivity of seed leachate (dSm^{-1}) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.180^{a}	0.189^{a}	0.216^{a}	0.241^{a}	0.286^{a}	0.334^{a}	0.345^{a}	0.358^{b}	0.423^{a}	0.456^{a}	0.508^{a}	0.562^{a}	0.748^{a}	0.828^{a}	0.405
ALP @ $0.5gKg^{-1}$	0.092^{e}	0.099^{g}	0.100^{f}	0.108^{g}	0.125^{f}	0.138^{h}	0.140^{i}	0.143^{i}	0.149^{i}	0.154^{j}	0.159^{j}	0.165^{j}	0.227^{h}	0.348^{j}	0.153
ALP @ $1gKg^{-1}$	0.113^{cdef}	0.128^{cdef}	0.137^{cde}	0.148^{def}	0.166^{cde}	0.185^{efgh}	0.208^{efgh}	0.222^{efg}	0.247^{efg}	0.263^{efg}	0.275^{efg}	0.290^{efg}	0.324^{f}	0.427^{hi}	0.224
ALP @ $2gKg^{-1}$	0.110^{def}	0.118^{def}	0.122^{de}	0.139^{def}	0.159^{def}	0.168^{ghi}	0.175^{hij}	0.189^{gh}	0.197^{hi}	0.219^{hi}	0.226^{hi}	0.237^{hi}	0.244^{ghi}	0.375^{jk}	0.191
FLP @ $0.5gKg^{-1}$	0.138^{bcde}	0.149^{abcd}	0.167^{bc}	0.176^{bcd}	0.186^{bcd}	0.217^{bcdef}	0.232^{def}	0.255^{cde}	0.274^{cdef}	0.290^{cde}	0.310^{cde}	0.320^{cde}	0.400^{de}	0.517^{cde}	0.259
FLP @ $1gKg^{-1}$	0.130^{bcde}	0.146^{bcd}	0.159^{bcd}	0.173^{bcde}	0.184^{bcd}	0.207^{cdefg}	0.221^{efg}	0.239^{def}	0.250^{efg}	0.278^{def}	0.288^{def}	0.291^{efg}	0.360^{ef}	0.481^{efg}	0.243
FLP @ $2gKg^{-1}$	0.100^{de}	0.108^{fg}	0.121^{ef}	0.135^{fg}	0.144^{ef}	0.157^{gh}	0.168^{hi}	0.168^{hi}	0.197^{h}	0.210^{i}	0.219^{i}	0.220^{i}	0.232^{gh}	0.398^{i}	0.184
PLP @ $0.5gKg^{-1}$	0.135^{bcde}	0.137^{bcde}	0.153^{bcd}	0.167^{bcde}	0.184^{bcd}	0.207^{cdefg}	0.219^{efg}	0.227^{efg}	0.257^{defg}	0.277^{def}	0.285^{def}	0.300^{def}	0.377^{e}	0.519^{cde}	0.246
PLP @ $1gKg^{-1}$	0.140^{bcd}	0.149^{abcd}	0.166^{bc}	0.166^{cde}	0.186^{bcd}	0.207^{cdefg}	0.221^{efg}	0.249^{cde}	0.282^{bcde}	0.290^{cde}	0.320^{cd}	0.333^{cd}	0.419^{cd}	0.510^{def}	0.26
PLP @ $2gKg^{-1}$	0.121^{bcdef}	0.126^{def}	0.133^{cde}	0.147^{def}	0.159^{def}	0.179^{fgh}	0.199^{fgh}	0.224^{efg}	0.236^{fgh}	0.244^{fgh}	0.258^{fgh}	0.264^{fgh}	0.273^{g}	0.476^{fg}	0.217
CLP @ $0.5gKg^{-1}$	0.114^{bcdef}	0.123^{def}	0.133^{cde}	0.148^{def}	0.156^{def}	0.165^{hi}	0.187^{ghi}	0.200^{fgh}	0.220^{ghi}	0.235^{ghi}	0.241^{ghi}	0.253^{ghi}	0.260^{gh}	0.403^{ij}	0.203
CLP @ $1gKg^{-1}$	0.144^{abcd}	0.148^{bcd}	0.150^{bcd}	0.164^{cde}	0.200^{bc}	0.220^{bcde}	0.240^{cde}	0.270^{cd}	0.300^{bc}	0.310^{bcd}	0.320^{cd}	0.350^{bc}	0.456^{bc}	0.554^{c}	0.273
CLP @ $2gKg^{-1}$	0.127^{bcdef}	0.130^{bcdef}	0.149^{bcd}	0.160^{cde}	0.177^{bcde}	0.186^{defgh}	0.210^{efgh}	0.220^{efg}	0.247^{efg}	0.266^{efg}	0.274^{efg}	0.283^{efg}	0.323^{f}	0.448^{gh}	0.229
NLP @ $0.5gKg^{-1}$	0.150^{abc}	0.169^{ab}	0.180^{ab}	0.207^{ab}	0.212^{b}	0.238^{bc}	0.274^{bc}	0.286^{c}	0.290^{bcd}	0.330^{bc}	0.364^{b}	0.376^{b}	0.474^{b}	0.600^{b}	0.296
NLP @ $1gKg^{-1}$	0.154^{ab}	0.167^{abc}	0.185^{ab}	0.206^{ab}	0.210^{b}	0.225^{bcd}	0.284^{b}	0.890^{a}	0.318^{b}	0.347^{b}	0.378^{b}	0.389^{b}	0.480^{b}	0.620^{b}	0.347
NLP @ $2gKg^{-1}$	0.150^{abc}	0.154^{abcd}	0.166^{bc}	0.192^{bc}	0.215^{b}	0.247^{b}	0.266^{bcd}	0.284^{c}	0.300^{bc}	0.309^{bcd}	0.340^{bc}	0.352^{bc}	0.458^{bc}	0.539^{cd}	0.284
SEM±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.02	0.02	0.02	0.02	0.03	0.03	0.02
CD (0.01)	0.053	0.055	0.059	0.062	0.063	0.066	0.066	0.069	0.077	0.078	0.08	0.081	0.085	0.087	
CD (0.05)	0.04	0.041	0.044	0.047	0.047	0.048	0.049	0.051	0.056	0.056	0.057	0.058	0.06	0.061	

Table 18: Effect of normal grade botanicals on dehydrogenase activity (OD) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.124	0.120	0.115	0.104	0.093^{d}	0.083^{d}	0.073^{f}	0.060^{f}	0.052^{f}	0.043^{f}	0.039^{fgh}	0.020^{fg}	0.012^{e}	0.007^{g}	0.068
ALP @ $0.5gKg^{-1}$	0.129	0.125	0.121	0.117	0.113^{abc}	0.105^{abc}	0.093^{bcde}	0.084^{bcd}	0.078^{abcd}	0.064^{bcde}	0.059^{bcde}	0.045^{bcd}	0.039^{bc}	0.028^{bcde}	0.086
ALP @ $1gKg^{-1}$	0.133	0.130	0.127	0.124	0.121^{a}	0.117^{a}	0.102^{abcd}	0.090^{bc}	0.084^{abc}	0.072^{ab}	0.064^{abcd}	0.052^{bcd}	0.042^{abc}	0.035^{abc}	0.092
ALP @ $2gKg^{-1}$	0.133	0.130	0.128	0.124	0.121^{a}	0.118^{a}	0.115^{a}	0.111^{a}	0.093^{a}	0.085^{a}	0.076^{a}	0.068^{a}	0.057^{a}	0.048^{a}	0.101
FLP @ $0.5gKg^{-1}$	0.130	0.127	0.125	0.123	0.118^{ab}	0.112^{ab}	0.109^{ab}	0.092^{bc}	0.087^{ab}	0.074^{ab}	0.066^{abc}	0.054^{abc}	0.047^{ab}	0.036^{abc}	0.093
FLP @ $1gKg^{-1}$	0.129	0.127	0.124	0.121	0.118^{ab}	0.114^{ab}	0.109^{ab}	0.094^{b}	0.089^{ab}	0.077^{ab}	0.066^{abc}	0.059^{ab}	0.040^{bc}	0.035^{abc}	0.093
FLP @ $2gKg^{-1}$	0.131	0.128	0.125	0.122	0.119^{ab}	0.115^{ab}	0.111^{a}	0.094^{b}	0.086^{ab}	0.075^{ab}	0.065^{abcd}	0.058^{ab}	0.047^{ab}	0.039^{ab}	0.094
PLP @ $0.5gKg^{-1}$	0.125	0.123	0.122	0.118	0.113^{abc}	0.107^{abc}	0.092^{cde}	0.086^{bc}	0.076^{bcd}	0.068^{bc}	0.052^{cdefg}	0.049^{bcd}	0.033^{bcd}	0.021^{cdefg}	0.085
PLP @ $1gKg^{-1}$	0.124	0.012	0.116	0.111	0.103^{bcd}	0.091^{bcd}	0.087^{def}	0.077^{cde}	0.069^{cde}	0.052^{def}	0.043^{efgh}	0.037^{def}	0.028^{cde}	0.022^{cdefg}	0.069
PLP @ $2gKg^{-1}$	0.125	0.122	0.116	0.112	0.097^{cd}	0.084^{cd}	0.076^{f}	0.068^{def}	0.059^{ef}	0.047^{f}	0.035^{h}	0.024^{efg}	0.019^{de}	0.012^{efg}	0.071
CLP @ $0.5gKg^{-1}$	0.128	0.125	0.122	0.119	0.115^{ab}	0.112^{ab}	0.099^{abcde}	0.087^{bc}	0.075^{bcd}	0.067^{bcd}	0.052^{cdefg}	0.057^{ab}	0.039^{bc}	0.029^{bcd}	0.086
CLP @ $1gKg^{-1}$	0.126	0.123	0.120	0.117	0.113^{abc}	0.093^{abc}	0.084^{ef}	0.078^{cde}	0.067^{def}	0.054^{cdef}	0.049^{defgh}	0.037^{def}	0.028^{cde}	0.019^{defg}	0.079
CLP @ $2gKg^{-1}$	0.129	0.127	0.124	0.121	0.117^{ab}	0.113^{ab}	0.102^{abcd}	0.092^{bc}	0.085^{abc}	0.071^{ab}	0.063^{abcd}	0.055^{abc}	0.046^{ab}	0.037^{abc}	0.092
NLP @ $0.5gKg^{-1}$	0.126	0.124	0.121	0.117	0.114^{ab}	0.111^{ab}	0.107^{abc}	0.095^{ab}	0.082^{abcd}	0.075^{ab}	0.069^{ab}	0.040^{cde}	0.048^{ab}	0.039^{ab}	0.092
NLP @ $1gKg^{-1}$	0.126	0.122	0.119	0.114	0.111^{abc}	0.105^{abc}	0.092^{cde}	0.087^{bc}	0.079^{abcd}	0.067^{bcd}	0.055^{bcdef}	0.049^{bcd}	0.037^{bc}	0.023^{bcdef}	0.085
NLP @ $2gKg^{-1}$	0.124	0.120	0.117	0.111	0.094^{d}	0.083^{d}	0.076^{f}	0.067^{ef}	0.059^{ef}	0.048^{ef}	0.037^{gh}	0.020^{g}	0.017^{de}	0.009^{fg}	0.070
SEM±	0.001	0.007	0.001	0.001	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.003	0.003
CD (0.01)	NS	NS	NS	NS	0.021	0.027	0.030	0.032	0.035	0.036	0.040	0.044	0.050	0.052	
CD (0.05)	NS	NS	NS	NS	0.016	0.018	0.019	0.019	0.020	0.020	0.021	0.022	0.025	0.025	

Table 19: Effect of normal grade botanicals on dehydrogenase activity (OD) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.120	0.109	0.091	0.081^{e}	0.074^{c}	0.063^{e}	0.053^{e}	0.041^{e}	0.038^{e}	0.034^{f}	0.032^{ef}	0.019^{f}	0.004^{e}	0.002^{e}	0.054
ALP @ 0.5gKg^{-1}	0.128	0.125	0.122	0.117^{ab}	0.114^{a}	0.111^{a}	0.108^{a}	0.101^{a}	0.092^{a}	0.086^{a}	0.077^{a}	0.063^{a}	0.058^{a}	0.047^{a}	0.096
ALP @ 1gKg^{-1}	0.121	0.120	0.118	0.115^{abcd}	0.113^{a}	0.105^{abc}	0.093^{abc}	0.088^{abc}	0.075^{bc}	0.065^{bcd}	0.054^{bc}	0.046^{bc}	0.033^{bc}	0.021^{bc}	0.083
ALP @ 2gKg^{-1}	0.124	0.120	0.117	0.113^{cd}	0.100^{ab}	0.096^{abcd}	0.086^{bcd}	0.074^{cd}	0.065^{cd}	0.053^{cde}	0.039^{cdef}	0.022^{ef}	0.019^{cde}	0.015^{cde}	0.075
FLP @ 0.5gKg^{-1}	0.123	0.120	0.118	0.115^{abc}	0.111^{a}	0.094^{bcd}	0.085^{cd}	0.077^{cd}	0.066^{cd}	0.052^{cde}	0.040^{cdef}	0.029^{def}	0.024^{cd}	0.019^{cd}	0.077
FLP @ 1gKg^{-1}	0.123	0.119	0.113	0.110^{d}	0.095^{b}	0.087^{d}	0.074^{d}	0.063^{d}	0.055^{d}	0.044^{ef}	0.030^{f}	0.027^{def}	0.020^{cde}	0.015^{cde}	0.070
FLP @ 2gKg^{-1}	0.125	0.123	0.120	0.118^{a}	0.114^{a}	0.110^{ab}	0.101^{ab}	0.094^{ab}	0.086^{ab}	0.077^{ab}	0.061^{b}	0.050^{ab}	0.042^{ab}	0.033^{ab}	0.090
PLP @ 0.5gKg^{-1}	0.123	0.118	0.114	0.108^{d}	0.100^{ab}	0.090^{cd}	0.085^{cd}	0.078^{cd}	0.064^{cd}	0.055^{cde}	0.045^{bcdef}	0.039^{bcd}	0.028^{bcd}	0.018^{bcd}	0.076
PLP @ 1gKg^{-1}	0.122	0.119	0.115	0.111^{cd}	0.105^{ab}	0.091^{cd}	0.085^{cd}	0.079^{bcd}	0.068^{cd}	0.057^{cde}	0.045^{bcdef}	0.035^{bcdef}	0.024^{cd}	0.019^{cd}	0.077
PLP @ 2gKg^{-1}	0.122	0.119	0.117	0.114^{abcd}	0.110^{ab}	0.090^{cd}	0.087^{bcd}	0.079^{bcd}	0.063^{cd}	0.050^{def}	0.047^{bcde}	0.036^{bcde}	0.027^{bcd}	0.020^{bcd}	0.077
CLP @ 0.5gKg^{-1}	0.124	0.122	0.120	0.115^{ab}	0.113^{a}	0.110^{ab}	0.096^{abc}	0.089^{abc}	0.078^{abc}	0.066^{bc}	0.052^{bcd}	0.041^{bcd}	0.033^{bc}	0.020^{bc}	0.084
CLP @ 1gKg^{-1}	0.125	0.121	0.117	0.113^{bcd}	0.100^{ab}	0.094^{bcd}	0.087^{bcd}	0.074^{cd}	0.062^{cd}	0.052^{cde}	0.041^{cdef}	0.029^{def}	0.022^{cd}	0.019^{cd}	0.075
CLP @ 2gKg^{-1}	0.124	0.122	0.120	0.117^{ab}	0.113^{a}	0.110^{ab}	0.092^{bc}	0.086^{abc}	0.074^{bc}	0.067^{bc}	0.054^{bc}	0.041^{bcd}	0.027^{bcd}	0.019^{bcd}	0.083
NLP @ 0.5gKg^{-1}	0.121	0.118	0.116	0.111^{cd}	0.108^{ab}	0.095^{abcd}	0.085^{cd}	0.076^{cd}	0.066^{cd}	0.059^{cde}	0.046^{bcde}	0.038^{bcde}	0.030^{bcd}	0.012^{bcd}	0.077
NLP @ 1gKg^{-1}	0.120	0.117	0.113	0.111^{cd}	0.107^{ab}	0.081^{d}	0.074^{d}	0.065^{d}	0.050^{d}	0.044^{ef}	0.037^{def}	0.028^{def}	0.015^{de}	0.008^{de}	0.070
NLP @ 2gKg^{-1}	0.122	0.120	0.118	0.114^{bcd}	0.100^{ab}	0.092^{cd}	0.085^{cd}	0.074^{cd}	0.066^{cd}	0.053^{cde}	0.041^{cdef}	0.031^{cdef}	0.022^{cd}	0.017^{cd}	0.075
SEM±	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002
CD (0.01)	NS	NS	NS	0.029	0.032	0.034	0.035	0.044	0.49	0.055	0.064	0.065	0.069	0.074	
CD (0.05)	NS	NS	NS	0.018	0.019	0.019	0.020	0.021	0.023	0.026	0.030	0.030	0.031	0.033	

FLP @ 2 g kg^{-1} (0.086) followed by T_{11}: CLP @ 0.5 g kg^{-1} (0.078) while minimum dehydrogenase activity was seen in T_{15}: NLP @ 1 g kg^{-1} (0.050). The untreated control recorded the least value of 0.038 at ninth month of storage.

4.2.10. Seed moisture content (%)

No significant differences were observed in the moisture content of seeds treated with normal grade botanicals in variety Anugraha (Table 20) and Ujwala (Table 21).

4.2.11. Seed microflora (%)

Significant difference among the treatments were observed for seed infection (%) in both agar and blotter method.

Irrespective of the method and treatments, highest seed infection was observed in untreated seeds. The seed infection was lower in blotter method compared to agar plate method.

In Anugraha, seed infection per cent was less in normal grade treatments (Table 22) such as T_4: ALP @ 2 g kg^{-1} (13.33), T_7: FLP @ 2 g kg^{-1} (13.67), T_{11}: CLP @ 0.5 g kg^{-1} (13.33) and T_5: FLP @ 0.5 g kg^{-1} (16.67). Seed infection per cent was high in untreated seeds (36.67) followed by T_{16}: NLP @ 2 g kg^{-1} (33.33). A similar trend was observed in agar plate method also. Treatments such as T_4: ALP @ 2 g kg^{-1} (16.00), T_7: FLP @ 2 g kg^{-1} (16.66), T_{11}: CLP @ 0.5 g kg^{-1} (16.67) and T_5: FLP @ 0.5 g kg^{-1} (20.00) compared to untreated (40.00) followed by T_{16}: NLP @ 2 g kg^{-1} (36.66).

In Ujwala, seed infection per cent was less in normal grade treatments (Table 22) such as T_2: ALP @ 0.5 g kg^{-1} (13.33), T_7: FLP @ 2 g kg^{-1} (13.66), T_{11}: CLP @ 0.5 g kg^{-1} (16.67) and T_4: ALP @ 2 g kg^{-1} (20.00). Seed infection per cent was high in untreated seeds (40.00) followed by T_{15}: NLP @ 1 g kg^{-1} (36.67). A similar trend was observed in agar plate method also. Treatments such as T_2: ALP @ 0.5 g kg^{-1} (16.00), T_7: FLP @ 2 g kg^{-1} (16.67), T_{11}: CLP @ 0.5 g kg^{-1} (20.00) and T_4: ALP @ 2 g kg^{-1} (23.33) compared to untreated (43.33) followed by T_{15}: NLP @ 1 g kg^{-1} (40.00).

The seed microflora observed in Anugraha and Ujwala at the end of twelfth and ninth month of storage period respectively. The storage fungi observed were *Aspergillus* sp, *Pencillium* sp and *Alternaria* sp (Plate 4).

Irrespective of the concentration of botanical, seed infection per cent was more in neem next to control in both the varieties.

Table 20: Effect of normal grade botanicals on moisture content (%) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.32	6.35	6.40	6.45	6.49	6.53	6.60	6.63	6.65	6.72	6.75	6.79	6.81	6.88	6.60
ALP @ 0.5gKg^{-1}	6.29	6.34	6.35	6.43	6.47	6.49	6.54	6.57	6.61	6.64	6.65	6.69	6.78	6.81	6.55
ALP @ 1gKg^{-1}	6.27	6.31	6.34	6.38	6.42	6.46	6.49	6.53	6.56	6.58	6.60	6.68	6.71	6.75	6.51
ALP @ 2gKg^{-1}	6.29	6.31	6.34	6.38	6.40	6.42	6.48	6.55	6.56	6.59	6.63	6.65	6.67	6.68	6.50
FLP @ 0.5gKg^{-1}	6.31	6.34	6.33	6.39	6.40	6.43	6.45	6.47	6.51	6.51	6.53	6.55	6.56	6.57	6.45
FLP @ 1gKg^{-1}	6.33	6.36	6.35	6.43	6.47	6.49	6.52	6.57	6.60	6.63	6.67	6.71	6.74	6.79	6.55
FLP @ 2gKg^{-1}	6.28	6.31	6.36	6.40	6.44	6.47	6.52	6.55	6.59	6.64	6.67	6.68	6.71	6.75	6.53
PLP @ 0.5gKg^{-1}	6.30	6.34	6.39	6.43	6.47	6.53	6.58	6.60	6.62	6.66	6.66	6.70	6.75	6.79	6.56
PLP @ 1gKg^{-1}	6.29	6.35	6.37	6.41	6.46	6.55	6.58	6.58	6.63	6.68	6.69	6.70	6.73	6.75	6.56
PLP @ 2gKg^{-1}	6.26	6.30	6.35	6.39	6.41	6.44	6.47	6.50	6.52	6.55	6.57	6.59	6.61	6.63	6.47
CLP @ 0.5gKg^{-1}	6.30	6.33	6.37	6.39	6.42	6.44	6.49	6.50	6.55	6.56	6.64	6.67	6.71	6.75	6.51
CLP @ 1gKg^{-1}	6.31	6.37	6.39	6.44	6.45	6.52	6.57	6.60	6.64	6.69	6.71	6.75	6.77	6.84	6.58
CLP @ 2gKg^{-1}	6.27	6.32	6.36	6.41	6.46	6.48	6.51	6.53	6.58	6.60	6.65	6.67	6.70	6.74	6.52
NLP @ 0.5gKg^{-1}	6.30	6.33	6.37	6.39	6.42	6.44	6.49	6.50	6.55	6.56	6.64	6.67	6.71	6.75	6.51
NLP @ 1gKg^{-1}	6.35	6.36	6.45	6.51	6.55	6.59	6.60	6.62	6.65	6.68	6.72	6.76	6.80	6.85	6.61
NLP @ 2gKg^{-1}	6.37	6.38	6.40	6.50	6.53	6.57	6.62	6.65	6.67	6.70	6.73	6.75	6.83	6.86	6.61
SEM±	0.007	0.006	0.008	0.010	0.011	0.013	0.013	0.013	0.012	0.016	0.015	0.015	0.018	0.021	0.012
CD (0.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

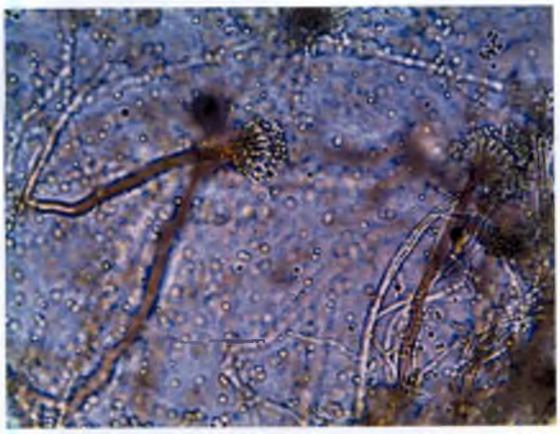
Table 21: Effect of normal grade botanicals on moisture content (%) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	7.09	7.20	7.25	7.31	7.35	7.48	7.59	7.68	7.81	7.85	7.95	8.00	8.04	8.05	7.62
ALP @ 0.5gKg^{-1}	7.02	7.02	7.04	7.05	7.10	7.12	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.50	7.20
ALP @ 1gKg^{-1}	7.02	7.09	7.16	7.23	7.29	7.36	7.43	7.50	7.57	7.64	7.70	7.77	7.84	7.91	7.47
ALP @ 2gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
FLP @ 0.5gKg^{-1}	7.02	7.04	7.05	7.10	7.12	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.50	7.50	7.24
FLP @ 1gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
FLP @ 2gKg^{-1}	7.00	7.03	7.05	7.06	7.12	7.05	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.50	7.20
PLP @ 0.5gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
PLP @ 1gKg^{-1}	7.03	7.15	7.20	7.29	7.31	7.46	7.55	7.64	7.72	7.81	7.90	7.92	8.01	8.01	7.57
PLP @ 2gKg^{-1}	7.02	7.08	7.15	7.21	7.27	7.34	7.40	7.46	7.53	7.59	7.65	7.71	7.78	7.84	7.43
CLP @ 0.5gKg^{-1}	7.03	7.10	7.18	7.25	7.32	7.40	7.47	7.55	7.62	7.69	7.77	7.84	7.91	7.99	7.51
CLP @ 1gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
CLP @ 2gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
NLP @ 0.5gKg^{-1}	7.03	7.11	7.18	7.26	7.34	7.41	7.49	7.56	7.64	7.72	7.79	7.87	7.95	8.00	7.53
NLP @ 1gKg^{-1}	7.02	7.08	7.15	7.21	7.27	7.34	7.40	7.46	7.53	7.59	7.65	7.71	7.78	7.84	7.43
NLP @ 2gKg^{-1}	7.03	7.09	7.13	7.21	7.30	7.39	7.47	7.56	7.65	7.73	7.80	7.86	7.90	7.93	7.50
SEM±	0.005	0.011	0.014	0.018	0.019	0.030	0.033	0.039	0.043	0.041	0.044	0.044	0.044	0.045	0.030
CD (0.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

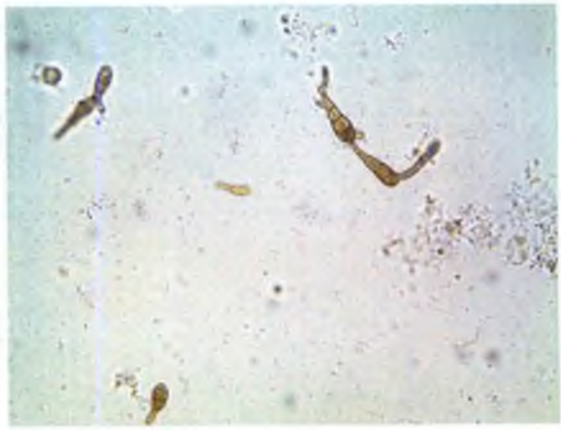
Table 22: Effect of normal grade botanicals on seed microflora (%) in Anugraha and Ujwala

Treatment	Seed infection (%) of Anugraha		Seed infection (%) of Ujwala	
	Blotter method	Agar method	Blotter method	Agar method
Control	36.67	40.00	40.00	43.33
ALP @ $0.5gKg^{-1}$	16.33	20.00	13.33	16.00
ALP @ $1gKg^{-1}$	16.66	20.00	33.33	36.67
ALP @ $2gKg^{-1}$	13.33	16.00	13.33	23.33
FLP @ $0.5gKg^{-1}$	16.67	20.00	20.00	23.33
FLP @ $1gKg^{-1}$	16.67	20.00	16.67	20.00
FLP @ $2gKg^{-1}$	13.67	16.66	13.66	16.67
PLP @ $0.5gKg^{-1}$	23.33	26.67	20.00	23.33
PLP @ $1gKg^{-1}$	26.66	23.33	30.00	33.33
PLP @ $2gKg^{-1}$	33.33	33.33	26.67	30.00
CLP @ $0.5gKg^{-1}$	13.33	16.67	16.67	20.00
CLP @ $1gKg^{-1}$	13.33	16.67	23.33	26.66
CLP @ $2gKg^{-1}$	23.33	26.67	23.33	23.67
NLP @ $0.5gKg^{-1}$	23.33	26.66	33.33	33.66
NLP @ $1gKg^{-1}$	23.33	30.00	36.67	40.00
NLP @ $2gKg^{-1}$	33.33	36.66	33.33	36.66

Plate 4: Seed Storage fungi observed in chilli seeds

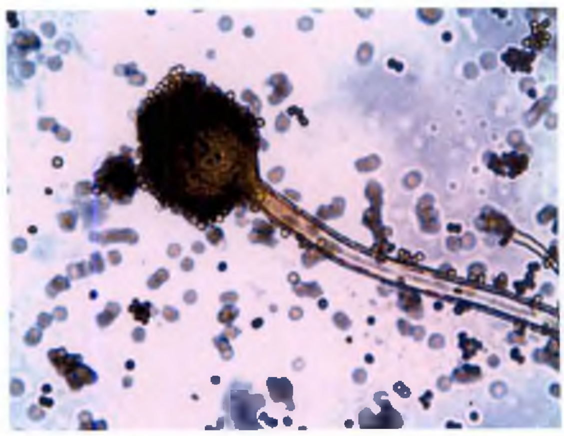


Penicillium sp.



Alternaria sp.

Aspergillus flavus



Aspergillus niger

4.3. Effect of seed treatments with nano size botanicals on seed quality parameters

4.3.1. Analysis of variance

The analysis of variance on observations recorded at monthly intervals for fourteen months of storage revealed that, significant differences existed among the nanopowder treatments on seed qualities like germination (%), seedling shoot and root length (cm), seedling dry weight (mg), seedling vigour indices, electrical conductivity of seed leachate (dSm^{-1}), dehydrogenase activity (OD) and seed microflora (%) in both Anugraha and Ujwala.

4.3.2. Germination (%)

In Anugraha, the germination per cent of seeds with nanopowders showed significant differences among the treatments and over the period of storage (Table 23). There was no significant difference observed in germination per cent till the fifth month of storage. However, it was seen that, seeds treated with nanopowders resulted in higher germination compared to control. Treated seeds maintained more than 60 percent (minimum seed certification standards), till twelfth month (63.11) of storage whereas the untreated control could retain MSCS only upto ninth month (64.32). Among the nanopowder seed treatments, maximum germination per cent was recorded in T_{11}: CLP @ 0.5 g kg^{-1} (72.10), T_6: FLP @ 1 g kg^{-1} (70.78) and T_5: FLP @ 0.5 g kg^{-1} (68.84) compared to control (36.30). The least germination per cent was observed in T_{10}: PLP @ 2 g kg^{-1} (55.79) among the treated seeds (Fig 14).

In Ujwala, the germination per cent of seeds treated with nanopowders showed significant differences among the treatments and over the period of storage (Table 24). There was no significant difference observed in germination per cent till the third month of storage. However, it was seen that, seeds treated with nanopowders resulted in higher germination compared to control. The germination as per the minimum seed certification standards was retained till ninth month of storage for treated seeds (61.76), whereas, it was only upto fifth month, for untreated seeds (63.80). Among the nanopowder treatments, maximum mean germination per cent was recorded by T_5: FLP @ 0.5 g kg^{-1} (64.56), T_{11}: CLP @ 0.5 g kg^{-1} (64.49) which were on par with T_6: FLP @ 1 g kg^{-1} (63.80) followed by T_{12}: CLP @ 1 g kg^{-1} (63.33) and T_3: ALP @ 1 g kg^{-1} (63.23) compared to control seeds (32.56). It was seen that, T_9: PLP @ 1 g kg^{-1} (63.93) produced least germination among the treated seeds (Fig 15).

In both the varieties, irrespective of concentration of botanical, least germination per cent was observed in pungam following untreated (control).

Fig 14: Effect of nano size botanicals on germination (%) in Anugraha

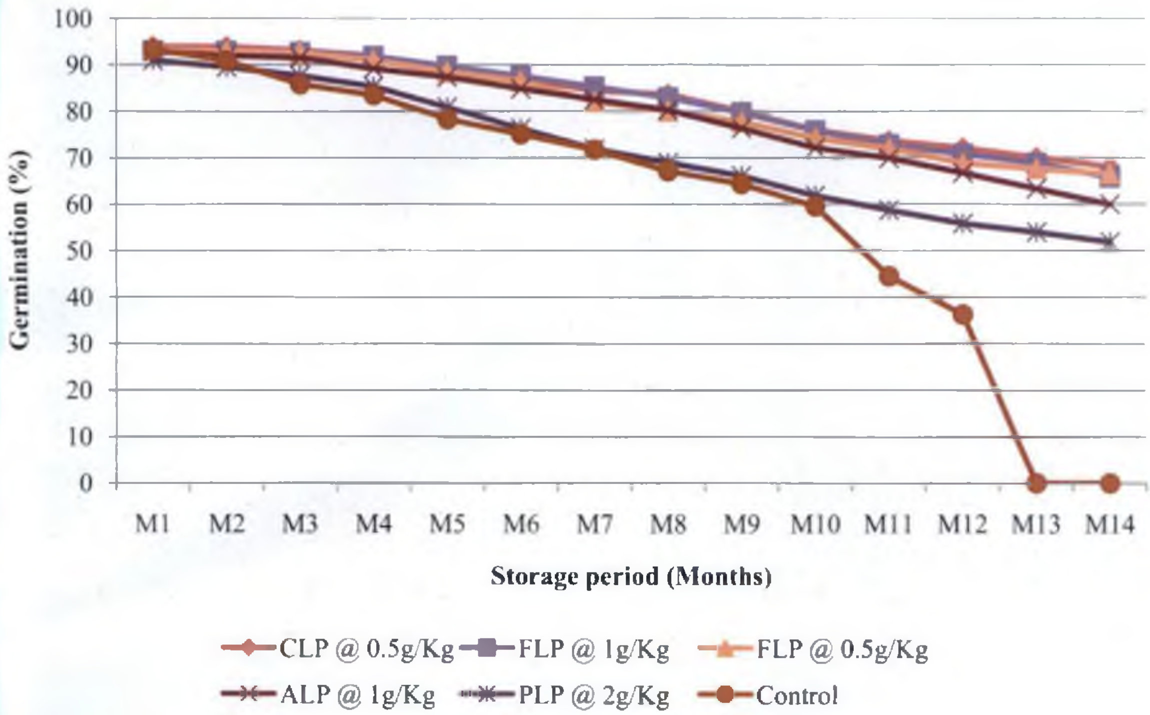


Fig 15: Effect of nano size botanicals on germination (%) in Ujwala

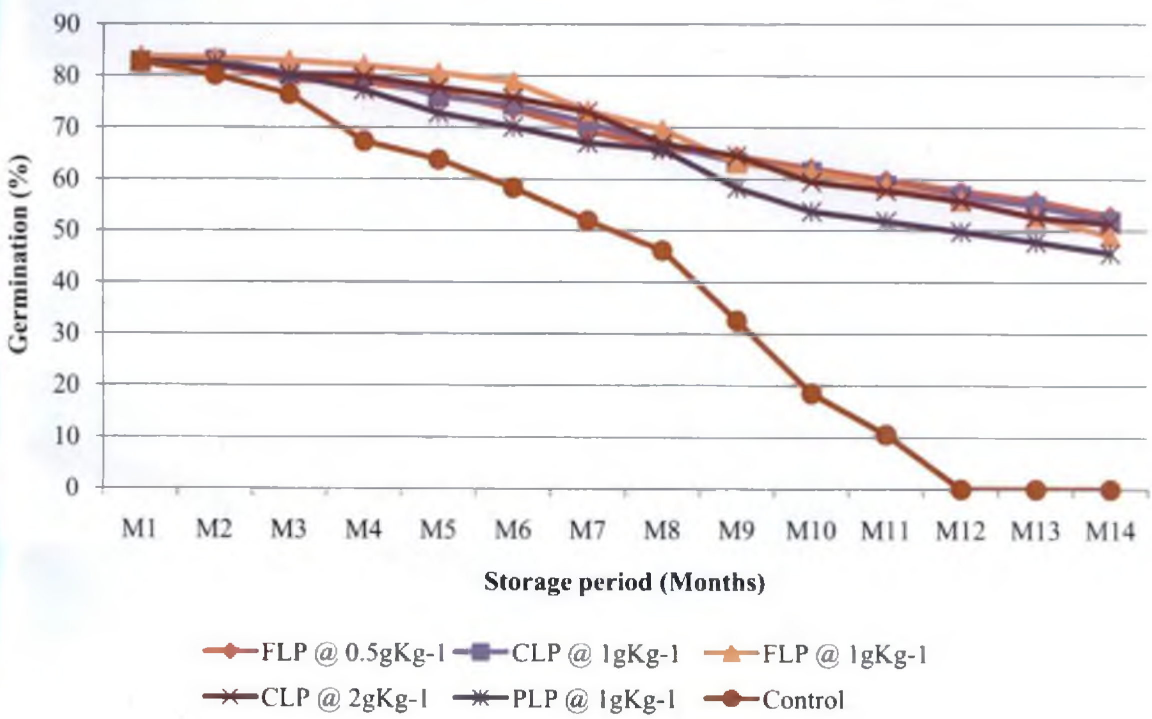


Table 23: Effect of nano size botanicals on germination (%) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	93.33 (9.69)	90.88 (9.56)	85.80 (9.29)	83.50 (9.16)	78.30^{e} (8.88)	75.09^{e} (8.69)	71.72^{e} (8.50)	67.09^{f} (8.22)	64.32^{f} (8.05)	59.48^{f} (7.86)	44.50^{g} (7.51)	36.30^{h} (7.05)	0.00 (5.89)	0.00 (5.18)	60.74 (8.11)
ALP @ 0.5gKg^{-1}	92.44 (9.64)	91.90 (9.61)	90.35 (9.51)	88.67 (9.44)	85.59^{abcd} (9.28)	82.51^{abc} (9.11)	79.89^{abcd} (8.97)	77.92^{abcd} (8.85)	74.00^{abcd} (8.63)	71.02^{abcd} (8.45)	66.89^{bcd} (8.21)	64.55^{bcde} (8.06)	61.88^{cd} (7.90)	58.50^{cd} (7.68)	77.58 (8.81)
ALP @ 1gKg^{-1}	92.84 (9.66)	91.88 (9.61)	91.50 (9.59)	89.13 (9.47)	87.31^{abc} (9.37)	84.81^{a} (9.23)	82.48^{ab} (9.13)	80.19^{ab} (8.98)	76.30^{abc} (8.76)	72.10^{abc} (8.52)	69.86^{abc} (8.39)	66.71^{abcd} (8.19)	63.29^{bcd} (7.98)	59.92^{bc} (7.77)	79.17 (8.90)
ALP @ 2gKg^{-1}	93.09 (9.67)	92.90 (9.66)	91.20 (9.57)	89.13 (9.46)	88.60^{ab} (9.43)	86.81^{a} (9.32)	83.44^{ab} (9.16)	80.43^{ab} (8.99)	76.10^{abc} (8.74)	71.18^{abc} (8.46)	67.51^{abcd} (8.24)	64.59^{bcde} (8.06)	61.60^{cd} (7.87)	58.49^{cde} (7.67)	78.93 (8.88)
FLP @ 0.5gKg^{-1}	93.10 (9.67)	92.89 (9.66)	92.59 (9.65)	90.93 (9.56)	88.40^{ab} (9.43)	86.40^{a} (9.32)	82.00^{abc} (9.08)	80.02^{ab} (8.97)	77.68^{ab} (8.84)	74.18^{ab} (8.64)	71.94^{ab} (8.51)	68.84^{abc} (8.32)	67.59^{abc} (8.25)	66.50^{ab} (8.18)	80.93 (9.01)
FLP @ 1gKg^{-1}	93.00 (9.67)	92.90 (9.66)	92.64 (9.65)	91.76 (9.60)	89.71^{a} (9.50)	87.56^{a} (9.38)	85.18^{a} (9.25)	82.89^{a} (9.13)	79.71^{ab} (8.89)	75.80^{a} (8.73)	72.81^{ab} (8.56)	70.78^{ab} (8.44)	68.80^{ab} (8.32)	65.78^{ab} (8.14)	82.09 (9.07)
FLP @ 2gKg^{-1}	92.44 (9.64)	91.55 (9.59)	90.15 (9.52)	88.21 (9.42)	85.62^{abcd} (9.28)	81.94^{abcd} (9.08)	78.45^{bcd} (8.88)	75.29^{bcde} (8.71)	72.57^{bcde} (8.55)	68.84^{bcde} (8.33)	66.95^{bcd} (8.21)	62.93^{cdef} (7.96)	58.81^{de} (7.70)	55.76^{cde} (7.50)	76.39 (8.74)
PLP @ 0.5gKg^{-1}	91.88 (9.61)	89.89 (9.51)	87.79 (9.40)	85.89 (9.29)	81.40^{cde} (9.05)	76.59^{cde} (8.78)	72.20^{e} (8.53)	68.86^{f} (8.33)	65.09^{f} (8.10)	61.88^{f} (7.90)	58.91^{efg} (7.71)	56.00^{g} (7.52)	54.77^{e} (7.43)	51.86^{de} (7.23)	71.64 (8.46)
PLP @ 1gKg^{-1}	91.80 (9.61)	89.66 (9.49)	87.92 (9.40)	86.08 (9.30)	81.38^{cde} (9.05)	76.67^{cde} (8.78)	72.16^{e} (8.52)	69.17^{ef} (8.35)	66.83^{ef} (8.20)	62.90^{ef} (7.96)	59.94^{efg} (7.77)	56.89^{fg} (7.57)	54.62^{e} (7.42)	52.03^{de} (7.25)	72 (8.48)
PLP @ 2gKg^{-1}	90.97 (9.56)	89.49 (9.49)	87.63 (9.39)	85.30 (9.26)	80.84^{de} (9.02)	76.29^{de} (8.76)	71.90^{e} (8.51)	68.88^{f} (8.33)	66.04^{ef} (8.16)	61.80^{f} (7.89)	58.64^{fg} (7.69)	55.79^{gh} (7.50)	53.90^{e} (7.37)	51.80^{e} (7.23)	71.38 (8.44)
CLP @ 0.5gKg^{-1}	93.94 (9.72)	93.88 (9.71)	93.09 (9.67)	91.88 (9.61)	88.90^{ab} (9.45)	86.89^{a} (9.35)	84.38^{ab} (9.21)	83.60^{a} (9.17)	79.94^{a} (8.97)	75.98^{a} (8.74)	73.64^{a} (8.61)	72.10^{a} (8.52)	70.06^{a} (8.40)	67.99^{a} (8.27)	82.59 (9.10)
CLP @ 1gKg^{-1}	92.84 (9.66)	91.80 (9.61)	90.59 (9.54)	87.82 (9.40)	85.39^{abcd} (9.27)	83.43^{ab} (9.16)	80.06^{abcd} (8.97)	78.83^{abc} (8.91)	74.81^{abcd} (8.68)	71.00^{abcd} (8.45)	67.66^{abcd} (8.26)	65.23^{bcde} (8.11)	62.50^{bcd} (7.94)	59.84^{bc} (7.77)	77.99 (8.84)
CLP @ 2gKg^{-1}	91.83 (9.61)	90.74 (9.55)	89.60 (9.49)	87.89 (9.40)	85.68^{abcd} (9.28)	82.70^{ab} (9.12)	78.50^{bcd} (8.89)	75.93^{bcd} (8.74)	72.61^{bcde} (8.55)	68.91^{bcde} (8.33)	65.31^{cde} (8.11)	61.54^{defg} (7.83)	58.76^{de} (7.70)	55.67^{cde} (7.49)	76.12 (8.72)
NLP @ 0.5gKg^{-1}	91.80 (9.61)	90.78 (9.55)	88.87 (9.45)	86.80 (9.34)	83.33^{bcde} (9.16)	78.31^{bcde} (8.88)	76.05^{cde} (8.75)	72.66^{cdef} (8.55)	70.10^{cdef} (8.40)	67.09^{cdef} (8.22)	63.90^{cdef} (8.02)	60.71^{defg} (7.82)	58.92^{de} (7.71)	56.19^{cde} (7.53)	74.68 (8.64)
NLP @ 1gKg^{-1}	91.80 (9.61)	90.76 (9.55)	88.79 (9.45)	83.11 (9.14)	80.02^{de} (8.97)	76.83^{e} (8.60)	73.91^{de} (8.62)	71.83^{def} (8.50)	68.90^{def} (8.33)	66.91^{cdef} (8.21)	63.86^{cdef} (8.02)	60.11^{defg} (7.78)	57.78^{de} (7.63)	55.78^{cde} (7.50)	73.6 (8.57)
NLP @ 2gKg^{-1}	91.58 (9.63)	90.87 (9.56)	88.75 (9.44)	85.91 (9.29)	83.68^{abcde} (9.17)	78.80^{bcde} (8.90)	74.59^{de} (8.66)	71.94^{def} (8.51)	68.90^{def} (8.33)	64.81^{def} (8.08)	61.90^{defg} (7.90)	59.88^{efg} (7.77)	57.63^{de} (7.62)	54.69^{cde} (7.42)	73.85 (8.59)
SEM±	0.20	0.32	0.52	0.66	0.88	1.10	1.19	1.35	1.28	1.23	1.33	1.48	2.06	2.35	1.08
CD (0.01)	NS	NS	NS	NS	NS	0.441	0.466	0.482	0.544	0.513	0.538	0.567	0.551	0.577	
CD (0.05)	NS	NS	NS	NS	0.339	0.328	0.346	0.358	0.405	0.382	0.401	0.421	0.410	0.429	

Values in parentheses are square root transformation values

Table 24: Effect of nano size botanicals on germination (%) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	82.67 (9.12)	80.10 (8.98)	76.40 (8.76)	67.33^{g} (8.23)	63.80^{g} (8.01)	58.30^{e} (7.67)	51.90^{d} (7.24)	46.13^{e} (6.83)	32.56^{f} (5.74)	18.50^{g} (4.35)	10.60^{c} (3.31)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	42.02 (6.09)
ALP @ 0.5gKg^{-1}	82.84 (9.13)	81.68 (9.06)	79.88 (8.96)	79.05^{bcde} (8.91)	76.42^{bcd} (8.77)	74.90^{abc} (8.68)	71.31^{abc} (8.47)	67.70^{abc} (8.26)	61.82^{abcde} (7.89)	59.80^{abcd} (7.77)	57.87^{ab} (7.63)	54.69^{ab} (7.42)	51.82^{abc} (7.17)	47.96^{ab} (6.95)	66.91 (8.17)
ALP @ 1gKg^{-1}	82.89 (9.13)	82.51 (9.11)	80.09 (8.94)	78.40^{bcde} (8.88)	75.98^{bcde} (8.74)	73.81^{abcd} (8.62)	70.08^{abc} (8.40)	66.20^{abc} (8.16)	63.80^{ab} (8.02)	60.10^{abc} (7.78)	58.70^{a} (7.69)	54.78^{ab} (7.43)	51.90^{abc} (7.23)	48.58^{ab} (7.00)	67.87 (8.24)
ALP @ 2gKg^{-1}	82.00 (9.08)	81.70 (9.07)	81.48 (9.05)	80.60^{ab} (9.01)	77.71^{abcd} (8.84)	76.00^{ab} (8.75)	73.12^{a} (8.58)	68.20^{ab} (8.29)	60.70^{abcde} (7.84)	56.40^{def} (7.54)	54.75^{ab} (7.43)	52.89^{ab} (7.31)	50.49^{abc} (7.14)	47.68^{ab} (6.94)	65.50 (8.09)
FLP @ 0.5gKg^{-1}	82.96 (9.13)	81.98 (9.08)	79.17 (8.92)	78.67^{bcde} (8.90)	76.80^{bcd} (8.80)	73.48^{abcd} (8.60)	69.39^{abc} (8.36)	66.00^{bc} (8.15)	64.49^{a} (8.06)	62.10^{a} (7.91)	59.85^{a} (7.77)	57.78^{a} (7.63)	55.84^{a} (7.50)	52.90^{a} (7.31)	70.00 (8.37)
FLP @ 1gKg^{-1}	83.76 (9.17)	83.45 (9.16)	82.94 (9.13)	82.00^{a} (9.08)	80.56^{a} (9.00)	78.80^{a} (8.90)	73.20^{a} (8.58)	69.66^{a} (8.37)	63.23^{abc} (7.98)	61.33^{ab} (7.86)	58.80^{a} (7.70)	55.89^{ab} (7.51)	52.77^{abc} (7.30)	48.99^{ab} (7.03)	68.71 (8.29)
FLP @ 2gKg^{-1}	83.81 (9.18)	82.92 (9.13)	81.99 (9.08)	80.80^{ab} (9.01)	78.80^{ab} (8.90)	74.98^{abcd} (8.63)	71.83^{ab} (8.50)	67.80^{abc} (8.26)	62.12^{abcde} (7.89)	58.73^{bcde} (7.67)	56.57^{ab} (7.55)	54.46^{ab} (7.41)	51.89^{abc} (7.23)	49.08^{ab} (7.04)	67.66 (8.22)
PLP @ 0.5gKg^{-1}	82.89 (9.13)	82.51 (9.11)	81.20 (9.04)	77.40^{cdef} (8.82)	75.80^{cdef} (8.66)	73.21^{abcd} (8.58)	70.53^{abc} (8.43)	64.80^{bcd} (8.08)	62.20^{abcd} (7.92)	58.88^{abcde} (7.71)	56.66^{ab} (7.56)	54.59^{ab} (7.42)	51.90^{abc} (7.23)	49.10^{ab} (7.04)	67.93 (8.23)
PLP @ 1gKg^{-1}	82.70 (9.12)	82.30 (9.10)	80.09 (8.98)	77.20^{def} (8.81)	72.75^{ef} (8.56)	70.09^{cd} (8.36)	67.01^{bc} (8.21)	65.77^{bcd} (8.14)	58.32^{e} (7.67)	53.73^{f} (7.36)	51.79^{b} (7.23)	49.78^{b} (7.09)	47.81^{bc} (6.95)	45.61^{b} (6.79)	63.93 (7.99)
PLP @ 2gKg^{-1}	82.80 (9.13)	82.20 (9.09)	81.19 (9.04)	80.10^{abc} (8.98)	78.00^{ab} (8.86)	76.10^{ab} (8.75)	72.51^{ab} (8.54)	68.02^{abc} (8.28)	60.80^{bcde} (7.83)	56.83^{cdef} (7.57)	54.80^{ab} (7.43)	52.79^{ab} (7.30)	50.88^{abc} (7.17)	48.83^{ab} (7.02)	65.93 (8.12)
CLP @ 0.5gKg^{-1}	82.80 (9.13)	82.22 (9.09)	81.22 (9.04)	80.00^{abc} (8.97)	78.53^{ab} (8.89)	74.12^{abcd} (8.64)	72.45^{ab} (8.54)	68.00^{abc} (8.28)	61.79^{abcde} (7.89)	58.89^{abcde} (7.71)	56.48^{ab} (7.55)	54.80^{ab} (7.44)	52.67^{abc} (7.29)	50.41^{ab} (7.12)	68.12 (8.25)
CLP @ 1gKg^{-1}	82.70 (9.12)	82.94 (9.13)	80.33 (8.99)	80.12^{abc} (8.98)	76.00^{bcde} (8.74)	74.40^{abc} (8.65)	70.92^{abc} (8.45)	66.80^{abc} (8.20)	63.33^{abc} (8.07)	61.42^{abcd} (7.74)	58.78^{ab} (7.63)	56.78^{ab} (7.50)	57.81^{abc} (7.28)	51.88^{ab} (7.20)	69.52 (8.27)
CLP @ 2gKg^{-1}	82.80 (9.13)	82.20 (9.09)	80.05 (8.97)	79.82^{abcd} (8.96)	77.75^{abc} (8.84)	75.67^{ab} (8.73)	73.01^{a} (8.57)	66.90^{abc} (8.21)	64.56^{a} (7.78)	59.48^{abcd} (7.56)	57.81^{ab} (7.44)	55.77^{ab} (7.28)	52.55^{abc} (7.14)	51.39^{ab} (6.99)	68.43 (8.11)
NLP @ 0.5gKg^{-1}	82.40 (9.10)	81.80 (9.07)	78.58 (8.89)	77.03^{bcde} (8.92)	76.55^{bcd} (8.77)	73.27^{abcd} (8.59)	69.17^{abc} (8.35)	64.47^{cd} (8.06)	60.10^{cde} (7.78)	56.60^{cdef} (7.56)	54.74^{ab} (7.44)	52.55^{ab} (7.28)	50.56^{abc} (7.14)	48.52^{ab} (6.99)	65.84 (8.11)
NLP @ 1gKg^{-1}	82.10 (9.09)	81.30 (9.04)	77.33 (8.82)	75.56^{f} (8.72)	72.66^{f} (8.55)	68.70^{d} (8.32)	65.72^{c} (8.13)	62.29^{d} (7.92)	58.90^{de} (7.71)	54.53^{f} (7.42)	51.90^{b} (7.24)	49.84^{b} (7.09)	46.58^{c} (6.86)	45.60^{b} (6.79)	64.57 (8.02)
NLP @ 2gKg^{-1}	82.33 (9.10)	81.77 (9.07)	78.90 (8.91)	76.40^{ef} (8.77)	74.43^{def} (8.65)	71.68^{bcd} (8.49)	68.10^{abc} (8.28)	64.67^{bcd} (8.07)	59.06^{de} (7.72)	55.51^{ef} (7.48)	52.08^{b} (7.25)	50.11^{b} (7.11)	47.90^{bc} (6.95)	45.88^{b} (6.80)	64.41 (8.02)
SEM±	0.10	0.26	0.49	0.85	0.89	1.07	1.22	1.38	1.88	2.56	2.92	3.42	3.26	3.10	1.63
CD (0.01)	NS	NS	NS	0.267	0.198	0.207	0.213	0.367	0.328	0.369	0.612	0.578	0.614	0.660	
CD (0.05)	NS	NS	NS	0.199	0.147	0.154	0.159	0.273	0.244	0.275	0.456	0.430	0.457	0.491	

Values in parentheses are square root transformation values

4.3.3. Shoot length (cm)

Effect of seed treatments over the storage period had a significant influence on seedling shoot length. It was clear that, seeds treated with nanopowders had higher shoot length compared to control.

In Anugraha, significant differences were recorded after four months of storage. Among the treatments (Table 25), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (6.68 cm), T_6: FLP @ 1 g kg^{-1} (6.33 cm) followed by T_5: FLP @ 0.5 g kg^{-1} (6.19 cm) and T_3: ALP @ 1 g kg^{-1} (6.19 cm) which were on par with each other, produced longer shoots than control (4.23 cm) at twelfth month of storage.

In Ujwala, among the seed treatments (Table 26), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (5.98 cm), T_{12}: CLP @ 1 g kg^{-1} (5.87 cm), T_2: ALP @ 0.5 g kg^{-1} (5.84 cm), T_7: FLP @ 2 g kg^{-1} (5.82 cm), T_6: FLP @ 1 g kg^{-1} (5.81 cm) were on par with T_{11}: CLP @ 0.5 g kg^{-1} (5.79 cm) produced longer shoots than control (4.37 cm) at ninth month of storage.

4.3.4. Root Length (cm)

Effect of seed treatments over the storage period had a significant influence on seedling root length. It was clear that, seeds treated with nanopowders had higher root length compared to control.

In Anugraha, among the seed treatments (Table 27), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (8.19 cm), T_6: FLP @ 1 g kg^{-1} (7.93 cm), T_3: ALP @ 1 g kg^{-1} (7.93 cm) and T_5: FLP @ 0.5 g kg^{-1} (7.77 cm) produced longer roots than control (5.33 cm) at twelfth month of storage.

In Ujwala, significant differences were recorded after first month of storage. Among the treatments (Table 28), maximum root length was observed in seeds treated with T_5: FLP @ 0.5 g kg^{-1} (7.57 cm), T_{12}: CLP @ 1 g kg^{-1} (7.53 cm), T_6: FLP @ 1 g kg^{-1} (7.51 cm), T_2: ALP @ 0.5 g kg^{-1} (7.49 cm) which were on par with T_{11}: CLP @ 0.5 g kg^{-1} (7.37 cm) produced longer roots compared to control (5.28 cm) at ninth month of storage.

4.3.5. Dry weight (mg)

Significant variation was observed for seedling dry weight due to botanical treatments over the period of storage.

Table 25: Effect of nano size botanicals on seedling shoot length (cm) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.89 (2.72)	6.66 (2.67)	6.29 (2.60)	6.11^{f} (2.57)	5.91^{e} (2.53)	5.73^{e} (2.49)	5.42^{e} (2.43)	5.27^{e} (2.40)	4.98^{e} (2.34)	4.79^{e} (2.30)	4.56^{e} (2.25)	4.23^{f} (2.17)	0.00 (0.71)	0.00 (0.71)	4.77 (2.21)
ALP @ 0.5gKg^{-1}	7.14 (2.76)	7.10 (2.76)	7.00 (2.74)	7.01^{abcd} (2.74)	6.72^{abcd} (2.69)	6.79^{abc} (2.70)	6.59^{abc} (2.66)	5.92^{b} (2.53)	5.83^{bcd} (2.52)	5.76^{bcd} (2.50)	5.64^{cd} (2.48)	5.50^{cde} (2.45)	5.44^{def} (2.44)	5.37^{def} (2.42)	6.27 (2.60)
ALP @ 1gKg^{-1}	7.20 (2.77)	7.18 (2.77)	7.12 (2.76)	7.09^{abc} (2.75)	6.92^{abcd} (2.72)	6.89^{abc} (2.72)	6.86^{ab} (2.71)	6.84^{a} (2.71)	6.66^{a} (2.67)	6.32^{abc} (2.61)	6.26^{abc} (2.60)	6.19^{abc} (2.58)	6.02^{bc} (2.55)	5.88^{bc} (2.53)	6.67 (2.68)
ALP @ 2gKg^{-1}	6.83 (2.71)	6.69 (2.68)	6.56 (2.66)	6.44^{bcdef} (2.63)	6.26^{cde} (2.60)	6.18^{cde} (2.58)	5.80^{de} (2.51)	5.71^{bcd} (2.49)	5.52^{de} (2.45)	5.43^{de} (2.43)	5.34^{d} (2.42)	5.24^{e} (2.40)	5.17^{efgh} (2.38)	5.02^{fghi} (2.35)	5.87 (2.52)
FLP @ 0.5gKg^{-1}	7.24 (2.78)	7.20 (2.77)	7.18 (2.77)	7.12^{abc} (2.76)	6.99^{abc} (2.74)	6.88^{abc} (2.72)	6.79^{ab} (2.70)	6.61^{a} (2.67)	6.41^{abc} (2.63)	6.38^{ab} (2.62)	6.21^{abc} (2.59)	6.19^{abc} (2.58)	6.09^{bc} (2.57)	5.98^{abc} (2.55)	6.66 (2.67)
FLP @ 1gKg^{-1}	7.41 (2.81)	7.36 (2.80)	7.20 (2.77)	7.16^{ab} (2.77)	7.06^{ab} (2.75)	6.98^{ab} (2.73)	6.88^{ab} (2.72)	6.78^{a} (2.70)	6.66^{a} (2.67)	6.59^{a} (2.66)	6.47^{ab} (2.64)	6.33^{ab} (2.61)	6.28^{ab} (2.60)	6.17^{ab} (2.58)	6.81 (2.70)
FLP @ 2gKg^{-1}	7.18 (2.77)	7.12 (2.76)	7.10 (2.76)	7.08^{abc} (2.75)	6.81^{abcd} (2.70)	6.69^{abcd} (2.68)	5.92^{cde} (2.53)	5.81^{bcd} (2.51)	5.72^{cde} (2.49)	5.69^{bcd} (2.49)	5.55^{cd} (2.46)	5.34^{de} (2.42)	5.29^{efg} (2.41)	5.14^{efghi} (2.37)	6.17 (2.58)
PLP @ 0.5gKg^{-1}	7.09 (2.75)	7.13 (2.76)	6.53 (2.65)	6.41^{cdef} (2.63)	6.32^{bcde} (2.61)	6.20^{cde} (2.59)	5.92^{cde} (2.53)	5.42^{de} (2.43)	5.37^{de} (2.42)	5.21^{de} (2.39)	5.11^{de} (2.37)	5.06^{ef} (2.36)	4.98^{gh} (2.34)	4.81^{i} (2.30)	5.83 (2.51)
PLP @ 1gKg^{-1}	7.12 (2.76)	7.20 (2.77)	6.71 (2.68)	6.31^{def} (2.61)	6.42^{bcde} (2.63)	6.19^{cde} (2.59)	5.98^{cde} (2.54)	5.51^{cde} (2.45)	5.43^{de} (2.43)	5.32^{de} (2.41)	5.19^{de} (2.38)	5.10^{ef} (2.36)	4.94^{gh} (2.33)	4.88^{hi} (2.32)	5.88 (2.52)
PLP @ 2gKg^{-1}	7.09 (2.75)	7.14 (2.76)	6.40 (2.63)	6.26^{ef} (2.60)	6.19^{de} (2.59)	6.03^{de} (2.55)	5.80^{de} (2.51)	5.49^{cde} (2.45)	5.26^{de} (2.40)	5.16^{de} (2.38)	5.08^{de} (2.36)	4.98^{ef} (2.34)	4.83^{h} (2.31)	4.79^{i} (2.30)	5.75 (2.49)
CLP @ 0.5gKg^{-1}	7.52 (2.83)	7.40 (2.81)	7.38 (2.81)	7.24^{a} (2.78)	7.18^{a} (2.77)	7.06^{a} (2.75)	6.99^{a} (2.74)	6.88^{a} (2.72)	6.89^{a} (2.72)	6.80^{a} (2.70)	6.76^{a} (2.69)	6.68^{a} (2.68)	6.49^{a} (2.64)	6.32^{a} (2.61)	6.97 (2.73)
CLP @ 1gKg^{-1}	7.11 (2.76)	7.09 (2.75)	7.08 (2.75)	7.00^{abcde} (2.74)	6.82^{abcd} (2.70)	6.79^{abc} (2.70)	6.62^{abc} (2.67)	5.98^{b} (2.55)	5.89^{bcd} (2.53)	5.81^{bcd} (2.51)	5.77^{bcd} (2.50)	5.67^{bcde} (2.48)	5.55^{de} (2.46)	5.46^{de} (2.44)	6.33 (2.61)
CLP @ 2gKg^{-1}	7.31 (2.79)	7.29 (2.79)	7.22 (2.78)	7.16^{ab} (2.77)	6.90^{abcd} (2.72)	6.82^{abc} (2.70)	6.81^{ab} (2.70)	6.72^{a} (2.69)	6.49^{ab} (2.64)	6.22^{abc} (2.59)	6.11^{abc} (2.57)	5.99^{abcd} (2.55)	5.80^{cd} (2.51)	5.72^{cd} (2.49)	6.61 (2.66)
NLP @ 0.5gKg^{-1}	7.09 (2.75)	6.97 (2.73)	6.71 (2.68)	6.58^{abcdef} (2.66)	6.48^{abcde} (2.64)	6.30^{bcde} (2.61)	6.20^{bcd} (2.59)	5.82^{bc} (2.51)	5.76^{bcd} (2.50)	5.60^{cd} (2.47)	5.56^{cd} (2.46)	5.44^{de} (2.44)	5.38^{ef} (2.42)	5.24^{efgh} (2.40)	6.08 (2.56)
NLP @ 1gKg^{-1}	7.14 (2.76)	6.99 (2.74)	6.89 (2.72)	6.72^{abcdef} (2.69)	6.72^{abcd} (2.69)	6.66^{abcd} (2.68)	6.52^{abcd} (2.65)	5.81^{bcd} (2.51)	2.00^{f} (1.58)	5.69^{bcd} (2.49)	5.60^{cd} (2.47)	5.54^{cde} (2.46)	5.48^{def} (2.45)	5.33^{defg} (2.41)	5.94 (2.52)
NLP @ 2gKg^{-1}	7.11 (2.76)	6.47 (2.64)	6.43 (2.63)	6.54^{abcdef} (2.65)	6.25^{cde} (2.60)	6.19^{cde} (2.59)	5.82^{de} (2.51)	5.61^{bcde} (2.47)	5.40^{de} (2.43)	5.38^{de} (2.42)	5.21^{de} (2.39)	5.18^{e} (2.38)	5.09^{fgh} (2.36)	4.95^{ghi} (2.33)	5.83 (2.51)
SEM±	0.04	0.06	0.09	0.10	0.09	0.10	0.13	0.14	0.28	0.14	0.15	0.15	0.37	0.36	0.13
CD (0.01)	NS	NS	NS	NS	0.144	0.146	0.184	0.186	0.191	0.190	0.192	0.196	0.182	0.183	
CD (0.05)	NS	NS	NS	NS	0.109	0.111	0.139	0.141	0.144	0.143	0.145	0.148	0.138	0.139	

Values in parentheses are square root transformation values

Table 26: Effect of nano size botanicals on seedling shoot length (cm) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	5.58^{g} (2.47)	5.23^{f} (2.39)	5.10^{f} (2.37)	5.04^{h} (2.35)	5.00^{g} (2.34)	4.96^{h} (2.34)	4.61^{g} (2.26)	4.56^{f} (2.25)	4.37^{e} (2.20)	4.12^{e} (2.15)	3.88^{f} (2.09)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	4.03 (1.95)
ALP @ 0.5gKg^{-1}	7.09^{a} (2.75)	7.03^{a} (2.74)	6.94^{a} (2.73)	6.84^{ab} (2.71)	6.79^{ab} (2.70)	6.56^{ab} (2.66)	6.50^{ab} (2.65)	6.30^{ab} (2.61)	5.84^{a} (2.52)	5.78^{a} (2.51)	5.58^{abc} (2.47)	5.49^{a} (2.45)	5.34^{ab} (2.42)	5.28^{ab} (2.40)	6.24 (2.59)
ALP @ 1gKg^{-1}	6.48^{cdef} (2.64)	6.30^{de} (2.61)	6.26^{cde} (2.60)	6.18^{def} (2.58)	6.09^{de} (2.57)	5.96^{ef} (2.54)	5.79^{de} (2.51)	5.77^{c} (2.50)	5.63^{abcd} (2.47)	5.56^{abcd} (2.46)	5.48^{abcde} (2.44)	5.37^{abc} (2.42)	5.26^{abc} (2.40)	5.16^{abcd} (2.38)	5.81 (2.51)
ALP @ 2gKg^{-1}	6.48^{cdef} (2.64)	6.42^{cde} (2.63)	6.38^{bcd} (2.62)	6.33^{cde} (2.61)	6.22^{cde} (2.59)	6.10^{def} (2.57)	5.79^{de} (2.51)	5.69^{cd} (2.49)	5.67^{abcd} (2.48)	5.59^{abc} (2.47)	5.48^{abcde} (2.44)	5.34^{abcd} (2.42)	5.21^{abc} (2.39)	5.13^{abcde} (2.37)	5.85 (2.52)
FLP @ 0.5gKg^{-1}	7.20^{a} (2.77)	7.16^{a} (2.77)	7.06^{a} (2.75)	6.98^{a} (2.73)	6.82^{a} (2.71)	6.74^{a} (2.69)	6.69^{a} (2.68)	6.59^{a} (2.66)	5.98^{a} (2.54)	5.89^{a} (2.53)	5.62^{a} (2.47)	5.50^{a} (2.45)	5.46^{a} (2.44)	5.37^{a} (2.42)	6.36 (2.62)
FLP @ 1gKg^{-1}	7.09^{a} (2.75)	7.00^{a} (2.74)	6.91^{a} (2.72)	6.85^{ab} (2.71)	6.76^{ab} (2.69)	6.50^{abc} (2.65)	6.43^{ab} (2.63)	6.31^{ab} (2.61)	5.81^{a} (2.51)	5.77^{a} (2.50)	5.61^{ab} (2.47)	5.54^{a} (2.46)	5.43^{a} (2.43)	5.37^{a} (2.42)	6.24 (2.59)
FLP @ 2gKg^{-1}	6.63^{bcd} (2.67)	6.58^{bcd} (2.66)	6.51^{bc} (2.65)	6.50^{bcd} (2.65)	6.40^{bcd} (2.63)	6.33^{bcde} (2.61)	6.18^{bcd} (2.58)	5.90^{c} (2.53)	5.82^{a} (2.51)	5.70^{ab} (2.49)	5.61^{ab} (2.47)	5.50^{a} (2.45)	5.43^{a} (2.43)	5.37^{a} (2.42)	6.03 (2.55)
PLP @ 0.5gKg^{-1}	6.82^{abc} (2.71)	6.80^{abc} (2.70)	6.74^{ab} (2.69)	6.63^{abc} (2.67)	6.51^{abc} (2.65)	6.42^{abcd} (2.63)	6.23^{b} (2.59)	5.89^{c} (2.53)	5.72^{abc} (2.49)	5.69^{ab} (2.49)	5.55^{abc} (2.46)	5.45^{ab} (2.44)	5.36^{ab} (2.42)	5.27^{abc} (2.40)	6.08 (2.56)
PLP @ 1gKg^{-1}	6.10^{f} (2.57)	6.03^{e} (2.55)	5.89^{e} (2.53)	5.76^{g} (2.50)	5.61^{f} (2.47)	5.50^{g} (2.45)	5.39^{f} (2.43)	5.26^{e} (2.40)	5.09^{d} (2.36)	4.83^{de} (2.31)	4.76^{e} (2.29)	4.64^{c} (2.26)	4.57^{c} (2.25)	4.46^{e} (2.22)	5.28 (2.40)
PLP @ 2gKg^{-1}	6.39^{def} (2.62)	6.30^{de} (2.61)	6.27^{cde} (2.60)	6.20^{def} (2.59)	6.11^{de} (2.57)	5.89^{fg} (2.53)	5.80^{de} (2.51)	5.72^{cd} (2.49)	5.68^{abcd} (2.49)	5.60^{abc} (2.47)	5.51^{abcd} (2.45)	5.44^{abc} (2.44)	5.36^{ab} (2.42)	5.20^{abc} (2.39)	5.82 (2.51)
CLP @ 0.5gKg^{-1}	6.93^{ab} (2.73)	6.83^{ab} (2.71)	6.74^{ab} (2.69)	6.69^{abc} (2.68)	6.63^{ab} (2.67)	6.49^{abcd} (2.64)	6.20^{bc} (2.59)	5.98^{bc} (2.55)	5.79^{ab} (2.51)	5.76^{a} (2.50)	5.67^{a} (2.48)	5.57^{a} (2.46)	5.46^{a} (2.44)	5.38^{a} (2.42)	6.15 (2.58)
CLP @ 1gKg^{-1}	7.18^{a} (2.77)	7.14^{a} (2.76)	7.09^{a} (2.75)	6.93^{a} (2.73)	6.80^{a} (2.70)	6.71^{ab} (2.69)	6.66^{a} (2.68)	6.43^{a} (2.63)	5.87^{a} (2.52)	5.83^{a} (2.51)	5.70^{a} (2.49)	5.57^{a} (2.46)	5.40^{a} (2.43)	5.31^{a} (2.41)	6.33 (2.61)
CLP @ 2gKg^{-1}	6.50^{cde} (2.65)	6.42^{cde} (2.63)	6.40^{bcd} (2.63)	6.33^{cde} (2.61)	6.22^{cde} (2.59)	6.13^{cdef} (2.57)	5.82^{cde} (2.51)	5.77^{c} (2.50)	5.68^{abcd} (2.49)	5.62^{abc} (2.47)	5.54^{abc} (2.46)	5.44^{abc} (2.44)	5.34^{ab} (2.42)	5.25^{abc} (2.40)	5.89 (2.53)
NLP @ 0.5gKg^{-1}	6.28^{def} (2.60)	6.21^{de} (2.59)	6.18^{cde} (2.58)	6.10^{efg} (2.57)	5.94^{ef} (2.54)	5.77^{fg} (2.50)	5.43^{ef} (2.43)	5.36^{de} (2.42)	5.20^{bcd} (2.39)	4.98^{bcd} (2.34)	4.87^{bcde} (2.32)	4.77^{bcde} (2.29)	4.68^{bc} (2.28)	4.60^{bcde} (2.26)	5.46 (2.44)
NLP @ 1gKg^{-1}	6.18^{ef} (2.58)	6.10^{e} (2.57)	6.03^{de} (2.56)	5.89^{fg} (2.53)	5.68^{f} (2.49)	5.51^{g} (2.45)	5.37^{f} (2.42)	5.27^{e} (2.40)	5.13^{cd} (2.37)	4.92^{cd} (2.33)	4.85^{cde} (2.31)	4.75^{cde} (2.29)	4.67^{bc} (2.27)	4.58^{cde} (2.25)	5.35 (2.42)
NLP @ 2gKg^{-1}	6.16^{ef} (2.58)	6.10^{e} (2.57)	6.06^{de} (2.56)	5.81^{fg} (2.51)	5.62^{f} (2.47)	5.54^{g} (2.46)	5.37^{f} (2.42)	5.20^{e} (2.39)	5.10^{d} (2.37)	4.84^{de} (2.31)	4.79^{de} (2.30)	4.66^{de} (2.27)	4.58^{c} (2.25)	4.49^{de} (2.23)	5.31 (2.41)
SEM±	0.11	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.11	0.13	0.13	0.34	0.33	0.33	0.16
CD (0.01)	0.100	0.100	0.102	0.103	0.105	0.104	0.105	0.107	0.166	0.207	0.211	0.195	0.196	0.198	
CD (0.05)	0.074	0.074	0.076	0.077	0.078	0.078	0.078	0.080	0.123	0.154	0.157	0.145	0.146	0.148	

Values in parentheses are square root transformation values

Table 27: Effect of nano size botanicals on seedling root length (cm) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	7.40^{i} (2.77)	7.31^{h} (2.76)	7.22^{i} (2.74)	7.00^{i} (2.72)	6.88^{i} (2.72)	6.60^{j} (2.66)	6.43^{k} (2.63)	6.25^{i} (2.60)	6.11^{h} (2.57)	5.97^{i} (2.54)	5.73^{h} (2.49)	5.33^{h} (2.41)	0.00 (0.71)	0.00 (0.71)	5.59 (2.36)
ALP @ 0.5gKg^{-1}	8.80^{def} (3.05)	8.72^{cde} (3.04)	8.68^{cdef} (3.03)	8.58^{cde} (3.01)	8.42^{cde} (2.99)	8.36^{bcd} (2.98)	8.28^{bcd} (2.96)	8.15^{bcd} (2.94)	8.04^{bc} (2.92)	7.87^{bcde} (2.89)	7.80^{bcd} (2.88)	7.71^{bcd} (2.87)	7.64^{abc} (2.85)	7.49^{abc} (2.83)	8.18 (2.95)
ALP @ 1gKg^{-1}	9.09^{cd} (3.10)	8.98^{bc} (3.08)	8.93^{bcd} (3.07)	8.86^{bc} (3.06)	8.84^{ab} (3.06)	8.71^{ab} (3.03)	8.54^{ab} (3.01)	8.43^{ab} (2.99)	8.39^{ab} (2.98)	8.20^{ab} (2.95)	8.04^{ab} (2.92)	7.93^{ab} (2.90)	7.78^{ab} (2.88)	7.67^{ab} (2.86)	8.46 (2.99)
ALP @ 2gKg^{-1}	8.42^{fg} (2.99)	8.31^{f} (2.97)	8.27^{g} (2.96)	8.18^{f} (2.95)	8.10^{ef} (2.93)	7.90^{efg} (2.90)	7.86^{fgh} (2.89)	7.70^{ef} (2.86)	7.62^{d} (2.85)	7.49^{ef} (2.83)	7.46^{de} (2.82)	7.33^{de} (2.80)	7.24^{bcd} (2.78)	7.17^{bcd} (2.77)	7.79 (2.88)
FLP @ 0.5gKg^{-1}	9.23^{bc} (3.12)	9.20^{ab} (3.11)	9.07^{bc} (3.09)	8.80^{bc} (3.05)	8.68^{abc} (3.03)	8.53^{abc} (3.00)	8.42^{abc} (2.99)	8.38^{ab} (2.98)	8.18^{b} (2.95)	8.06^{bc} (2.93)	7.89^{bc} (2.90)	7.77^{bc} (2.88)	7.69^{abc} (2.86)	7.67^{ab} (2.86)	8.40 (2.98)
FLP @ 1gKg^{-1}	9.50^{ab} (3.16)	9.41^{a} (3.15)	9.32^{ab} (3.13)	9.06^{ab} (3.09)	8.92^{a} (3.07)	8.84^{a} (3.06)	8.71^{a} (3.03)	8.49^{ab} (3.00)	8.21^{ab} (2.95)	8.17^{ab} (2.94)	8.04^{ab} (2.92)	7.93^{ab} (2.90)	7.84^{ab} (2.89)	7.70^{ab} (2.86)	8.58 (3.01)
FLP @ 2gKg^{-1}	8.63^{efg} (3.02)	8.51^{def} (3.00)	8.40^{efg} (2.98)	8.31^{def} (2.97)	8.29^{cde} (2.96)	8.14^{cde} (2.94)	8.09^{cdef} (2.93)	7.82^{cde} (2.88)	7.69^{cd} (2.86)	7.58^{def} (2.84)	7.53^{cde} (2.83)	7.43^{cde} (2.82)	7.38^{abc} (2.81)	7.20^{bcd} (2.77)	7.93 (2.90)
PLP @ 0.5gKg^{-1}	7.78^{hi} (2.88)	7.63^{gh} (2.85)	7.54^{hi} (2.84)	7.41^{gh} (2.81)	7.39^{gh} (2.81)	7.23^{hi} (2.78)	7.18^{ij} (2.77)	7.03^{gh} (2.74)	6.89^{fg} (2.72)	6.79^{h} (2.70)	6.71^{g} (2.68)	6.58^{g} (2.66)	6.47^{e} (2.64)	6.35^{e} (2.62)	7.07 (2.75)
PLP @ 1gKg^{-1}	7.89^{h} (2.90)	7.80^{g} (2.88)	7.72^{h} (2.87)	7.64^{g} (2.85)	7.60^{g} (2.85)	7.51^{gh} (2.83)	7.49^{hi} (2.83)	7.33^{fg} (2.80)	7.20^{ef} (2.77)	6.99^{gh} (2.74)	6.90^{fg} (2.72)	6.81^{fg} (2.70)	6.71^{de} (2.68)	6.60^{de} (2.66)	7.30 (2.79)
PLP @ 2gKg^{-1}	7.78^{hi} (2.88)	7.65^{gh} (2.85)	7.31^{i} (2.79)	7.24^{hi} (2.78)	7.17^{hi} (2.77)	7.07^{i} (2.75)	6.94^{j} (2.73)	6.80^{h} (2.70)	6.73^{g} (2.69)	6.69^{h} (2.68)	6.63^{g} (2.67)	6.54^{g} (2.65)	6.45^{e} (2.64)	6.37^{e} (2.62)	6.96 (2.73)
CLP @ 0.5gKg^{-1}	9.68^{a} (3.19)	9.54^{a} (3.17)	9.49^{a} (3.16)	9.30^{a} (3.13)	8.99^{a} (3.08)	8.86^{a} (3.06)	8.79^{a} (3.05)	8.69^{a} (3.03)	8.58^{a} (3.01)	8.48^{a} (3.00)	8.37^{a} (2.98)	8.19^{a} (2.95)	7.98^{a} (2.91)	7.89^{a} (2.90)	8.77 (3.04)
CLP @ 1gKg^{-1}	8.80^{def} (3.05)	8.76^{cde} (3.04)	8.67^{def} (3.03)	8.58^{cde} (3.01)	8.41^{cde} (2.98)	8.39^{bcd} (2.98)	8.27^{bcde} (2.96)	8.14^{bcd} (2.94)	8.06^{bc} (2.93)	7.89^{bcd} (2.90)	7.81^{bcd} (2.88)	7.75^{bc} (2.87)	7.68^{abc} (2.86)	7.59^{ab} (2.84)	8.20 (2.95)
CLP @ 2gKg^{-1}	8.62^{efg} (3.02)	8.40^{ef} (2.98)	8.33^{fg} (2.97)	8.26^{def} (2.96)	8.17^{de} (2.94)	8.07^{def} (2.93)	7.88^{efgh} (2.89)	7.73^{e} (2.87)	7.69^{cd} (2.86)	7.55^{def} (2.84)	7.50^{cde} (2.83)	7.42^{cde} (2.81)	7.36^{bc} (2.80)	7.27^{bc} (2.79)	7.88 (2.89)
NLP @ 0.5gKg^{-1}	8.61^{efg} (3.02)	8.40^{ef} (2.98)	8.31^{fg} (2.97)	8.23^{ef} (2.95)	8.16^{de} (2.94)	8.09^{def} (2.93)	7.89^{defg} (2.90)	7.78^{de} (2.88)	7.71^{cd} (2.87)	7.68^{cdef} (2.86)	7.56^{cde} (2.84)	7.43^{cde} (2.82)	7.38^{abc} (2.81)	7.27^{bc} (2.79)	7.89 (2.90)
NLP @ 1gKg^{-1}	8.86^{cde} (3.06)	8.80^{cd} (3.05)	8.76^{cde} (3.04)	8.64^{cd} (3.02)	8.51^{bcd} (3.00)	8.42^{bcd} (2.99)	8.30^{bc} (2.97)	8.21^{bc} (2.95)	8.19^{ab} (2.95)	7.99^{bc} (2.91)	7.80^{bcd} (2.88)	7.71^{bcd} (2.87)	7.67^{abc} (2.86)	7.58^{ab} (2.84)	8.25 (2.96)
NLP @ 2gKg^{-1}	8.33^{g} (2.97)	8.20^{f} (2.95)	8.18^{g} (2.95)	8.06^{f} (2.93)	7.72^{fg} (2.87)	7.72^{fg} (2.87)	7.65^{gh} (2.85)	7.50^{ef} (2.83)	7.41^{de} (2.81)	7.32^{fg} (2.80)	7.20^{ef} (2.77)	7.18^{ef} (2.77)	7.09^{cd} (2.75)	6.90^{cde} (2.72)	7.60 (2.85)
SEM±	0.16	0.16	0.17	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.16	0.16	0.18	0.18	0.16
CD (0.01)	0.090	0.090	0.092	0.093	0.095	0.094	0.095	0.097	0.156	0.197	0.201	0.185	0.186	0.188	
CD (0.05)	0.069	0.069	0.071	0.072	0.073	0.073	0.073	0.075	0.118	0.149	0.152	0.140	0.141	0.143	

Values in parentheses are square root transformation values

Table 28: Effect of nano size botanicals on seedling root length (cm) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.94 (2.79)	6.62^{a} (2.67)	6.55^{d} (2.65)	6.49^{d} (2.64)	6.38^{f} (2.63)	6.15^{f} (2.59)	5.88^{d} (2.55)	5.62^{e} (2.47)	5.28^{f} (2.40)	5.15^{e} (2.41)	4.71^{f} (2.28)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	4.70 (2.16)
ALP @ 0.5gKg^{-1}	8.09 (2.94)	8.01^{abc} (2.93)	7.91^{a} (2.92)	7.82^{ab} (2.89)	7.80^{abc} (2.88)	7.70^{abc} (2.86)	7.61^{a} (2.85)	7.52^{a} (2.84)	7.49^{a} (2.83)	7.39^{a} (2.82)	7.27^{a} (2.79)	7.14^{ab} (2.76)	7.09^{a} (2.75)	6.94^{ab} (2.73)	7.56 (2.84)
ALP @ 1gKg^{-1}	7.74 (2.87)	7.65^{abc} (2.85)	7.43^{abc} (2.82)	7.30^{bc} (2.79)	7.19^{bcd} (2.77)	7.03^{bcd} (2.74)	6.79^{c} (2.70)	6.64^{d} (2.67)	6.14^{cde} (2.58)	6.30^{cd} (2.61)	6.25^{cde} (2.60)	6.17^{cdef} (2.58)	6.12^{bcd} (2.57)	6.09^{cd} (2.57)	6.77 (2.69)
ALP @ 2gKg^{-1}	7.74 (2.87)	7.66^{bc} (2.86)	7.58^{ab} (2.84)	7.38^{abc} (2.81)	7.14^{cde} (2.76)	6.87^{cde} (2.71)	6.77^{c} (2.70)	6.59^{d} (2.66)	6.37^{cde} (2.62)	6.34^{cd} (2.61)	6.26^{cde} (2.60)	6.18^{cde} (2.58)	6.14^{bc} (2.58)	6.10^{cd} (2.57)	6.79 (2.70)
FLP @ 0.5gKg^{-1}	8.20 (2.95)	8.14^{bc} (2.94)	8.09^{a} (2.93)	8.06^{a} (2.93)	7.98^{a} (2.91)	7.89^{a} (2.90)	7.75^{a} (2.87)	7.69^{a} (2.86)	7.57^{a} (2.84)	7.49^{a} (2.83)	7.37^{a} (2.80)	7.28^{a} (2.79)	7.17^{a} (2.77)	7.05^{a} (2.75)	7.70 (2.86)
FLP @ 1gKg^{-1}	8.14 (2.93)	8.09^{bc} (2.92)	8.00^{a} (2.90)	7.88^{ab} (2.88)	7.81^{abc} (2.88)	7.69^{abc} (2.86)	7.63^{a} (2.85)	7.58^{ab} (2.83)	7.51^{a} (2.83)	7.43^{ab} (2.81)	7.38^{a} (2.81)	7.23^{a} (2.78)	7.11^{a} (2.76)	7.01^{a} (2.74)	7.61 (2.84)
FLP @ 2gKg^{-1}	7.82 (2.88)	7.71^{cd} (2.86)	7.60^{ab} (2.84)	7.41^{abc} (2.81)	7.30^{abcd} (2.79)	7.14^{abcd} (2.76)	6.89^{bc} (2.72)	6.71^{cd} (2.68)	6.65^{cd} (2.67)	6.57^{c} (2.66)	6.49^{bcd} (2.64)	6.37^{cd} (2.62)	6.26^{b} (2.60)	6.15^{c} (2.58)	6.93 (2.72)
PLP @ 0.5gKg^{-1}	7.83 (2.88)	7.76^{cd} (2.87)	7.59^{ab} (2.84)	7.38^{abc} (2.81)	7.26^{abcd} (2.78)	7.03^{abcd} (2.74)	6.86^{bc} (2.71)	6.73^{cd} (2.69)	6.67^{bcd} (2.68)	6.58^{c} (2.66)	6.47^{cd} (2.64)	6.35^{cd} (2.62)	6.27^{b} (2.60)	6.17^{c} (2.58)	6.93 (2.72)
PLP @ 1gKg^{-1}	7.22 (2.78)	7.17^{d} (2.77)	6.81^{cd} (2.70)	6.76^{cd} (2.69)	6.63^{def} (2.67)	6.44^{def} (2.63)	6.36^{cd} (2.62)	6.18^{de} (2.58)	5.71^{ef} (2.49)	5.68^{de} (2.49)	5.59^{e} (2.47)	5.50^{f} (2.45)	5.40^{e} (2.43)	5.30^{e} (2.41)	6.20 (2.58)
PLP @ 2gKg^{-1}	7.48 (2.82)	7.33^{a} (2.80)	7.16^{bcd} (2.77)	6.98^{cd} (2.73)	6.48^{ef} (2.64)	6.63^{ef} (2.67)	6.48^{cd} (2.64)	6.28^{d} (2.60)	5.99^{de} (2.55)	5.87^{de} (2.52)	5.79^{de} (2.51)	5.68^{def} (2.49)	5.54^{cde} (2.46)	5.40^{e} (2.43)	6.36 (2.62)
CLP @ 0.5gKg^{-1}	7.93 (2.90)	7.80^{a} (2.88)	7.75^{ab} (2.87)	7.70^{ab} (2.86)	7.66^{abc} (2.86)	7.53^{abc} (2.83)	7.48^{ab} (2.82)	7.41^{abc} (2.81)	7.37^{ab} (2.81)	7.30^{ab} (2.79)	7.23^{ab} (2.78)	7.15^{ab} (2.77)	7.07^{a} (2.75)	6.89^{ab} (2.72)	7.45 (2.82)
CLP @ 1gKg^{-1}	8.15 (2.94)	8.13^{ab} (2.94)	8.06^{a} (2.93)	8.00^{ab} (2.91)	7.89^{ab} (2.90)	7.80^{ab} (2.88)	7.72^{a} (2.87)	7.60^{a} (2.85)	7.53^{a} (2.83)	7.35^{ab} (2.80)	7.29^{a} (2.79)	7.22^{a} (2.78)	7.13^{a} (2.76)	7.00^{ab} (2.74)	7.63 (2.85)
CLP @ 2gKg^{-1}	7.80 (2.88)	7.69^{abc} (2.86)	7.65^{ab} (2.85)	7.44^{abc} (2.82)	7.32^{abcd} (2.80)	7.20^{abcd} (2.77)	6.90^{bc} (2.72)	6.82^{bcd} (2.70)	6.73^{bc} (2.69)	6.66^{bc} (2.68)	6.52^{bc} (2.65)	6.47^{bc} (2.64)	6.36^{b} (2.62)	6.28^{bc} (2.60)	6.99 (2.73)
NLP @ 0.5gKg^{-1}	7.41 (2.81)	7.36^{abc} (2.80)	7.14^{bcd} (2.76)	6.89^{cd} (2.72)	6.71^{def} (2.68)	6.59^{def} (2.66)	6.40^{cd} (2.63)	6.21^{de} (2.59)	5.98^{de} (2.54)	5.83^{de} (2.51)	5.76^{e} (2.50)	5.68^{ef} (2.48)	5.51^{cde} (2.45)	5.44^{de} (2.44)	6.35 (2.61)
NLP @ 1gKg^{-1}	7.40 (2.81)	7.36^{abc} (2.80)	7.20^{bcd} (2.77)	6.98^{cd} (2.73)	6.82^{def} (2.70)	6.73^{def} (2.69)	6.50^{cd} (2.64)	6.33^{d} (2.61)	5.89^{ef} (2.53)	5.72^{de} (2.49)	5.60^{e} (2.47)	5.54^{ef} (2.46)	5.42^{e} (2.43)	5.34^{e} (2.42)	6.35 (2.61)
NLP @ 2gKg^{-1}	7.33 (2.80)	7.27^{abc} (2.79)	7.13^{bcd} (2.76)	6.92^{cd} (2.72)	6.81^{def} (2.70)	6.65^{def} (2.67)	6.41^{cd} (2.63)	6.21^{de} (2.59)	5.78^{ef} (2.51)	5.71^{de} (2.49)	5.61^{e} (2.47)	5.55^{ef} (2.46)	5.48^{de} (2.44)	5.33^{e} (2.41)	6.30 (2.60)
SEM±	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.16	0.19	0.19	0.20	0.43	0.43	0.42	0.19
CD (0.01)	NS	0.163	0.165	0.168	0.170	0.170	0.173	0.175	0.176	0.178	0.180	0.176	0.178	0.181	
CD (0.05)	NS	0.121	0.123	0.125	0.127	0.127	0.128	0.130	0.131	0.132	0.134	0.131	0.132	0.135	

All the replicate values having zero are not included in the analysis   Values in parentheses are square root transformation values

In Anugraha, among the seeds treated with nanopowders (Table 29), T_{11}: CLP @ 0.5 g kg^{-1} (20.83 mg) which were on par with T_6: FLP @ 1 g kg^{-1} (20.79 mg) and T_{13}: CLP @ 2 g kg^{-1} (19.80 mg), T_3: ALP @ 1 g kg^{-1} (19.74 mg), T_5: FLP @ 0.5 g kg^{-1} (19.70 mg) were on par with each other produced maximum dry weight compared to control (12.80 mg) at twelfth month of storage.

In Ujwala, among the seeds treated with nanopowders (Table 30), T_{12}: CLP @ 1 g kg^{-1} (17.38 mg), T_6: FLP @ 1 g kg^{-1} (17.24 mg), T_5: FLP @ 0.5 g kg^{-1} (17.22 mg) followed by T_3: ALP @ 1 g kg^{-1} (16.78 mg) and T_2: ALP @ 0.5 g kg^{-1} (16.65 mg) produced maximum dry weight while minimum of 14.80 mg was observed in T_9: PLP @ 1 g kg^{-1} compared to control (11.66 mg) at ninth month of storage.

4.3.6. Vigour index I

Vigour index I of seeds treated with nanopowders revealed significant differences among the treatments and over period of storage. There was no significant difference for vigour index I upto fourth and second month of storage in Anugraha and Ujwala respectively. However, seedling vigour index declined progressively throughout the storage period and nanopowder treatments revealed higher vigour index compared to control.

In Anugraha, among the nanopowder treatments (Table 31), maximum vigour index observed was in T_{11}: CLP @ 0.5 g kg^{-1} (1072) followed by T_6: FLP @ 1 g kg^{-1} (1011) and T_5: FLP @ 0.5 g kg^{-1} (964) while minimum vigour index was observed in T_{10}: PLP @ 2 g kg^{-1} (643) compared to control (349) at twelfth month of storage.

In Ujwala, among the nanopowder treatments (Table 32), maximum vigour index I was observed in T_5: FLP @ 0.5 g kg^{-1} (862) which was on par with T_6: FLP @ 1 g kg^{-1} (853), T_{11}: CLP @ 0.5 g kg^{-1} (852), T_2: ALP @ 0.5 g kg^{-1} (834) and T_{12}: CLP @ 1 g kg^{-1} (821) while minimum vigour index was observed in T_9: PLP @ 1 g kg^{-1} (633) compared to control (315) at ninth month of storage.

Irrespective of the concentration of botanical, the least performing botanical was pungam in both the varieties next to untreated (control).

4.3.7. Vigour index II

Vigour index II of seeds treated with nanopowders revealed significant differences among the treatments and over the period of storage. There was no significant difference for vigour index II upto fourth and second month of storage in Anugraha and Ujwala

Table 29: Effect of nano size botanicals on seedling dry weight (mg) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	22.10^{g} (4.75)	21.18^{i} (4.66)	20.50^{e} (4.58)	19.58^{f} (4.48)	19.43^{g} (4.46)	18.54^{e} (4.36)	18.33^{g} (4.34)	17.78^{g} (4.28)	17.53^{g} (4.25)	16.54^{e} (4.13)	14.75^{f} (3.90)	12.80^{f} (3.65)	0.00 (0.71)	0.00 (0.71)	15.65 (3.80)
ALP @ 0.5gKg^{-1}	24.20^{bcd} (4.97)	24.10^{cd} (4.96)	23.46^{c} (4.89)	23.39^{b} (4.89)	22.60^{c} (4.81)	22.45^{b} (4.79)	21.66^{b} (4.71)	21.60^{b} (4.70)	20.40^{cd} (4.57)	19.58^{c} (4.48)	19.70^{c} (4.49)	18.81^{cd} (4.39)	18.66^{c} (4.38)	18.50^{b} (4.36)	21.37 (4.67)
ALP @ 1gKg^{-1}	24.10^{bcde} (4.96)	24.01^{cdef} (4.95)	23.66^{c} (4.91)	23.54^{b} (4.90)	22.70^{bc} (4.82)	22.64^{b} (4.81)	21.60^{b} (4.70)	22.59^{a} (4.80)	21.49^{b} (4.69)	20.67^{b} (4.60)	20.64^{b} (4.60)	19.74^{b} (4.50)	19.60^{b} (4.48)	19.52^{a} (4.47)	21.89 (4.73)
ALP @ 2gKg^{-1}	23.46^{def} (4.89)	23.39^{defgh} (4.89)	22.66^{d} (4.81)	22.54^{cde} (4.80)	21.55^{ef} (4.70)	21.43^{cd} (4.68)	20.57^{e} (4.59)	20.33^{de} (4.56)	19.40^{ef} (4.46)	19.21^{cd} (4.44)	18.24^{de} (4.33)	18.15^{de} (4.32)	17.58^{d} (4.25)	17.40^{e} (4.23)	20.42 (4.57)
FLP @ 0.5gKg^{-1}	24.20^{bcd} (4.97)	24.03^{cde} (4.95)	23.62^{c} (4.91)	23.49^{b} (4.90)	22.63^{c} (4.81)	22.57^{b} (4.80)	21.77^{b} (4.72)	22.60^{a} (4.81)	21.50^{b} (4.69)	20.71^{b} (4.61)	20.64^{b} (4.60)	19.70^{b} (4.49)	19.64^{b} (4.49)	19.55^{a} (4.48)	21.90 (4.73)
FLP @ 1gKg^{-1}	25.17^{a} (5.07)	25.03^{ab} (5.05)	24.54^{ab} (5.00)	24.50^{a} (5.00)	23.44^{ab} (4.89)	23.40^{a} (4.89)	22.60^{a} (4.81)	22.53^{a} (4.80)	22.41^{a} (4.79)	21.61^{a} (4.70)	21.57^{a} (4.70)	20.79^{a} (4.61)	20.71^{a} (4.61)	19.69^{a} (4.49)	22.71 (4.81)
FLP @ 2gKg^{-1}	24.09^{bcde} (4.96)	23.80^{cdefg} (4.93)	23.54^{c} (4.90)	22.47^{cde} (4.79)	22.38^{cd} (4.78)	21.53^{cd} (4.69)	21.48^{bcd} (4.69)	20.77^{cd} (4.61)	19.89^{cde} (4.52)	19.80^{c} (4.51)	18.71^{d} (4.38)	18.66^{d} (4.38)	17.44^{def} (4.24)	17.38^{cd} (4.23)	20.85 (4.61)
PLP @ 0.5gKg^{-1}	22.88^{f} (4.84)	22.75^{h} (4.82)	22.60^{d} (4.81)	21.85^{de} (4.73)	21.77^{de} (4.72)	20.80^{d} (4.62)	19.79^{f} (4.50)	19.63^{ef} (4.49)	18.74^{f} (4.39)	18.69^{d} (4.38)	17.64^{e} (4.26)	17.61^{e} (4.26)	16.84^{efg} (4.16)	16.79^{cde} (4.16)	19.88 (4.51)
PLP @ 1gKg^{-1}	23.12^{f} (4.86)	23.02^{h} (4.85)	22.55^{d} (4.80)	21.80^{e} (4.72)	21.77^{de} (4.72)	20.84^{d} (4.62)	20.79^{de} (4.61)	19.50^{f} (4.47)	19.45^{ef} (4.47)	18.53^{d} (4.36)	17.60^{e} (4.25)	17.55^{e} (4.25)	16.74^{g} (4.15)	16.68^{de} (4.14)	20.00 (4.52)
PLP @ 2gKg^{-1}	22.89^{f} (4.84)	22.79^{h} (4.83)	22.67^{d} (4.81)	21.90^{cde} (4.73)	20.94^{f} (4.63)	20.89^{d} (4.62)	19.70^{f} (4.49)	19.67^{ef} (4.49)	18.80^{f} (4.39)	18.75^{d} (4.39)	17.55^{e} (4.25)	17.49^{e} (4.24)	16.78^{fg} (4.16)	16.60^{e} (4.14)	19.82 (4.50)
CLP @ 0.5gKg^{-1}	25.20^{a} (5.07)	25.11^{a} (5.06)	24.66^{a} (5.02)	24.60^{a} (5.01)	23.50^{a} (4.90)	23.44^{a} (4.89)	22.57^{a} (4.80)	22.50^{a} (4.80)	22.45^{a} (4.79)	21.68^{a} (4.71)	21.62^{a} (4.70)	20.83^{a} (4.62)	20.79^{a} (4.61)	19.88^{a} (4.51)	22.77 (4.82)
CLP @ 1gKg^{-1}	24.34^{b} (4.98)	24.29^{bc} (4.98)	23.80^{bc} (4.93)	23.74^{b} (4.92)	22.66^{c} (4.81)	22.57^{b} (4.80)	21.58^{bc} (4.70)	21.49^{bc} (4.69)	20.44^{c} (4.58)	19.62^{c} (4.49)	19.54^{c} (4.48)	19.44^{bc} (4.47)	18.60^{c} (4.37)	18.54^{b} (4.36)	21.48 (4.68)
CLP @ 2gKg^{-1}	24.22^{bc} (4.97)	24.10^{cd} (4.96)	23.76^{c} (4.93)	22.56^{cd} (4.80)	22.47^{cd} (4.79)	22.40^{b} (4.79)	21.66^{b} (4.71)	21.57^{b} (4.70)	21.46^{b} (4.69)	20.73^{b} (4.61)	20.65^{b} (4.60)	19.80^{b} (4.51)	19.74^{b} (4.50)	18.33^{b} (4.34)	21.68 (4.71)
NLP @ 0.5gKg^{-1}	23.50^{cdef} (4.90)	23.30^{efgh} (4.88)	22.49^{d} (4.79)	22.37^{cde} (4.78)	22.20^{cde} (4.76)	21.90^{bc} (4.73)	21.86^{ab} (4.73)	20.80^{cd} (4.62)	19.80^{cde} (4.51)	19.73^{c} (4.50)	18.50^{d} (4.36)	17.59^{e} (4.25)	17.50^{de} (4.24)	16.64^{e} (4.14)	20.58 (4.59)
NLP @ 1gKg^{-1}	23.49^{cdef} (4.90)	23.28^{fgh} (4.88)	23.10^{cd} (4.86)	22.60^{c} (4.81)	22.55^{c} (4.80)	22.48^{b} (4.79)	20.84^{cde} (4.62)	19.75^{ef} (4.50)	19.70^{cde} (4.49)	18.74^{d} (4.39)	18.68^{d} (4.38)	17.84^{e} (4.28)	17.80^{d} (4.28)	16.78^{cde} (4.16)	20.55 (4.58)
NLP @ 2gKg^{-1}	23.40^{ef} (4.89)	23.21^{gh} (4.87)	22.71^{d} (4.82)	22.64^{c} (4.81)	22.59^{c} (4.81)	22.50^{b} (4.80)	20.80^{de} (4.62)	20.10^{def} (4.54)	19.66^{de} (4.49)	18.66^{d} (4.38)	18.57^{d} (4.37)	17.79^{e} (4.28)	17.80^{d} (4.28)	16.70^{de} (4.15)	20.51 (4.58)
SEM±	0.21	0.24	0.25	0.30	0.25	0.30	0.28	0.35	0.34	0.33	0.44	0.47	1.20	1.16	0.41
CD (0.01)	0.075	0.076	0.074	0.075	0.073	0.073	0.074	0.072	0.074	0.074	0.073	0.075	0.074	0.075	
CD (0.05)	0.051	0.048	0.050	0.051	0.049	0.050	0.050	0.048	0.050	0.050	0.049	0.051	0.050	0.051	

All the replicate values having zero are not included in the analysis

Table 30: Effect of nano size botanicals on seedling dry weight (mg) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	17.19^{f} (4.21)	17.09^{e} (4.19)	16.42^{d} (4.11)	16.21^{f} (4.09)	16.08^{d} (4.07)	15.27^{d} (3.97)	15.17^{c} (3.96)	13.89^{f} (3.79)	11.66^{h} (3.49)	9.74^{h} (3.20)	5.43^{h} (2.43)	0.00^{h} (0.71)	0.00^{h} (0.71)	0.00^{g} (0.71)	11.01 (3.12)
ALP @ 0.5gKg^{-1}	18.26^{bc} (4.33)	18.20^{b} (4.32)	18.12^{b} (4.32)	17.64^{cde} (4.26)	16.54^{c} (4.13)	17.46^{b} (4.24)	17.40^{a} (4.23)	17.20^{a} (4.21)	16.65^{b} (4.14)	16.48^{bc} (4.12)	16.39^{bc} (4.11)	16.33^{b} (4.10)	16.24^{b} (4.09)	16.17^{bc} (4.08)	17.08 (4.19)
ALP @ 1gKg^{-1}	18.33^{b} (4.34)	18.20^{b} (4.32)	18.17^{b} (4.32)	17.68^{c} (4.26)	17.59^{b} (4.25)	17.44^{b} (4.24)	17.39^{a} (4.23)	17.25^{a} (4.21)	16.78^{b} (4.16)	16.63^{b} (4.14)	16.55^{b} (4.13)	16.49^{b} (4.12)	16.41^{b} (4.11)	16.35^{b} (4.10)	17.23 (4.21)
ALP @ 2gKg^{-1}	18.45^{b} (4.35)	18.32^{b} (4.34)	18.19^{b} (4.32)	17.55^{cde} (4.25)	17.44^{b} (4.24)	17.31^{b} (4.22)	17.20^{a} (4.21)	16.33^{b} (4.10)	16.22^{c} (4.09)	16.12^{c} (4.08)	16.07^{c} (4.07)	15.92^{c} (4.05)	15.84^{c} (4.04)	15.79^{c} (4.04)	16.91 (4.17)
FLP @ 0.5gKg^{-1}	19.01^{a} (4.42)	18.80^{a} (4.39)	18.73^{a} (4.39)	18.66^{a} (4.38)	18.46^{a} (4.35)	18.22^{a} (4.33)	17.59^{a} (4.25)	17.40^{a} (4.23)	17.22^{a} (4.21)	17.11^{a} (4.20)	17.08^{a} (4.19)	16.91^{a} (4.17)	16.88^{a} (4.17)	16.76^{a} (4.15)	17.77 (4.27)
FLP @ 1gKg^{-1}	18.40^{b} (4.35)	18.33^{b} (4.34)	18.24^{b} (4.33)	18.11^{b} (4.31)	17.60^{b} (4.25)	17.54^{b} (4.25)	17.41^{a} (4.23)	17.37^{a} (4.23)	17.24^{a} (4.21)	17.18^{a} (4.20)	17.08^{a} (4.19)	16.90^{a} (4.17)	16.85^{a} (4.17)	16.75^{a} (4.15)	17.5 (4.24)
FLP @ 2gKg^{-1}	18.24^{bc} (4.33)	18.19^{b} (4.32)	18.09^{b} (4.31)	17.70^{c} (4.27)	17.67^{b} (4.26)	17.54^{b} (4.25)	16.54^{b} (4.13)	16.38^{b} (4.11)	15.77^{d} (4.03)	15.60^{d} (4.01)	15.52^{d} (4.00)	15.47^{d} (4.00)	15.39^{d} (3.99)	15.20^{d} (3.96)	16.66 (4.14)
PLP @ 0.5gKg^{-1}	18.34^{b} (4.34)	18.24^{b} (4.33)	18.11^{b} (4.31)	17.67^{cd} (4.26)	17.58^{b} (4.25)	17.41^{b} (4.23)	16.37^{b} (4.11)	16.20^{b} (4.09)	15.22^{e} (3.96)	15.10^{ef} (3.95)	15.01^{ef} (3.94)	14.90^{ef} (3.92)	14.86^{ef} (3.92)	14.75^{e} (3.91)	16.41 (4.11)
PLP @ 1gKg^{-1}	17.63^{c} (4.26)	17.48^{de} (4.24)	16.55^{d} (4.13)	16.41^{f} (4.11)	16.20^{cd} (4.09)	15.22^{d} (3.96)	15.14^{c} (3.95)	15.00^{cd} (3.94)	14.80^{fg} (3.91)	14.68^{g} (3.90)	14.49^{g} (3.87)	14.40^{g} (3.86)	14.33^{g} (3.85)	14.24^{f} (3.84)	15.47 (3.99)
PLP @ 2gKg^{-1}	18.17^{bcd} (4.32)	18.09^{bc} (4.31)	17.47^{c} (4.24)	17.28^{de} (4.22)	16.44^{cd} (4.12)	16.33^{c} (4.10)	15.40^{c} (3.99)	15.31^{c} (3.98)	15.71^{d} (4.03)	14.72^{fg} (3.90)	14.63^{fg} (3.89)	14.55^{fg} (3.88)	14.49^{fg} (3.87)	14.35^{f} (3.85)	15.92 (4.05)
CLP @ 0.5gKg^{-1}	18.43^{b} (4.35)	18.33^{b} (4.34)	18.10^{b} (4.31)	17.55^{cde} (4.25)	17.44^{b} (4.24)	17.31^{b} (4.22)	16.54^{b} (4.13)	16.31^{b} (4.10)	16.18^{c} (4.08)	15.20^{e} (3.96)	15.11^{e} (3.95)	15.05^{e} (3.94)	14.97^{e} (3.93)	14.84^{de} (3.92)	16.53 (4.12)
CLP @ 1gKg^{-1}	19.20^{a} (4.44)	19.02^{a} (4.42)	18.79^{a} (4.39)	18.57^{a} (4.37)	17.72^{b} (4.27)	17.68^{b} (4.26)	17.50^{a} (4.24)	17.44^{a} (4.24)	17.38^{a} (4.23)	17.21^{a} (4.21)	17.14^{a} (4.20)	17.09^{a} (4.19)	16.89^{a} (4.17)	16.80^{a} (4.16)	17.75 (4.27)
CLP @ 2gKg^{-1}	18.19^{bcd} (4.32)	18.10^{bc} (4.31)	17.46^{c} (4.24)	17.26^{e} (4.21)	16.50^{c} (4.12)	16.40^{c} (4.11)	16.33^{b} (4.10)	15.30^{c} (3.97)	15.27^{e} (3.97)	15.20^{e} (3.96)	15.13^{de} (3.95)	15.08^{e} (3.95)	14.88^{e} (3.92)	14.78^{e} (3.91)	16.13 (4.08)
NLP @ 0.5gKg^{-1}	18.39^{b} (4.35)	18.19^{b} (4.32)	17.50^{c} (4.24)	17.46^{cde} (4.24)	17.37^{b} (4.23)	16.34^{c} (4.10)	16.20^{b} (4.09)	15.27^{c} (3.97)	15.17^{ef} (3.96)	15.11^{ef} (3.95)	15.01^{ef} (3.94)	14.90^{ef} (3.92)	14.82^{ef} (3.91)	14.76^{e} (3.91)	16.18 (4.08)
NLP @ 1gKg^{-1}	17.93^{cde} (4.29)	17.77^{cd} (4.27)	17.65^{c} (4.26)	16.20^{f} (4.09)	16.10^{d} (4.07)	15.28^{d} (3.97)	15.14^{c} (3.95)	14.52^{e} (3.88)	14.44^{g} (3.87)	14.37^{g} (3.86)	14.41^{g} (3.86)	14.33^{g} (3.85)	14.25^{g} (3.84)	14.20^{f} (3.83)	15.48 (3.99)
NLP @ 2gKg^{-1}	17.84^{de} (4.28)	17.65^{d} (4.26)	17.47^{c} (4.24)	16.43^{f} (4.11)	16.25^{cd} (4.09)	15.30^{d} (3.97)	15.25^{c} (3.97)	14.68^{de} (3.90)	14.58^{g} (3.88)	14.40^{g} (3.86)	14.38^{g} (3.86)	14.29^{g} (3.85)	14.20^{g} (3.83)	14.18^{f} (3.83)	15.49 (4.00)
SEM±	0.12	0.12	0.17	0.19	0.19	0.25	0.24	0.29	0.36	0.45	0.68	1.00	0.99	0.99	0.37
CD (0.01)	0.049	0.046	0.048	0.049	0.047	0.047	0.048	0.046	0.048	0.048	0.047	0.049	0.048	0.049	
CD (0.05)	0.038	0.035	0.037	0.038	0.036	0.037	0.037	0.035	0.037	0.037	0.036	0.038	0.037	0.038	

Values in parentheses are square root transformation values

Table 31: Effect of nano size botanicals on vigour index I during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1315	1253^{e}	1143^{h}	1003^{h}	1003^{f}	927^{a}	851^{i}	774^{j}	715^{ij}	603^{h}	461^{h}	349^{h}	0	0	753
ALP @ 0.5gKg^{-1}	1473	1453^{abcd}	1411^{abcde}	1382^{abcde}	1295^{abcd}	1250^{ef}	1188^{bcd}	1096^{cde}	1026^{cde}	967^{bcd}	899^{bcd}	852^{cde}	809^{def}	752^{cde}	1132
ALP @ 1gKg^{-1}	1513	1486^{abcd}	1469^{abcd}	1422^{abcd}	1377^{ab}	1324^{abcd}	1276^{abc}	1225^{ab}	1149^{abc}	1048^{abc}	1000^{abc}	943^{bc}	874^{bcd}	813^{bc}	1209
ALP @ 2gKg^{-1}	1421	1395^{cde}	1354^{cdefg}	1305^{cdefg}	1274^{bcd}	1219^{ab}	1141^{cde}	1080de	1002^{def}	921^{cde}	866de	813de	766^{def}	714^{cdef}	1091
FLP @ 0.5gKg^{-1}	1536	1526^{abc}	1506^{abc}	1450^{abc}	1387^{ab}	1333^{bcde}	1250^{abc}	1201^{abc}	1136^{abcd}	1073^{ab}	1017^{ab}	964^{abc}	934^{abc}	910^{ab}	1230
FLP @ 1gKg^{-1}	1574	1560^{ab}	1532^{ab}	1490^{ab}	1436^{a}	1387^{ab}	1330^{ab}	1267^{a}	1173^{ab}	1121^{a}	1058^{a}	1011^{ab}	973^{ab}	914^{ab}	1273
FLP @ 2gKg^{-1}	1461	1430^{abcde}	1396^{bcdef}	1357^{abcdef}	1292^{abcd}	1214^{bcde}	1098^{def}	1026^{def}	972^{efg}	912de	875^{cde}	803^{def}	744^{efgh}	687^{defg}	1090
PLP @ 0.5gKg^{-1}	1367	1327de	1236^{fgh}	1187^{gh}	1116^{ef}	1029^{fg}	946^{ghi}	858^{hi}	798^{hij}	743^{gh}	697^{gh}	652^{g}	627^{hi}	579^{g}	940
PLP @ 1gKg^{-1}	1378	1346de	1269^{efgh}	1201^{fgh}	1141^{def}	1051^{fg}	972^{fghi}	888^{ghi}	845^{ghi}	775^{fgh}	725^{fg}	678^{fg}	637^{ghi}	598^{fg}	965
PLP @ 2gKg^{-1}	1353	1324de	1202^{gh}	1152^{gh}	1081^{ef}	1000^{g}	917^{hi}	847^{hi}	793^{hij}	733^{gh}	688^{gh}	643^{g}	609^{i}	578^{g}	923
CLP @ 0.5gKg^{-1}	1617	1591^{a}	1572^{a}	1521^{a}	1439^{a}	1384^{fg}	1332^{a}	1302^{a}	1237^{a}	1161^{a}	1114^{a}	1072^{a}	1015^{a}	967^{a}	1309
CLP @ 1gKg^{-1}	1476	1454^{abcd}	1426^{abcde}	1367^{abcde}	1300^{abc}	1265^{a}	1191^{abcd}	1113^{bcd}	1043^{bcde}	972^{bcd}	918^{bcd}	874^{cd}	826^{cde}	780^{cd}	1143
CLP @ 2gKg^{-1}	1462	1423^{bcde}	1393^{bcdef}	1355^{bcdef}	1291^{abcd}	1231^{abc}	1152^{cd}	1097^{cde}	1028^{cde}	948^{bcde}	888^{bcde}	816de	773^{def}	722^{cde}	1113
NLP @ 0.5gKg^{-1}	1440	1395^{cde}	1334^{defg}	1285^{defg}	1219^{cde}	1126^{bcde}	1071^{defg}	987^{efg}	944^{efg}	890^{def}	838^{def}	781^{def}	751^{efg}	702^{cdef}	1055
NLP @ 1gKg^{-1}	1470	1434^{abcde}	1391^{bcdef}	1278^{defg}	1220^{cde}	1108^{cdef}	1097^{def}	1008^{def}	704^{j}	917de	857de	798^{def}	761^{def}	721^{cde}	1055
NLP @ 2gKg^{-1}	1425	1334de	1298^{efgh}	1255^{efgh}	1170^{cde}	1097^{def}	1006^{efgh}	944^{fgh}	884^{fgh}	824^{efg}	769^{efg}	741^{efg}	703^{fghi}	649^{efg}	1007
SEM±	19.57	22.48	29.47	30.46	31.68	35.16	36.67	39.29	41.11	37.72	40.65	42.95	57.35	54.63	35.81
CD (0.01)	NS	NS	NS	NS	2.833	2.409	3.358	2.826	1.980	3.255	3.225	3.325	3.333	2.660	
CD (0.05)	NS	NS	NS	NS	2.108	1.793	2.499	2.102	1.473	2.422	2.399	2.474	2.480	1.979	

Table 32: Effect of nano size botanicals on vigour index I during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1063^{d}	950^{d}	892^{f}	777^{h}	726^{i}	648^{i}	544^{g}	471^{g}	315^{f}	173^{f}	92^{f}	0	0	0	473
ALP @ $0.5gKg^{-1}$	1231^{abc}	1202^{abc}	1177^{abc}	1151^{abc}	1123^{abc}	1039^{abcde}	992^{abcd}	910^{abc}	834^{ab}	787^{ab}	734^{a}	698^{a}	656^{a}	611^{ab}	939
ALP @ $1gKg^{-1}$	1179^{abcd}	1152^{abc}	1088^{bcde}	1057^{def}	1009^{efg}	958^{efg}	882^{def}	822^{de}	732^{d}	684^{bcd}	646^{abc}	610^{ab}	576^{abcd}	551^{bc}	853
ALP @ $2gKg^{-1}$	1167^{abcd}	1151^{abc}	1138^{abcde}	1105^{bcde}	1039^{cdef}	985^{def}	919^{bcde}	838^{cd}	752^{cd}	702^{bc}	656^{ab}	608^{ab}	578^{abcd}	539^{bcd}	870
FLP @ $0.5gKg^{-1}$	1277^{a}	1263^{a}	1240^{a}	1207^{a}	1176^{a}	1123^{a}	1035^{a}	967^{a}	862^{a}	812^{a}	742^{a}	703^{a}	653^{ab}	649^{a}	979
FLP @ $1gKg^{-1}$	1258^{ab}	1227^{ab}	1186^{ab}	1160^{abc}	1114^{abcd}	1065^{abcd}	1001^{abc}	937^{ab}	853^{ab}	742^{abc}	710^{ab}	671^{ab}	630^{abc}	607^{ab}	940
FLP @ $2gKg^{-1}$	1212^{abc}	1185^{abc}	1156^{abcd}	1124^{abcd}	1079^{bcde}	996^{bcde}	940^{abcd}	855^{bcd}	805^{bc}	750^{abc}	694^{ab}	655^{ab}	610^{abc}	574^{abc}	903
PLP @ $0.5gKg^{-1}$	1215^{abc}	1201^{abc}	1163^{abc}	1084^{cde}	1025^{def}	985^{cdef}	924^{abcde}	818^{de}	755^{cd}	685^{bcd}	645^{abc}	609^{ab}	582^{abc}	556^{bc}	875
PLP @ $1gKg^{-1}$	1115^{cd}	1095^{c}	1024^{def}	973^{fg}	909^{h}	841^{h}	780^{f}	723^{f}	633^{e}	557^{e}	521^{e}	482^{d}	457^{f}	442^{f}	754
PLP @ $2gKg^{-1}$	1148^{abcd}	1120^{bc}	1090^{bcde}	1056^{defg}	982^{fgh}	953^{efg}	890^{cdef}	816^{de}	739^{d}	675^{cd}	630^{bcd}	585^{bc}	541^{cdef}	496^{cdef}	837
CLP @ $0.5gKg^{-1}$	1277^{a}	1255^{a}	1200^{ab}	1184^{ab}	1139^{ab}	1075^{abc}	1002^{abc}	943^{a}	852^{ab}	758^{abc}	698^{ab}	659^{ab}	628^{abc}	608^{ab}	948
CLP @ $1gKg^{-1}$	1269^{a}	1267^{a}	1217^{ab}	1196^{a}	1117^{abcd}	1079^{ab}	1021^{ab}	938^{ab}	821^{ab}	734^{abc}	686^{ab}	639^{ab}	592^{abc}	540^{bc}	937
CLP @ $2gKg^{-1}$	1185^{abcd}	1161^{abc}	1126^{abcde}	1100^{bcde}	1053^{bcdef}	1009^{bcde}	930^{abcde}	843^{cd}	765^{cd}	698^{bc}	647^{abc}	598^{bc}	562^{bcde}	530^{bcde}	872
NLP @ $0.5gKg^{-1}$	1129^{bcd}	1109^{bc}	1048^{cde}	1027^{efg}	969^{fgh}	905^{fgh}	819^{ef}	745^{ef}	662^{e}	589^{de}	539^{de}	507^{cd}	466^{f}	448^{ef}	783
NLP @ $1gKg^{-1}$	1102^{cd}	1087^{c}	1018^{ef}	966^{g}	890^{h}	830^{h}	788^{f}	753^{ef}	650^{e}	587^{de}	555^{cde}	512^{cd}	487^{def}	455^{def}	763
NLP @ $2gKg^{-1}$	1111^{cd}	1094^{c}	1042^{cde}	973^{fg}	926^{gh}	872^{gh}	802^{f}	738^{ef}	635^{e}	565^{e}	536^{de}	509^{cd}	476^{ef}	438^{f}	765
SEM±	17.07	20.62	22.89	27.79	28.84	29.83	30.96	30.49	33.57	37.48	38.64	41.49	38.96	37.34	30.39
CD (0.01)	NS	NS	NS	3.094	3.231	2.807	3.756	3.224	2.378	3.653	3.623	3.723	3.731	3.058	
CD (0.05)	NS	NS	2.808	2.205	2.307	1.992	2.698	2.301	1.672	2.621	2.598	2.673	2.679	2.178	

respectively. The seedling vigour index declined progressively throughout the storage period. Treated seeds had higher vigour index II compared to control.

In Anugraha, there was no significant difference for vigour index II upto fourth month of storage. Among the nanopowder treatments (Table 33), maximum vigour index II observed was in seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (1503) were on par with T_6: FLP @ 1 g kg^{-1} (1473) followed by T_5: FLP @ 0.5 g kg^{-1} (1358) and T_3: ALP @ 1 g kg^{-1} (1318) while minimum vigour index II was observed in T_9: PLP @ 1 g kg^{-1} (999) compared to control (466) at twelfth month of storage.

In Ujwala, there was no significant difference for vigour index II upto third month of storage. Among the nanopowder seed treatments (Table 34), maximum vigour index II was observed in treatments such asT_5: FLP @ 0.5 g kg^{-1} (1125), T_2: ALP @ 0.5 g kg^{-1} (1107) were on par with T_6: FLP @ 1 g kg^{-1} (1082) followed by T_{12}: CLP @ 1 g kg^{-1} (1075) while minimum vigour index was observed in T_9: PLP @ 1 g kg^{-1} (830) compared to control (380) at ninth month of storage.

In both the varieties, irrespective of the concentration of botanicals, the least performing botanical was pungam following untreated (control).

4.3.8. Electrical conductivity (dSm^{-1})

Effects of nanopowder treatments over storage period on electrical conductivity were found to be significant. The results revealed that, electrical conductivity of seeds increased with increase in storage period. At the end of the storage period, treated seeds possessed minimum electrical conductivity.

In Anugraha, among seed treatments (Table 35), T_{11}: CLP @ 0.5 g kg^{-1} (0.864 dSm^{-1}) were on par with T_6: FLP @ 1 g kg^{-1} (0.897 dSm^{-1}) and T_2: ALP @ 0.5 g kg^{-1} (1.044 dSm^{-1}) were on par with T_5: FLP @ 0.5 g kg^{-1} (1.059 dSm^{-1}), T_{12}: CLP @ 1 g kg^{-1} (1.068 dSm^{-1}), T_3: ALP @ 1 g kg^{-1} (1.068 dSm^{-1}) had lower electrical conductivity than control (1.795 dSm^{-1}) at twelfth month of storage.

In Ujwala, among seed treatments (Table 36), T_{11}: CLP @ 0.5 g kg^{-1} (0.747 dSm^{-1}), T_6: FLP @ 1 g kg^{-1} (0.780 dSm^{-1}), T_7: FLP @ 2 g kg^{-1} (0.844 dSm^{-1}) and T_5: FLP @ 0.5 g kg^{-1} (0.869 dSm^{-1}) had lower electrical conductivity value than control (1.138 dSm^{-1}) at ninth month of storage.

Table 33: Effect of nano size botanicals on vigour index II during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	2064	1926^{e}	1761^{f}	1636^{f}	1523^{f}	1393^{h}	1316^{f}	1194^{h}	1129^{i}	928^{i}	658^{j}	466^{g}	0^{f}	0^{h}	1142
ALP @ 0.5gKg^{-1}	2237	2215^{abcd}	2112^{bcde}	2074^{bcd}	1934^{abcd}	1852^{cde}	1730^{b}	1683^{bc}	1509^{bcdef}	1390^{cdef}	1318^{cde}	1214^{bcd}	1154^{cd}	1082^{cde}	1679
ALP @ 1gKg^{-1}	2238	2207^{abcd}	2165^{abcd}	2099^{abcd}	1983^{abc}	1921^{abcd}	1790^{ab}	1812^{ab}	1640^{abc}	1491^{bcd}	1443^{abc}	1318^{bc}	1241^{bc}	1170^{bc}	1751
ALP @ 2gKg^{-1}	2185	2174^{bcd}	2068^{cde}	2010^{cde}	1910^{cd}	1854^{cde}	1717^{b}	1636^{cd}	1477^{cdef}	1368^{def}	1232^{def}	1173^{cde}	1084^{d}	1019^{def}	1636
FLP @ 0.5gKg^{-1}	2255	2234^{abc}	2188^{abc}	2138^{abc}	2002^{abc}	1951^{abc}	1787^{ab}	1810^{ab}	1672^{ab}	1538^{abc}	1487^{ab}	1358^{ab}	1329^{ab}	1302^{ab}	1789
FLP @ 1gKg^{-1}	2342	2327^{ab}	2274^{ab}	2250^{ab}	2104^{a}	2050^{a}	1926^{a}	1869^{a}	1766^{a}	1639^{ab}	1572^{a}	1473^{a}	1426^{a}	1297^{ab}	1880
FLP @ 2gKg^{-1}	2226	2178^{bcd}	2121^{abcde}	1981^{cde}	1915^{cd}	1763^{def}	1685^{bc}	1563^{cde}	1442^{defg}	1362^{def}	1252^{def}	1174^{cde}	1025de	968^{efg}	1618
PLP @ 0.5gKg^{-1}	2102	2045de	1984^{e}	1877^{e}	1772de	1593^{g}	1429^{ef}	1352^{fgh}	1220^{hi}	1157^{hi}	1039^{hi}	986^{f}	923^{e}	871^{g}	1454
PLP @ 1gKg^{-1}	2123	2064^{cde}	1983^{e}	1877^{e}	1772de	1598^{g}	1500de	1349^{gh}	1300^{gh}	1166^{h}	1055^{ghi}	999^{f}	915^{e}	868^{g}	1469
PLP @ 2gKg^{-1}	2083	2040de	1987de	1868^{e}	1693^{ef}	1594^{g}	1417^{ef}	1355^{fg}	1242^{hi}	1159^{hi}	1030^{i}	976^{f}	905^{e}	860^{g}	1444
CLP @ 0.5gKg^{-1}	2368	2358^{a}	2296^{a}	2261^{a}	2090^{ab}	2037^{ab}	1905^{a}	1882^{a}	1795^{a}	1648^{a}	1593^{a}	1503^{a}	1457^{a}	1352^{a}	1896
CLP @ 1gKg^{-1}	2259	2229^{abc}	2155^{abcde}	2084^{abcd}	1934^{abcd}	1882^{bcd}	1727^{b}	1693^{bc}	1529^{bcde}	1392^{cdef}	1322^{cde}	1267^{bc}	1162^{cd}	1109^{cd}	1696
CLP @ 2gKg^{-1}	2224	2187^{abcd}	2129^{abcde}	1983^{cde}	1925^{bcd}	1852^{cde}	1700^{bc}	1638^{cd}	1558^{bcd}	1428^{cde}	1348^{bcd}	1205^{cde}	1160^{cd}	1020^{def}	1668
NLP @ 0.5gKg^{-1}	2157	2115^{cd}	1998de	1941de	1850^{cde}	1715^{efg}	1662^{bcd}	1511^{def}	1388^{efgh}	1323^{efg}	1182^{efgh}	1067^{def}	1031de	935^{fg}	1562
NLP @ 1gKg^{-1}	2157	2114^{cd}	2052^{cde}	1879^{e}	1805de	1652^{fg}	1541^{cde}	1419^{efg}	1358^{fgh}	1255^{fgh}	1194^{efg}	1073^{def}	1029de	937^{fg}	1533
NLP @ 2gKg^{-1}	2159	2110^{cd}	2016^{cde}	1946de	1891^{cd}	1774^{def}	1552^{cde}	1447^{efg}	1355^{fgh}	1210^{gh}	1150^{fghi}	1066^{ef}	1026de	914^{fg}	1544
SEM±	21.63	27.53	32.62	39.4	36.64	45.08	43.75	52.61	48.63	47.95	58.89	60.86	82.12	76.83	46.82
CD (0.01)	NS	NS	NS	NS	1.303	2.006	2.038	1.330	1.355	2.215	2.238	2.217	2.268	2.098	
CD (0.05)	NS	NS	NS	NS	0.969	1.493	1.516	0.989	1.008	1.648	1.665	1.649	1.687	1.561	

Table 34: Effect of nano size botanicals on vigour index II during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	1421	1369	1255^{e}	1092^{g}	1026^{f}	890^{f}	787^{h}	641^{i}	380^{j}	181^{i}	58^{g}	0^{f}	0^{h}	0^{g}	650
ALP @ 0.5gKg^{-1}	1524	1498	1457^{abc}	1432^{abcd}	1345^{bcd}	1314^{ab}	1241^{ab}	1176^{ab}	1107^{a}	966^{ab}	932^{a}	887^{a}	845^{a}	819^{ab}	1182
ALP @ 1gKg^{-1}	1520	1502	1443^{abcd}	1386^{cde}	1337^{bcd}	1287^{abc}	1219^{abc}	1142^{abc}	1045^{bcde}	958^{abc}	908^{a}	870^{a}	828^{ab}	798^{abc}	1160
ALP @ 2gKg^{-1}	1513	1497	1482^{abc}	1415^{bcde}	1355^{abc}	1315^{ab}	1258^{a}	1114^{bc}	1014de	948^{abcd}	897^{ab}	840^{abc}	806^{abc}	757^{bcd}	1158
FLP @ 0.5gKg^{-1}	1548	1532	1509^{a}	1483^{a}	1437^{a}	1399^{a}	1292^{a}	1222^{a}	1125^{a}	1063^{a}	991^{a}	949^{a}	886^{a}	888^{a}	1238
FLP @ 1gKg^{-1}	1577	1541	1483^{abc}	1468^{ab}	1420^{a}	1339^{ab}	1220^{abc}	1148^{abc}	1082^{ab}	969^{ab}	918^{a}	872^{a}	839^{a}	820^{ab}	1192
FLP @ 2gKg^{-1}	1529	1508	1484^{abc}	1430^{abcde}	1393^{ab}	1298^{abc}	1188^{abcd}	1110^{cd}	1018^{cde}	954^{abcd}	891^{abc}	855^{ab}	803^{abcd}	758^{bcd}	1158
PLP @ 0.5gKg^{-1}	1520	1504	1471^{abc}	1368^{e}	1309^{cd}	1275^{abc}	1154^{bcd}	1050de	929^{g}	843^{efgh}	805^{cdef}	769^{bcd}	744^{bcdef}	717^{cde}	1104
PLP @ 1gKg^{-1}	1471	1445	1365^{cde}	1224^{f}	1170^{e}	1050^{e}	994^{g}	905^{h}	830^{i}	751^{h}	717^{f}	671^{e}	646^{g}	632^{f}	991
PLP @ 2gKg^{-1}	1588	1577	1509^{a}	1488^{a}	1346^{bcd}	1316^{ab}	1240^{ab}	1165^{abc}	1065^{abcd}	960^{abc}	911^{a}	853^{ab}	798^{abcd}	738^{bcde}	1182
CLP @ 0.5gKg^{-1}	1526	1507	1470^{abc}	1404^{cde}	1370^{abc}	1283^{abc}	1198^{abcd}	1109^{cd}	1026^{bcde}	915^{bcde}	860^{abcd}	826^{abc}	785^{abcde}	740^{bcde}	1144
CLP @ 1gKg^{-1}	1529	1518	1503^{ab}	1446^{abc}	1332^{bcd}	1376^{a}	1273^{a}	1198^{a}	1075^{abc}	1012^{a}	945^{a}	907^{a}	852^{a}	859^{a}	1202
CLP @ 2gKg^{-1}	1507	1488	1398^{abcd}	1378de	1283^{d}	1241^{bc}	1192^{abcd}	1024^{ef}	942^{fg}	862^{defg}	798^{def}	755^{cde}	713^{defg}	678^{def}	1090
NLP @ 0.5gKg^{-1}	1516	1487	1376^{bcde}	1380de	1330^{bcd}	1197^{cd}	1120^{cde}	984^{fg}	899^{gh}	822^{efgh}	763^{ef}	725de	679^{fg}	660^{ef}	1067
NLP @ 1gKg^{-1}	1458	1439	1326de	1267^{f}	1179^{e}	1057^{e}	1015^{fg}	987^{efg}	891^{gh}	819^{fgh}	786^{def}	727de	700^{efg}	663^{ef}	1022
NLP @ 2gKg^{-1}	1468	1444	1378^{bcde}	1255^{f}	1209^{e}	1097de	1037^{efg}	950^{gh}	851^{hi}	770^{gh}	740^{ef}	712de	671^{fg}	632^{f}	1015
SEM±	10.37	11.81	17.85	26.02	25.27	33.12	32.05	34.62	43.38	48.67	52.44	53.24	50.50	48.84	33.63
CD (0.01)	NS	NS	NS	1.247	1.407	2.11	2.142	1.434	1.459	2.319	2.342	2.321	2.372	2.202	
CD (0.05)	NS	NS	1.775	0.908	1.026	1.55	1.573	1.46	1.065	1.705	1.722	1.706	1.744	1.618	

Table 35: Effect of nano size botanicals on electrical conductivity of seed leachate (dSm^{-1}) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.593^{a}	0.680^{a}	0.764^{a}	0.841^{a}	0.853^{a}	0.979^{a}	1.025^{a}	1.125^{a}	1.138^{a}	1.456^{a}	1.628^{a}	1.795^{a}	1.827^{a}	1.994^{a}	1.193
ALP @ $0.5gKg^{-1}$	0.384^{fg}	0.552^{b}	0.691^{b}	0.684^{ef}	0.722^{fg}	0.730^{f}	0.820^{de}	0.843^{d}	0.927^{cde}	0.946^{de}	0.994^{e}	1.044^{f}	1.180^{g}	1.267^{h}	0.842
ALP @ $1gKg^{-1}$	0.347^{ghi}	0.468^{de}	0.574^{d}	0.652^{fg}	0.670^{hi}	0.737^{ef}	0.780^{ef}	0.841^{d}	0.893^{ef}	0.889^{fg}	0.958^{e}	1.068^{f}	1.089^{h}	1.186^{i}	0.797
ALP @ $2gKg^{-1}$	0.447^{cd}	0.546^{b}	0.657^{bc}	0.769^{b}	0.783^{cd}	0.815^{d}	0.829^{d}	0.879^{cd}	0.899^{def}	0.978^{cd}	1.047^{d}	1.186^{c}	1.340^{d}	1.499^{de}	0.905
FLP @ $0.5gKg^{-1}$	0.339^{hi}	0.459^{de}	0.555^{de}	0.627^{gh}	0.654^{i}	0.730^{f}	0.753^{f}	0.843^{d}	0.869^{f}	0.876^{g}	0.908^{f}	1.059^{f}	1.059^{h}	1.127^{j}	0.776
FLP @ $1gKg^{-1}$	0.328^{hi}	0.456^{de}	0.567^{d}	0.610^{hi}	0.648^{i}	0.688^{g}	0.706^{g}	0.756^{e}	0.788^{g}	0.829^{h}	0.869^{f}	0.897^{g}	0.949^{i}	1.130^{j}	0.73
FLP @ $2gKg^{-1}$	0.398^{ef}	0.519^{bc}	0.637^{c}	0.650^{fg}	0.735^{efg}	0.759^{ef}	0.811^{de}	0.860^{cd}	0.947^{bc}	0.967^{cd}	1.087^{c}	1.127^{c}	1.167^{g}	1.394^{g}	0.861
PLP @ $0.5gKg^{-1}$	0.495^{b}	0.544^{b}	0.690^{b}	0.760^{bc}	0.843^{a}	0.840^{cd}	0.874^{bc}	0.898^{c}	0.958^{bc}	1.089^{b}	1.169^{b}	1.245^{b}	1.486^{b}	1.583^{c}	0.962
PLP @ $1gKg^{-1}$	0.479^{bc}	0.514^{bc}	0.644^{c}	0.726^{cd}	0.829^{ab}	0.880^{b}	0.900^{b}	0.964^{b}	0.987^{b}	0.999^{c}	1.067^{cd}	1.194^{c}	1.284^{e}	1.507^{d}	0.927
PLP @ $2gKg^{-1}$	0.493^{b}	0.539^{b}	0.685^{b}	0.764^{bc}	0.845^{a}	0.868^{bc}	0.881^{bc}	0.956^{b}	0.986^{b}	1.095^{b}	1.188^{b}	1.264^{b}	1.389^{c}	1.691^{b}	0.975
CLP @ $0.5gKg^{-1}$	0.320^{i}	0.445^{e}	0.526^{e}	0.571^{i}	0.644^{i}	0.657^{g}	0.678^{g}	0.709^{f}	0.758^{g}	0.779^{i}	0.821^{g}	0.864^{g}	0.924^{i}	1.064^{k}	0.697
CLP @ $1gKg^{-1}$	0.360^{fgh}	0.493^{cd}	0.589^{d}	0.640^{gh}	0.700^{gh}	0.730^{f}	0.811^{de}	0.880^{cd}	0.980^{b}	0.917^{ef}	0.997^{e}	1.068^{f}	1.084^{h}	1.254^{h}	0.822
CLP @ $2gKg^{-1}$	0.427^{de}	0.537^{b}	0.655^{bc}	0.719^{de}	0.753^{def}	0.770^{e}	0.842^{cd}	0.864^{cd}	0.889^{ef}	0.947^{de}	1.094^{c}	1.139^{de}	1.239^{f}	1.457^{f}	0.881
NLP @ $0.5gKg^{-1}$	0.439^{d}	0.540^{b}	0.659^{bc}	0.738^{bcd}	0.768^{cde}	0.811^{d}	0.828^{d}	0.853^{d}	0.894^{ef}	0.997^{c}	1.039^{d}	1.167^{cd}	1.257^{ef}	1.463^{ef}	0.89
NLP @ $1gKg^{-1}$	0.486^{bc}	0.536^{b}	0.660^{bc}	0.728^{cd}	0.790^{bcd}	0.811^{d}	0.846^{cd}	0.895^{c}	0.894^{ef}	0.986^{cd}	1.074^{cd}	1.169^{cd}	1.386^{c}	1.560^{c}	0.916
NLP @ $2gKg^{-1}$	0.459^{bcd}	0.517^{bc}	0.667^{bc}	0.756^{bcd}	0.800^{bc}	0.880^{b}	0.889^{b}	0.896^{c}	0.938^{cd}	0.998^{c}	1.057^{cd}	1.167^{cd}	1.279^{ef}	1.489^{def}	0.914
SEM±	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05	0.06	0.06	0.03
CD (0.01)	0.053	0.055	0.059	0.062	0.063	0.066	0.066	0.069	0.077	0.078	0.080	0.081	0.085	0.087	
CD (0.05)	0.040	0.041	0.044	0.047	0.047	0.048	0.049	0.051	0.056	0.056	0.057	0.058	0.060	0.061	

Table 36: Effect of nano size botanicals on electrical conductivity of seed leachate (dSm^{-1}) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.593^{a}	0.680^{a}	0.764^{a}	0.841^{a}	0.853^{a}	0.979^{a}	1.025^{a}	1.125^{a}	1.138^{a}	1.456^{a}	1.628^{a}	1.795^{a}	1.827^{a}	1.994^{a}	1.193
ALP @ $0.5gKg^{-1}$	0.384^{fg}	0.552^{b}	0.691^{b}	0.684^{ef}	0.722^{fg}	0.730^{f}	0.820^{de}	0.843^{d}	0.927^{cde}	0.946^{de}	0.994^{e}	1.044^{f}	1.180^{g}	1.267^{h}	0.842
ALP @ $1gKg^{-1}$	0.347^{ghi}	0.468^{de}	0.574^{d}	0.652^{fg}	0.670^{hi}	0.737^{ef}	0.780^{ef}	0.841^{d}	0.893^{ef}	0.889^{fg}	0.958^{e}	1.068^{f}	1.089^{h}	1.186^{i}	0.797
ALP @ $2gKg^{-1}$	0.447^{cd}	0.546^{b}	0.657^{bc}	0.769^{b}	0.783^{cd}	0.815^{d}	0.829^{d}	0.879^{cd}	0.899^{def}	0.978^{cd}	1.047^{d}	1.186^{e}	1.340^{d}	1.499^{de}	0.905
FLP @ $0.5gKg^{-1}$	0.339^{hi}	0.459^{de}	0.555^{de}	0.627^{gh}	0.654^{i}	0.730^{f}	0.753^{f}	0.843^{d}	0.869^{f}	0.876^{g}	0.908^{f}	1.059^{f}	1.059^{h}	1.127^{j}	0.776
FLP @ $1gKg^{-1}$	0.310^{j}	0.440^{f}	0.557^{f}	0.600^{gh}	0.637^{i}	0.687^{g}	0.700^{h}	0.747^{g}	0.780^{h}	0.810^{h}	0.841^{i}	0.880^{h}	0.940^{j}	1.100^{i}	0.716
FLP @ $2gKg^{-1}$	0.329^{ij}	0.448^{ef}	0.549^{f}	0.620^{fg}	0.657^{i}	0.729^{f}	0.748^{g}	0.837^{ef}	0.844^{g}	0.865^{g}	0.890^{h}	1.040^{g}	1.044^{i}	1.118^{i}	0.766
PLP @ $0.5gKg^{-1}$	0.488^{b}	0.531^{bc}	0.689^{b}	0.757^{b}	0.840^{ab}	0.866^{b}	0.874^{bc}	0.941^{b}	0.973^{b}	1.097^{b}	1.174^{b}	1.259^{b}	1.375^{c}	1.612^{b}	0.963
PLP @ $1gKg^{-1}$	0.479^{bc}	0.514^{bc}	0.644^{c}	0.726^{cd}	0.829^{ab}	0.880^{b}	0.900^{b}	0.964^{b}	0.987^{b}	0.999^{c}	1.067^{cd}	1.194^{c}	1.284^{e}	1.507^{d}	0.927
PLP @ $2gKg^{-1}$	0.493^{b}	0.539^{b}	0.685^{b}	0.764^{bc}	0.845^{a}	0.868^{bc}	0.881^{bc}	0.956^{b}	0.986^{b}	1.095^{b}	1.188^{b}	1.264^{b}	1.389^{c}	1.691^{b}	0.975
CLP @ $0.5gKg^{-1}$	0.300^{j}	0.439^{f}	0.500^{g}	0.567^{h}	0.640^{i}	0.650^{g}	0.672^{h}	0.700^{h}	0.747^{h}	0.762^{i}	0.810^{i}	0.834^{i}	0.907^{j}	1.044^{j}	0.684
CLP @ $1gKg^{-1}$	0.360^{fgh}	0.493^{cd}	0.589^{d}	0.640^{gh}	0.700^{gh}	0.730^{f}	0.811^{de}	0.880^{cd}	0.980^{b}	0.917^{ef}	0.997^{e}	1.068^{f}	1.084^{h}	1.254^{h}	0.822
CLP @ $2gKg^{-1}$	0.427^{de}	0.537^{b}	0.655^{bc}	0.719^{de}	0.753^{def}	0.770^{e}	0.842^{cd}	0.864^{cd}	0.889^{ef}	0.947^{dc}	1.094^{c}	1.139^{de}	1.239^{f}	1.457^{f}	0.881
NLP @ $0.5gKg^{-1}$	0.439^{d}	0.540^{b}	0.659^{bc}	0.738^{bcd}	0.768^{cde}	0.811^{d}	0.828^{d}	0.853^{d}	0.894^{ef}	0.997^{c}	1.039^{d}	1.167^{cd}	1.257^{ef}	1.463^{ef}	0.89
NLP @ $1gKg^{-1}$	0.486^{bc}	0.536^{b}	0.660^{bc}	0.728^{cd}	0.790^{bcd}	0.811^{d}	0.846^{cd}	0.895^{c}	0.894^{ef}	0.986^{cd}	1.074^{cd}	1.169^{cd}	1.386^{c}	1.560^{c}	0.916
NLP @ $2gKg^{-1}$	0.459^{bcd}	0.517^{bc}	0.667^{bc}	0.756^{bcd}	0.800^{bc}	0.880^{b}	0.889^{b}	0.896^{c}	0.938^{cd}	0.998^{c}	1.057^{cd}	1.167^{cd}	1.279^{ef}	1.489^{def}	0.914
SEM±	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.05	0.06	0.06	0.03
CD (0.01)	0.053	0.055	0.059	0.062	0.063	0.066	0.066	0.069	0.077	0.078	0.08	0.081	0.085	0.087	
CD (0.05)	0.04	0.041	0.044	0.047	0.047	0.048	0.049	0.051	0.056	0.056	0.057	0.058	0.06	0.061	

4.3.9. Dehydrogenase activity (OD value)

Effect of nanopowder treatments over the period of storage on dehydrogenase enzyme activity resulted in significant differences after five and two months of storage in Anugraha and Ujwala respectively. Reduction in dehydrogenase activity of seeds was observed at the end of storage period.

In Anugraha, among the seed treatments (Table 37), maximum dehydrogenase activity was recorded by the seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (0.080) followed by T_6: FLP @ 1 g kg^{-1} (0.067) and T_{13}: CLP @ 2 g kg^{-1} (0.059), T_2: ALP @ 0.5 g kg^{-1} (0.059) were on par with T_{15}: NLP @ 1 g kg^{-1} (0.058), T_4: ALP @ 2 g kg^{-1} (0.057), T_3: ALP @ 1 g kg^{-1} (0.056) while minimum dehydrogenase activity was seen in T_{10}: PLP @ 2 g kg^{-1} (0.037) compared to control (0.020) at twelfth month of storage.

In Ujwala, among the seed treatments (Table 38), maximum dehydrogenase activity was recorded in T_5: FLP @ 0.5 g kg^{-1} (0.107) which was on par with T_{12}: CLP @ 1 g kg^{-1} (0.091) followed byT_{13}: CLP @ 2 g kg^{-1} (0.083) on par with T_{11}: CLP @ 0.5 g kg^{-1} (0.080) and T_6: FLP @ 1 g kg^{-1} (0.080) while minimum dehydrogenase activity was seen in T_9: PLP @ 1 g kg^{-1} (0.051) compared to control (0.038) at ninth month of storage.

4.3.10. Seed moisture content (%)

No significant differences were observed in the moisture content of seeds treated with nanopowders in variety Anugraha (Table 39) and Ujwala (Table 40).

4.3.11. Seed microflora (%)

Significant difference among the treatments were observed for seed infection (%) in both agar and blotter method.

Irrespective of the method and treatments, highest seed infection was observed in untreated seeds. The seed infection was lower in blotter method compared to agar plate method.

In Anugraha, seed infection per cent was less in nanopowder treatments (Table 41) such as T_{11}: CLP @ 0.5 g kg^{-1} (10.00), T_6: FLP @ 1 g kg^{-1} (13.33), T_5: FLP @ 0.5 g kg^{-1} (13.33) and T_3: ALP @ 1 g kg^{-1} (13.33). Seed infection per cent was high in untreated seeds (36.67) followed by T_{10}: PLP @ 2 g kg^{-1} (30.00). A similar trend was observed in agar plate method also. Treatments such as T_{11}: CLP @ 0.5 g kg^{-1} (13.33), T_6: FLP @ 1 g kg^{-1} (16.67), T_5: FLP

Table 37: Effect of nano size botanicals on dehydrogenase activity (OD) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.124	0.120	0.115	0.104	0.093	0.083^{c}	0.073^{e}	0.060^{d}	0.052^{f}	0.043^{e}	0.039^{e}	0.023^{e}	0.012^{e}	0.007^{f}	0.068
ALP @ 0.5gKg^{-1}	0.128	0.125	0.121	0.118	0.114	0.111^{ab}	0.102^{abcd}	0.090^{bc}	0.085^{bcd}	0.076^{bc}	0.063^{bc}	0.059^{bc}	0.047^{bc}	0.038^{bc}	0.091
ALP @ 1gKg^{-1}	0.131	0.128	0.124	0.121	0.117	0.114^{a}	0.111^{ab}	0.092^{bc}	0.084^{bcd}	0.076^{bc}	0.063^{bc}	0.056^{bc}	0.042^{bc}	0.035^{bcd}	0.092
ALP @ 2gKg^{-1}	0.126	0.124	0.122	0.120	0.117	0.115^{a}	0.111^{ab}	0.095^{ab}	0.089^{bc}	0.074^{bc}	0.068^{bc}	0.057^{bc}	0.044^{bc}	0.038^{bc}	0.093
FLP @ 0.5gKg^{-1}	0.128	0.125	0.122	0.117	0.113	0.107^{ab}	0.094^{cd}	0.085^{bc}	0.078^{bcde}	0.069^{bc}	0.057^{cd}	0.045^{cd}	0.038^{c}	0.027^{cde}	0.086
FLP @ 1gKg^{-1}	0.135	0.132	0.128	0.125	0.122	0.118^{a}	0.114^{a}	0.111^{a}	0.092^{ab}	0.084^{ab}	0.076^{ab}	0.067^{ab}	0.058^{b}	0.045^{ab}	0.101
FLP @ 2gKg^{-1}	0.129	0.125	0.122	0.117	0.114	0.111^{ab}	0.095^{bcd}	0.084^{bc}	0.076^{cde}	0.064^{cd}	0.058^{cd}	0.049^{cd}	0.037^{cd}	0.028^{cde}	0.086
PLP @ 0.5gKg^{-1}	0.127	0.124	0.121	0.117	0.114	0.111^{ab}	0.093^{cd}	0.082^{bc}	0.073^{de}	0.064^{cd}	0.057^{cd}	0.048^{cd}	0.039^{c}	0.025^{cde}	0.085
PLP @ 1gKg^{-1}	0.126	0.123	0.120	0.117	0.114	0.111^{ab}	0.097^{bcd}	0.087^{bc}	0.075^{cde}	0.068^{bc}	0.057^{cd}	0.049^{cd}	0.036^{cd}	0.027^{cde}	0.086
PLP @ 2gKg^{-1}	0.125	0.122	0.120	0.117	0.112	0.097^{bc}	0.086^{de}	0.077^{c}	0.064^{ef}	0.050^{de}	0.043^{de}	0.037^{de}	0.021^{de}	0.019^{ef}	0.078
CLP @ 0.5gKg^{-1}	0.135	0.132	0.128	0.124	0.121	0.119^{a}	0.114^{a}	0.111^{a}	0.107^{a}	0.095^{a}	0.088^{a}	0.080^{a}	0.075^{a}	0.060^{a}	0.106
CLP @ 1gKg^{-1}	0.130	0.127	0.124	0.121	0.118	0.113^{ab}	0.104^{abc}	0.090^{bc}	0.082^{bcd}	0.078^{bc}	0.068^{bc}	0.052^{bcd}	0.043^{bc}	0.032^{bcde}	0.092
CLP @ 2gKg^{-1}	0.131	0.127	0.124	0.120	0.118	0.114^{a}	0.111^{ab}	0.091^{bc}	0.084^{bcd}	0.076^{bc}	0.067^{bc}	0.059^{bc}	0.045^{bc}	0.032^{bcde}	0.093
NLP @ 0.5gKg^{-1}	0.127	0.124	0.121	0.117	0.113	0.109^{ab}	0.096^{bcd}	0.085^{bc}	0.076^{cde}	0.067^{c}	0.054^{cde}	0.049^{cd}	0.036^{cd}	0.020^{def}	0.085
NLP @ 1gKg^{-1}	0.127	0.124	0.121	0.118	0.114	0.111^{ab}	0.107^{abc}	0.093^{b}	0.084^{bcd}	0.076^{bc}	0.065^{bc}	0.058^{bc}	0.047^{bc}	0.039^{bc}	0.092
NLP @ 2gKg^{-1}	0.125	0.122	0.120	0.117	0.114	0.111^{ab}	0.095^{bcd}	0.088^{bc}	0.075^{cde}	0.067^{c}	0.058^{cd}	0.046^{cd}	0.038^{c}	0.029^{cde}	0.086
SEM±	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002
CD (0.01)	NS	NS	NS	NS	NS	0.015	0.018	0.020	0.021	0.026	0.032	0.034	0.039	0.041	
CD (0.05)	NS	NS	NS	NS	NS	0.014	0.015	0.015	0.016	0.017	0.019	0.019	0.020	0.021	

Table 38: Effect of nano size botanicals on dehydrogenase activity (OD) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	0.120	0.109	0.091^{de}	0.081^{c}	0.074^{e}	0.063^{f}	0.053^{g}	0.041^{h}	0.038^{g}	0.034^{g}	0.032^{g}	0.019^{h}	0.004^{g}	0.002^{f}	0.054
ALP @ 0.5gKg^{-1}	0.126	0.124	0.121^{ab}	0.118^{a}	0.114^{ab}	0.109^{ab}	0.092^{bcde}	0.086^{cd}	0.074^{cd}	0.066^{bcde}	0.057^{bcd}	0.048^{cde}	0.037^{cdef}	0.026^{de}	0.086
ALP @ 1gKg^{-1}	0.122	0.120	0.118^{bcd}	0.114^{ab}	0.110^{abc}	0.104^{abc}	0.093^{bcde}	0.081^{cdef}	0.076^{bcd}	0.061^{cdef}	0.056^{bcde}	0.042^{defg}	0.033^{def}	0.024^{de}	0.082
ALP @ 2gKg^{-1}	0.123	0.120	0.116^{bcd}	0.113^{ab}	0.107^{abcd}	0.091^{cde}	0.084^{cdef}	0.075^{defg}	0.067^{cdef}	0.056^{ef}	0.043^{defg}	0.035^{efgh}	0.024^{ef}	0.015^{ef}	0.076
FLP @ 0.5gKg^{-1}	0.130	0.128	0.125^{a}	0.122^{a}	0.119^{a}	0.116^{a}	0.114^{a}	0.111^{a}	0.107^{a}	0.097^{a}	0.085^{a}	0.074^{ab}	0.067^{b}	0.057^{a}	0.104
FLP @ 1gKg^{-1}	0.128	0.125	0.122^{a}	0.119^{a}	0.115^{a}	0.111^{a}	0.099^{abc}	0.084^{cde}	0.080^{bcd}	0.074^{bcd}	0.066^{bc}	0.078^{a}	0.067^{b}	0.056^{ab}	0.095
FLP @ 2gKg^{-1}	0.125	0.122	0.118^{abcd}	0.115^{ab}	0.111^{abc}	0.101^{abcd}	0.094^{bcd}	0.088^{bcd}	0.072^{cde}	0.061^{cdef}	0.053^{bcdef}	0.041^{defg}	0.031^{def}	0.022^{de}	0.082
PLP @ 0.5gKg^{-1}	0.123	0.120	0.119^{abc}	0.115^{ab}	0.109^{abc}	0.093^{bcde}	0.084^{cdef}	0.073^{defg}	0.068^{cdef}	0.058^{ef}	0.051^{cdef}	0.039^{defg}	0.031^{def}	0.027^{cde}	0.079
PLP @ 1gKg^{-1}	0.120	0.118	0.115^{cd}	0.111^{ab}	0.096^{cd}	0.087^{de}	0.079^{def}	0.067^{fg}	0.058^{ef}	0.047^{fg}	0.040^{efg}	0.028^{gh}	0.022^{f}	0.019^{de}	0.072
PLP @ 2gKg^{-1}	0.121	0.119	0.117^{bcd}	0.114^{ab}	0.110^{abc}	0.094^{bcde}	0.083^{cdef}	0.078^{defg}	0.066^{def}	0.059^{def}	0.045^{defg}	0.039^{defg}	0.027^{ef}	0.020^{de}	0.078
CLP @ 0.5gKg^{-1}	0.125	0.122	0.120^{abc}	0.118^{a}	0.115^{a}	0.112^{a}	0.105^{ab}	0.096^{abc}	0.080^{bcd}	0.065^{bcde}	0.056^{bcde}	0.047^{cdef}	0.039^{cde}	0.028^{cde}	0.088
CLP @ 1gKg^{-1}	0.128	0.125	0.122^{ab}	0.119^{a}	0.116^{a}	0.114^{a}	0.111^{a}	0.104^{ab}	0.091^{ab}	0.079^{b}	0.068^{b}	0.059^{bc}	0.050^{c}	0.041^{bc}	0.095
CLP @ 2gKg^{-1}	0.125	0.123	0.120^{ab}	0.117^{a}	0.114^{ab}	0.111^{a}	0.104^{ab}	0.097^{abc}	0.083^{bc}	0.075^{bc}	0.063^{bc}	0.052^{cd}	0.045^{cd}	0.033^{cd}	0.090
NLP @ 0.5gKg^{-1}	0.121	0.117	0.011^{c}	0.100^{b}	0.092^{d}	0.083^{e}	0.074^{f}	0.068^{efg}	0.055^{f}	0.046^{fg}	0.038^{fg}	0.027^{gh}	0.200^{a}	0.014^{ef}	0.075
NLP @ 1gKg^{-1}	0.120	0.118	0.114^{cd}	0.112^{ab}	0.098^{bcd}	0.089^{cde}	0.078^{ef}	0.064^{g}	0.057^{ef}	0.049^{fg}	0.041^{defg}	0.033^{efgh}	0.032^{def}	0.025^{de}	0.074
NLP @ 2gKg^{-1}	0.121	0.119	0.115^{bcd}	0.111^{ab}	0.097^{cd}	0.088^{cde}	0.076^{f}	0.067^{fg}	0.058^{ef}	0.047^{fg}	0.040^{efg}	0.031^{fgh}	0.027^{ef}	0.019^{de}	0.073
SEM±	0.001	0.001	0.007	0.002	0.003	0.004	0.004	0.004	0.004	0.004	0.003	0.004	0.011	0.004	0.003
CD (0.01)	NS	NS	0.032	0.034	0.039	0.041	0.49	0.055	0.064	0.065	0.069	0.074	0.077	0.080	
CD (0.05)	NS	NS	0.019	0.019	0.020	0.021	0.023	0.026	0.030	0.030	0.031	0.033	0.034	0.036	

Table 39: Effect of nano size botanicals on moisture content (%) during storage period in Anugraha

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	6.32	6.35	6.40	6.45	6.49	6.53	6.60	6.63	6.65	6.72	6.75	6.79	6.81	6.88	6.60
ALP @ 0.5gKg^{-1}	6.29	6.31	6.34	6.38	6.40	6.42	6.48	6.55	6.56	6.59	6.63	6.65	6.67	6.68	6.50
ALP @ 1gKg^{-1}	6.27	6.32	6.36	6.41	6.46	6.48	6.51	6.53	6.58	6.60	6.65	6.67	6.70	6.74	6.52
ALP @ 2gKg^{-1}	6.26	6.30	6.35	6.39	6.41	6.44	6.47	6.50	6.52	6.55	6.57	6.59	6.61	6.63	6.47
FLP @ 0.5gKg^{-1}	6.29	6.31	6.34	6.38	6.40	6.42	6.48	6.55	6.56	6.59	6.63	6.65	6.67	6.68	6.50
FLP @ 1gKg^{-1}	6.31	6.34	6.33	6.39	6.40	6.43	6.45	6.47	6.51	6.51	6.53	6.55	6.56	6.57	6.45
FLP @ 2gKg^{-1}	6.30	6.33	6.37	6.39	6.42	6.44	6.49	6.50	6.55	6.56	6.64	6.67	6.71	6.75	6.51
PLP @ 0.5gKg^{-1}	6.29	6.34	6.35	6.43	6.47	6.49	6.54	6.57	6.61	6.64	6.65	6.69	6.78	6.81	6.55
PLP @ 1gKg^{-1}	6.29	6.35	6.37	6.41	6.46	6.55	6.58	6.58	6.63	6.68	6.69	6.70	6.73	6.75	6.56
PLP @ 2gKg^{-1}	6.31	6.37	6.39	6.44	6.45	6.52	6.57	6.60	6.64	6.69	6.71	6.75	6.77	6.84	6.58
CLP @ 0.5gKg^{-1}	6.30	6.33	6.34	6.35	6.38	6.40	6.40	6.42	6.43	6.49	6.50	6.52	6.53	6.53	6.42
CLP @ 1gKg^{-1}	6.26	6.30	6.35	6.39	6.41	6.44	6.47	6.50	6.52	6.55	6.57	6.59	6.61	6.63	6.47
CLP @ 2gKg^{-1}	6.22	6.30	6.32	6.35	6.40	6.43	6.41	6.48	6.50	6.50	6.50	6.53	6.60	6.61	6.44
NLP @ 0.5gKg^{-1}	6.29	6.35	6.37	6.41	6.46	6.55	6.58	6.58	6.63	6.68	6.69	6.70	6.73	6.75	6.56
NLP @ 1gKg^{-1}	6.27	6.32	6.36	6.41	6.46	6.48	6.51	6.53	6.58	6.60	6.65	6.67	6.70	6.74	6.52
NLP @ 2gKg^{-1}	6.33	6.36	6.35	6.43	6.47	6.49	6.52	6.57	6.60	6.63	6.67	6.71	6.74	6.79	6.55
SEM±	0.007	0.006	0.005	0.007	0.009	0.012	0.015	0.014	0.015	0.018	0.018	0.019	0.020	0.025	0.013
CD (0.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table 40: Effect of nano size botanicals on moisture content (%) during storage period in Ujwala

Treatments	Storage period (months)														Mean
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	
Control	7.09	7.20	7.25	7.31	7.35	7.48	7.59	7.68	7.81	7.85	7.95	8.00	8.04	8.05	7.62
ALP @ 0.5gKg^{-1}	7.02	7.09	7.17	7.23	7.28	7.36	7.43	7.50	7.58	7.65	7.73	7.80	7.87	7.95	7.16
ALP @ 1gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
ALP @ 2gKg^{-1}	7.02	7.09	7.16	7.23	7.29	7.36	7.43	7.50	7.57	7.64	7.70	7.77	7.84	7.91	7.47
FLP @ 0.5gKg^{-1}	7.00	7.02	7.04	7.05	7.10	7.12	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.50	7.20
FLP @ 1gKg^{-1}	7.00	7.01	7.02	7.03	7.03	7.05	7.12	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.48
FLP @ 2gKg^{-1}	7.01	7.11	7.15	7.25	7.35	7.41	7.52	7.60	7.69	7.75	7.81	7.88	7.91	7.95	7.53
PLP @ 0.5gKg^{-1}	7.01	7.10	7.18	7.27	7.36	7.44	7.54	7.62	7.70	7.79	7.88	7.89	7.92	7.96	7.55
PLP @ 1gKg^{-1}	7.03	7.11	7.18	7.26	7.34	7.41	7.49	7.56	7.64	7.72	7.79	7.87	7.95	8.00	7.53
PLP @ 2gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
CLP @ 0.5gKg^{-1}	7.02	7.08	7.15	7.21	7.27	7.34	7.40	7.46	7.53	7.59	7.65	7.71	7.78	7.84	7.43
CLP @ 1gKg^{-1}	7.00	7.03	7.05	7.06	7.12	7.05	7.14	7.16	7.18	7.30	7.35	7.40	7.46	7.50	7.20
CLP @ 2gKg^{-1}	7.03	7.10	7.18	7.25	7.32	7.40	7.47	7.55	7.62	7.69	7.77	7.84	7.91	7.99	7.51
NLP @ 0.5gKg^{-1}	7.03	7.09	7.13	7.21	7.30	7.39	7.47	7.56	7.65	7.73	7.80	7.86	7.90	7.93	7.50
NLP @ 1gKg^{-1}	7.03	7.12	7.20	7.29	7.31	7.46	7.55	7.64	7.72	7.81	7.90	7.92	7.95	8.01	7.57
NLP @ 2gKg^{-1}	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49	7.55	7.62	7.68	7.74	7.80	7.40
SEM±	0.005	0.011	0.015	0.021	0.024	0.034	0.037	0.043	0.050	0.049	0.050	0.049	0.048	0.048	0.035
CD (0.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table 41: Effect of nano size botanicals on seed microflora (%) in Anugraha and Ujwala

Treatment	Seed infection (%) of Anugraha		Seed infection (%) of Ujwala	
	Blotter method	Agar method	Blotter method	Agar method
Control	36.67	40.00	40.00	43.33
ALP @ 0.5gKg^{-1}	13.33	23.33	16.67	23.33
ALP @ 1gKg^{-1}	13.33	20.00	23.33	26.66
ALP @ 2gKg^{-1}	16.66	20.00	20.00	23.33
FLP @ 0.5gKg^{-1}	13.33	20.00	10.00	13.33
FLP @ 1gKg^{-1}	13.33	16.67	16.66	20.33
FLP @ 2gKg^{-1}	16.66	20.00	16.66	20.00
PLP @ 0.5gKg^{-1}	23.33	26.67	30.00	33.33
PLP @ 1gKg^{-1}	26.66	30.00	33.33	36.67
PLP @ 2gKg^{-1}	30.00	33.33	26.67	30.00
CLP @ 0.5gKg^{-1}	10.00	13.33	16.67	16.67
CLP @ 1gKg^{-1}	13.67	16.67	13.33	16.67
CLP @ 2gKg^{-1}	16.33	20.00	16.67	20.00
NLP @ 0.5gKg^{-1}	16.66	20.00	23.33	26.67
NLP @ 1gKg^{-1}	23.33	26.67	26.67	30.00
NLP @ 2gKg^{-1}	26.67	23.33	23.33	26.66

@ 0.5 g kg^{-1} (20.00) and T_3: ALP @ 1 g kg^{-1} (20.00) compared to untreated (40.00) followed by T_{10}: PLP @ 2 g kg^{-1} (33.33).

In Ujwala, seed infection per cent was less in nanopowder treatments (Table 41) such as T_5: FLP @ 0.5 g kg^{-1} (10.00), T_{11}: CLP @ 0.5 g kg^{-1} (13.00), T_{12}: CLP @ 1 g kg^{-1} (13.33) and T_6: FLP @ 1 g kg^{-1} (16.66). Seed infection per cent was high in untreated seeds (40.00) followed by T_9: PLP @ 1 g kg^{-1} (33.33). A similar trend was observed in agar plate method also. Treatments such as T_5: FLP @ 0.5 g kg^{-1} (13.33), T_{11}: CLP @ 0.5 g kg^{-1} (16.67), T_{12}: CLP @ 1 g kg^{-1} (16.67) and T_6: FLP @ 1 g kg^{-1} (20.33) compared to untreated (43.33) followed by T_9: PLP @ 1 g kg^{-1} (36.67).

The seed microflora observed in Anugraha and Ujwala at the end of twelfth and ninth month of storage period respectively. The storage fungi observed were *Aspergillus* sp., *Pencillium* sp. and *Alternaria* sp. (Plate 4).

Irrespective of the concentration of botanicals, seed infection per cent was more in pungam next to control in both the varieties.

4.4. Field performance of seeds treated with botanicals on yield attributes

4.4.1. Analysis of Variance

The analysis of variance on yield attributes such as plant height (cm), days to 50% flowering (days), number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight per plant (g), and fruit yield per plant (g) revealed significant differences among the treatments in both Anugraha (Table 42) and Ujwala (Table 43).

4.4.2. Plant height (cm)

Significant differences were observed for plant height among the seed treatments. Seed treatment with botanicals (both normal grade and nanopowders) were found to have a favourable effect on plant height. The treated seeds produced taller plants than control.

In Anugraha, among the normal grade powders (Table 44), taller plants were produced by treatments such as T_4: ALP @ 2 g kg^{-1} (82.0 cm), T_5: FLP @ 0.5 g kg^{-1} (81.5 cm), T_7: FLP @ 2 g kg^{-1} (81.3 cm) which were on par with each other followed by T_6: FLP @ 1 g kg^{-1} (80.0 cm) while in control (68.0 cm). Among treated seed, least plant height recorded was 73.6 cm in T_{16}: NLP @ 2 g kg^{-1} of seed. In case of nanopowder treatments (Table 45), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (85.0 cm), T_6: FLP @ 1 g kg^{-1} (83.6 cm) and T_5: FLP @ 0.5 g kg^{-1} (82.6 cm) were on par with T_{12}: CLP @ 1 g kg^{-1} (81.4 cm) were superior by

Table 42: Analysis of variance on field performance of botanicals in Anugraha

Anugraha	Normal grade					Nanopowders				
	Plant Height (cm)									
Source of variation	**dF**	**SS**	**MSS**	**F cal**	**F prob**	**dF**	**c**	**MSS**	**F cal**	**F prob**
Replications	2	2.375	1.188	0.097	0.908	2	2.375	1.188	0.097	0.908
Treatments	15	543.988	36.266	2.959	0.006	15	919.588	61.306	5.003	0
Error	30	367.625	12.254	-	-	30	367.625	12.254	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Days to 50% flowering (days)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	345.403	23.027	9154.3	0	15	338.203	22.547	8963.48	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Number of fruits per plant									
Replications	2	2.375	1.188	0.097	0.908	2	2.375	1.188	0.097	0.908
Treatments	15	5704.31	380.288	31.033	0	15	18758.8	1250.59	102.054	0
Error	30	367.625	12.254	-	-	30	367.625	12.254	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit length (cm)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	4.584	0.306	121.478	0	15	5.581	0.372	147.923	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit girth (cm)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	2.378	0.159	63.019	0	15	4.123	0.275	109.276	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit weight per plant (g)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	0.394	0.026	10.446	0	15	0.643	0.043	17.031	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit yield per plant (g)									
Replications	2	61.714	30.857	0.161	0.852	2	66.794	33.397	0.146	0.864
Treatments	15	48150.2	3210.02	16.74	0	15	125051	8336.7	36.552	0
Error	30	5752.59	191.753	-	-	30	6842.41	228.08	-	-
Total	47	-	-	-	-	47	-	-	-	-

dF – degree of freedom, SS – Sum of squares, MSS – Mean sum of squares

Table 43: Analysis of variance on field performance of botanicals in Ujwala

Ujwala	Normal grade					Nanopowders				
	Plant Height (cm)									
Source of variation	**dF**	**SS**	**MSS**	**F cal**	**F prob**	**dF**	**c**	**MSS**	**F cal**	**F prob**
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	345.403	23.027	9154.3	0	15	338.203	22.547	8963.48	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Days to 50% flowering (days)									
Replications	2	2.375	1.188	0.097	0.908	2	2.375	1.188	0.097	0.908
Treatments	15	543.988	36.266	2.959	0.006	15	919.588	61.306	5.003	0
Error	30	367.625	12.254	-	-	30	367.625	12.254	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Number of fruits per plant									
Replications	2	2.375	1.188	0.097	0.908	2	2.375	1.188	0.097	0.908
Treatments	15	3671.25	244.75	19.973	0	15	6266.81	417.788	34.094	0
Error	30	367.625	12.254	-	-	30	367.625	12.254	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit length (cm)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	5.758	0.384	152.609	0	15	6.399	0.427	169.602	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit girth (cm)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	4.98	0.332	131.986	0	15	4.457	0.297	118.135	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit weight per plant (g)									
Replications	2	0.001	0.001	0.226	0.799	2	0.001	0.001	0.226	0.799
Treatments	15	0.328	0.022	8.686	0	15	0.508	0.034	13.451	0
Error	30	0.075	0.003	-	-	30	0.075	0.003	-	-
Total	47	-	-	-	-	47	-	-	-	-
	Fruit yield per plant (g)									
Replications	2	31.109	15.554	0.112	0.895	2	31.631	15.815	0.104	0.901
Treatments	15	28582.9	1905.52	13.7	0	15	49804.9	3320.33	21.886	0
Error	30	4172.78	139.093	-	-	30	4551.26	151.709	-	-
Total	47	-	-	-	-	47	-	-	-	-

dF – degree of freedom, SS – Sum of squares, MSS -- Mean sum of squares

Table 44: Effect of normal grade botanicals on field performance in Anugraha and Ujwala

Treatment	Days to flowering (days)		Plant height (cm)		No. of fruits per plant		Fruit length (cm)		Fruit girth (cm)		Fruit weight per plant (g)		Fruit yield per plant (g)	
	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala
Control	87	88	68.0^{d}	70.0^{n}	165^{h}	147^{i}	6.11^{k}	6.00^{l}	1.90^{i}	2.20^{k}	1.16^{g}	**1.12^{c}**	200^{h}	165^{g}
ALP @ $0.5gKg^{-1}$	82	80	79.3^{abc}	80.9^{a}	198^{bcd}	178^{a}	6.70^{e}	7.20^{a}	2.50^{c}	3.20^{a}	1.37^{cde}	1.42^{a}	271^{cd}	253^{a}
ALP @ $1gKg^{-1}$	82	83	78.4^{abc}	78.5^{g}	201^{bc}	165^{de}	6.60^{f}	6.80^{e}	2.40^{d}	2.80^{e}	1.39^{cd}	1.27^{cd}	286^{bc}	210^{de}
ALP @ $2gKg^{-1}$	80	82	82.0^{a}	79.2^{e}	210^{a}	168^{cd}	7.20^{a}	7.00^{c}	2.70^{a}	3.00^{c}	1.50^{a}	1.29^{bc}	315^{a}	217^{cd}
FLP @ $0.5gKg^{-1}$	82	84	81.5^{a}	77.3^{h}	202^{bc}	161^{ef}	7.00^{b}	6.60^{g}	2.60^{b}	2.70^{f}	1.42^{abc}	1.22^{cd}	280^{bc}	196^{ef}
FLP @ $1gKg^{-1}$	82	82	80.0^{abc}	78.5^{g}	200^{bcd}	163^{def}	6.60^{f}	6.70^{f}	2.50^{c}	2.60^{g}	1.40^{bcd}	1.22^{cd}	280^{bc}	199^{def}
FLP @ $2gKg^{-1}$	81	81	81.3^{a}	80.1^{b}	208^{a}	174^{ab}	7.00^{b}	7.10^{b}	2.60^{b}	3.20^{a}	1.48^{ab}	1.37^{a}	308^{a}	238^{ab}
PLP @ $0.5gKg^{-1}$	85	84	76.6^{abc}	76.7^{i}	190^{e}	158^{fg}	6.40^{h}	6.60^{g}	2.20^{f}	2.50^{h}	1.32^{def}	1.23^{cd}	251^{de}	194^{ef}
PLP @ $1gKg^{-1}$	84	86	78.1^{abc}	76.4^{j}	196^{cd}	158^{fg}	6.90^{c}	6.40^{i}	2.40^{d}	2.50^{h}	1.34^{cde}	1.23^{cd}	263^{cd}	194^{ef}
PLP @ $2gKg^{-1}$	84	85	75.2^{bc}	79.3^{d}	180^{fg}	171^{bc}	6.30^{i}	6.90^{d}	2.10^{g}	2.90^{d}	1.24^{fg}	1.36^{ab}	223^{fg}	233^{bc}
CLP @ $0.5gKg^{-1}$	83	82	76.8^{abc}	80.0^{c}	195^{de}	173^{abc}	6.40^{h}	7.00^{c}	2.30^{e}	3.10^{b}	1.37^{cde}	1.37^{ab}	267^{cd}	237^{ab}
CLP @ $1gKg^{-1}$	82	83	77.3^{abc}	77.3^{h}	195^{de}	160^{ef}	6.40^{h}	6.50^{h}	2.30^{e}	2.40^{i}	1.38^{cd}	1.20^{de}	269^{cd}	192^{ef}
CLP @ $2gKg^{-1}$	82	82	78.1^{abc}	78.8^{f}	201^{bc}	171^{bc}	6.50^{g}	6.80^{e}	2.50^{c}	3.00^{c}	1.40^{bcd}	1.36^{ab}	281^{bc}	233^{bc}
NLP @ $0.5gKg^{-1}$	85	86	75.0^{bc}	75.3^{k}	184^{f}	153^{gh}	6.30^{i}	6.30^{j}	2.10^{g}	2.40^{i}	1.29^{ef}	1.22^{cd}	237^{ef}	187^{f}
NLP @ $1gKg^{-1}$	86	87	75.3^{bc}	74.2^{m}	197^{bcd}	152^{hi}	6.80^{d}	6.10^{k}	2.40^{d}	2.30^{j}	1.37^{cde}	1.19^{de}	281^{bc}	181^{fg}
NLP @ $2gKg^{-1}$	86	86	73.6^{c}	74.8^{l}	178^{g}	154^{gh}	6.20^{j}	6.30^{j}	2.01^{h}	2.40^{i}	1.19^{g}	1.21^{cd}	212^{gh}	186^{f}
SEM±	0.52	0.60	0.87	0.69	2.81	0.02	0.08	0.09	0.06	0.08	0.02	0.02	13.18	6.30
CD (0.01)	7.760	0.109	7.110	0.108	7.210	7.860	0.101	0.113	0.118	0.108	0.113	0.113	31.093	26.48
CD (0.05)	5.786	0.082	5.486	0.080	5.536	5.836	0.079	0.084	0.088	0.080	0.084	0.084	23.088	19.66

Table 45: Effect of nano size botanicals on field performance in Anugraha and Ujwala

Treatment	Days to flowering (days)		Plant height (cm)		No. of fruits per plant		Fruit length (cm)		Fruit girth (cm)		Fruit weight per plant (g)		Fruit yield per plant (g)	
	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala	Anugraha	Ujwala
Control	87	88	68.0^{c}	70.0^{q}	165^{h}	147^{i}	6.11^{k}	6.00^{m}	1.90^{i}	2.20^{j}	1.16^{j}	1.12^{f}	200^{k}	165^{h}
ALP @ 0.5gKg^{-1}	81	85	77.0^{bcd}	79.9^{e}	212de	177^{bc}	6.90^{e}	6.90^{e}	2.50^{e}	2.90^{d}	1.44^{def}	1.39^{ab}	305^{ef}	246^{bc}
ALP @ 1gKg^{-1}	85	85	78.5^{bcd}	79.2^{h}	220^{bc}	169de	6.70^{g}	6.50^{i}	2.60^{d}	2.60^{g}	1.50^{abcd}	1.30^{cd}	330^{cde}	220de
ALP @ 2gKg^{-1}	81	82	78.4^{bcd}	79.4^{g}	198^{f}	165^{ef}	7.01^{d}	6.60^{h}	2.90^{a}	2.60^{g}	1.54^{ab}	1.28^{cde}	305^{ef}	211^{ef}
FLP @ 0.5gKg^{-1}	80	78	82.6^{abc}	81.8^{a}	223^{b}	183^{a}	7.10^{c}	7.31^{a}	2.70^{c}	3.30^{a}	1.53^{abc}	1.47^{a}	341^{bc}	269^{a}
FLP @ 1gKg^{-1}	79	81	83.6^{ab}	80.5^{c}	235^{a}	182^{ab}	6.80^{f}	7.10^{c}	2.80^{b}	3.00^{c}	1.54^{ab}	1.42^{ab}	362^{ab}	257^{ab}
FLP @ 2gKg^{-1}	83	84	79.4^{bcd}	80.1^{d}	222^{b}	178^{bc}	7.20^{b}	6.70^{g}	2.50^{e}	3.00^{c}	1.53^{abc}	1.45^{a}	340^{bcd}	258^{ab}
PLP @ 0.5gKg^{-1}	85	85	75.0^{d}	79.0^{i}	184^{g}	177^{bc}	6.40^{i}	6.80^{f}	2.11^{gh}	2.90^{d}	1.28^{hi}	1.42^{ab}	236^{j}	255^{ab}
PLP @ 1gKg^{-1}	85	86	76.2^{cd}	76.1^{op}	187^{g}	155^{h}	6.40^{i}	6.20^{l}	2.20^{g}	2.40^{h}	1.30^{ghi}	1.20^{ef}	243^{ij}	186^{g}
PLP @ 2gKg^{-1}	86	86	74.6^{d}	77.4^{l}	182^{g}	163^{fg}	6.30^{j}	6.50^{i}.	2.08^{h}	2.80^{e}	1.27^{i}	1.26^{cde}	231^{j}	205^{efg}
CLP @ 0.5gKg^{-1}	78	83	85.0^{a}	78.4^{j}	237^{a}	183^{ab}	7.40^{a}	7.00^{d}	2.90^{a}	3.10^{b}	1.57^{a}	1.39^{ab}	372^{a}	252^{ab}
CLP @ 1gKg^{-1}	81	79	81.4^{abc}	81.1^{b}	216^{cd}	178^{bc}	7.01^{d}	7.20^{b}	2.60^{d}	3.10^{b}	1.45^{cde}	1.46^{a}	313^{ef}	260^{ab}
CLP @ 2gKg^{-1}	82	82	80.3^{bcd}	79.7^{f}	216^{cd}	174^{cd}	7.00^{d}	6.60^{h}	2.60^{d}	2.70^{f}	1.46^{bcde}	1.34^{bc}	315^{def}	233^{cd}
NLP @ 0.5gKg^{-1}	85	83	76.3^{cd}	78.2^{k}	209^{e}	165^{ef}	6.70^{g}	6.40^{j}	2.40^{f}	2.50^{i}	1.41^{ef}	1.27^{cde}	295^{fg}	210^{ef}
NLP @ 1gKg^{-1}	84	84	78.2^{bcd}	77.3^{m}	215de	158^{gh}	6.80^{f}	6.30^{k}	2.50^{e}	2.40^{i}	1.38^{efg}	1.22^{de}	297^{gf}	193^{fg}
NLP @ 2gKg^{-1}	84	85	76.2^{cd}	76.8^{n}	198^{f}	157^{h}	6.60^{h}	6.30^{k}	2.20^{g}	2.51^{i}	1.36^{fgh}	1.23^{de}	265^{hi}	193^{fg}
SEM±	0.68	0.72	1.13	0.69	5.10	0.03	0.09	0.09	0.08	0.08	0.03	0.03	8.18	8.32
CD (0.01)	7.110	0.108	7.760	0.109	7.860	7.620	0.113	0.121	0.115	0.109	0.119	0.115	33.910	27.66
CD (0.05)	5.486	0.080	5.786	0.082	5.836	5.716	0.084	0.088	0.086	0.082	0.089	0.085	25.180	20.54

producing taller plants. The control recorded the least plant height of 68.0 cm. Least plant height recorded was 74.6 cm in T_{10}: PLP @ 2 g kg^{-1} of seed among the treated seeds.

In Ujwala, normal grade treatments (Table 44) such as T_2: ALP @ 0.5 g kg^{-1} (80.9 cm) followed by T_7: FLP @ 2 g kg^{-1} (80.1 cm), T_{11}: CLP @ 0.5 g kg^{-1} (80.0 cm) and T_{10}: PLP @ 2 g kg^{-1} (79.3) was superior in producing taller plants compared to control (70.0 cm). Among the treated seeds, least plant height recorded was 74.2 cm in T_{15}: NLP @ 1 g kg^{-1} of seed. In nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (81.8 cm), T_{12}: CLP @ 1 g kg^{-1} (81.1 cm) and T_6: FLP @ 1 g kg^{-1} (80.5 cm) followed by T_7: FLP @ 2 g kg^{-1} (80.1 cm), T_2: ALP @ 0.5 g kg^{-1} (79.9 cm) were superior by producing taller plants compared to control (70.0 cm). Least plant height recorded was 76.1 cm in T_9: PLP @ 1 g kg^{-1} of seed among the treated seeds.

4.4.3. Days to 50% flowering (days)

Significant differences were observed among the seed treatments. Seed treatment with botanicals (both normal grade and nanopowders) were found to have a favourable effect on days to flowering.

In Anugraha, the overall mean of seeds treated with normal grade powders showed flowering (83 days). Among the treatments (Table 44), seed treated with T_4: ALP @ 2 g kg^{-1} (80 days) and T_7: FLP @ 2 g kg^{-1} (81 days) produced the flowers while in control (87 days). Irrespective of the concentration of botanicals, normal grade powders such as ALP, FLP, PLP, CLP and NLP produced flowers around 81 days, 82 days, 84 days, 82 days and 86 days, respectively. In case of nanopowders treatments (Table 45), the overall mean of treated seeds produced early flowering (82 days). Among the treatments, seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (78 days), T_6: FLP @ 1 g kg^{-1} (79 days) and T_5: FLP @ 0.5 g kg^{-1} (80 days) produced the flowers earlier while there was a delay in the control (87 days). Irrespective of the concentration of botanicals, nanopowders such as ALP, FLP, PLP, CLP and NLP produced flowers around 83 days, 80 days, 85 days, 80 days and 84 days, respectively.

In Ujwala, the overall mean of seeds treated with normal grade powders showed flowering (84 days). Among the treatments (Table 44), T_2: ALP @ 0.5 g kg^{-1} and T_7: FLP @ 2 g kg^{-1} produced the flowers earlier (80 and 81 days, respectively) while there was a delay in the control (88 days). In case of nanopowder treatments (Table 45). The overall mean of treated seeds showed earlier flowering (83 days) than control (88 days). Among the treatments, seed treated with T_5: FLP @ 0.5 g kg^{-1}, T_{12}: CLP @ 1 g kg^{-1} and T_6: FLP @ 1 g

kg^{-1} produced the flowers earlier (78, 79 and 81 days, respectively) while there was a delay in the control (88 days).

4.4.4. Number of fruits per plant

Compared to untreated seeds, the seeds treated with normal grade powders and nanopowders recorded maximum number of fruits.

In Anugraha, more number of fruits produced by normal grade powder treatments (Table 44) such as T_4: ALP @ 2 g kg^{-1} (210) were on par with T_7: FLP @ 2 g kg^{-1} (208) followed by T_5: FLP @ 0.5 g kg^{-1} (202), T_{13}: CLP @ 2 g kg^{-1} (201) which were on par with each other compared to control (165). The number of fruits produced were less in T_{16}: NLP @ 2 g kg^{-1} (178) among the treated seeds. In case of nanopowder treatments (Table 45), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (237) were on par with T_6: FLP @ 1 g kg^{-1} (235) followed by T_5: FLP @ 0.5 g kg^{-1} (223) and T_7: FLP @ 2 g kg^{-1} (222) produced more number of fruits compared to control (165). The number of fruits produced were less in T_{10}: PLP @ 2 g kg^{-1} (182) among the treated seeds.

In Ujwala, seeds treated with normal grade powders (Table 44) such as T_2: ALP @ 0.5 g kg^{-1} (178) which was on par with T_7: FLP @ 2 g kg^{-1} (174) and T_{11}: CLP @ 0.5 g kg^{-1} (173) followed by T_{13}: CLP @ 2 g kg^{-1} (171) and T_{10}: PLP @ 2 g kg^{-1} (171) produced more number of fruits compared to control (147). The number of fruits produced were less in T_{15}: NLP @ 1 g kg^{-1} (152) among the treated seeds. In case of nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (183) which was on par with T_{11}: CLP @ 0.5 g kg^{-1} (181) and T_6: FLP @ 1 g kg^{-1} (181) followed by T_{12}: CLP @ 1 g kg^{-1} (178) and T_7: FLP @ 2 g kg^{-1} (178) produced more number of fruits compared to control (147). The number of fruits produced were less in T_9: PLP @ 1 g kg^{-1} (155) among the treated seeds.

4.4.5. Fruit length (cm)

Fruit length of seeds treated with botanicals (both normal grade and nanopowders) was more compared to control.

In Anugraha, normal grade treatments (Table 44) such as T_4: ALP @ 2 g kg^{-1} (7.2 cm) followed by T_7: FLP @ 2 g kg^{-1} (7.0 cm) and T_5: FLP @ 0.5 g kg^{-1} (7.0 cm) were on par with T_9: PLP @ 1 g kg^{-1} (6.9 cm) produced longer fruits compared to control (6.1 cm). The least fruit length was observed in T_{16}: NLP @ 2 g kg^{-1} (6.2 cm) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (7.4 cm), T_6: FLP @ 1 g kg^{-1} (7.2 cm) and T_5: FLP @ 0.5 g kg^{-1} (7.1 cm) followed by T_{12}: CLP @ 1 g kg^{-1}

(7.0 cm), T_{13}: CLP @ 2 g kg^{-1} (7.0 cm) produced longer fruits compared to control (6.1 cm). The least fruit length was observed in T_{10}: PLP @ 2 g kg^{-1} (6.3 cm) among the treated seeds.

In Ujwala, normal grade treatments (Table 44), such as T_2: ALP @ 0.5 g kg^{-1} (7.2 cm), T_7: FLP @ 2 g kg^{-1} (7.1 cm) followed by T_{11}: CLP @ 0.5 g kg^{-1} (7.0 cm) and T_4: ALP @ 2 g kg^{-1} (7.0 cm) produced longer fruits compared to control (6.0 cm). The least fruit length was observed in T_{15}: NLP @ 1 g kg^{-1} (6.1 cm) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (7.3 cm), T_{12}: CLP @ 1 g kg^{-1} (7.2 cm) and T_6: FLP @ 1 g kg^{-1} (7.1 cm), T_{11}: CLP @ 0.5 g kg^{-1} (7.0 cm), T_2: ALP @ 0.5 g kg^{-1} (6.90 cm) produced longer fruits compared to control (6.0 cm).The fruit length was least in T_9: PLP @ 1 g kg^{-1} (6.2 cm) among the treated seeds.

4.4.6. Fruit girth (cm)

Fruit girth of seeds treated with botanicals (both normal grade and nanopowders) was more compared to control.

In Anugraha, normal grade treatments (Table 44) such as T_4: ALP @ 2 g kg^{-1} (2.7 cm) followed by T_7: FLP @ 2 g kg^{-1} (2.6 cm), T_5: FLP @ 0.5 g kg^{-1} (2.6 cm) and T_6: FLP @ 1 g kg^{-1} (2.5 cm) produced increased fruit girth compared to control (1.9 cm). The least fruit girth was observed in T_{16}: NLP @ 2 g kg^{-1} (2.0 cm) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (2.9 cm), T_6: FLP @ 1 g kg^{-1} (2.8 cm) and T_5: FLP @ 0.5 g kg^{-1} (2.7 cm) produced more fruit girth compared to control (1.9 cm).The least fruit girth was observed in T_{10}: PLP @ 2 g kg^{-1} (2.1 cm) among the treated seeds.

In Ujwala, normal grade treatments (Table 44), such as T_2: ALP @ 0.5 g kg^{-1} (3.2 cm), T_7: FLP @ 2 g kg^{-1} (3.2 cm) and T_{11}: CLP @ 0.5 g kg^{-1} (3.1 cm) followed by T_4: ALP @ 2 g kg^{-1} (3.0 cm) and T_{12}: CLP @ 2 g kg^{-1} (3.0 cm) produced increased fruit girth compared to control (2.2 cm). The least fruit girth was observed in T_{15}: NLP @ 1 g kg^{-1} (2.3 cm) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (3.3 cm) followed by T_{11}: CLP @ 0.5 g kg^{-1} (3.1 cm), T_{12}: CLP @ 1 g kg^{-1} (3.1 cm) and T_6: FLP @ 1 g kg^{-1} (3.0 cm), T_7: FLP @ 2 g kg^{-1} (3.0 cm) produced increased fruit girth compared to control (2.2 cm). The least fruit girth was observed in T_9: PLP @ 1 g kg^{-1} (2.4 cm) among the treated seeds.

4.4.7. Fruit weight per plant (g)

Fruit weight per plant (g) of seeds treated with botanicals (both normal grade and nanopowders) was more compared to control.

In Anugraha, normal grade treatments (Table 44) such as T_4: ALP @ 2 g kg^{-1} (1.50 g), T_7: FLP @ 2 g kg^{-1} (1.48 g) and T_5: FLP @ 0.5 g kg^{-1} (1.42 g) were on par with each other recorded more fruit weight compared to control (1.16 g).The least fruit weight per plant was observed in T_{16}: NLP @ 2 g kg^{-1} (1.19 g) among the treated seeds. In nanopowder treatments (Table 45), T_{11}: CLP @ 0.5 g kg^{-1} (1.57 g), T_4: ALP @ 2 g kg^{-1} (1.54 g), T_6: FLP @ 1 g kg^{-1} (1.54 g) followed by T_5: FLP @ 0.5 g kg^{-1} (1.53 g) and T_7: FLP @ 2 g kg^{-1} (1.53 g) recorded the more fruit weight compared to control (1.16 g). The least fruit weight per plant was observed in T_{10}: PLP @ 2 g kg^{-1} (1.27 g) among the treated seeds.

In Ujwala, normal grade treatments (Table 44) such as T_2: ALP @ 0.5 g kg^{-1} (1.42 g) which were on par with T_7: FLP @ 2 g kg^{-1}(1.37 g), T_{11}: CLP @ 0.5 g kg^{-1} (1.37 g) and T_{10}: PLP @ 2 g kg^{-1} (1.37 g) recorded more fruit weight compared to control (1.12 g). The least fruit weight per plant was observed in T_{15}: NLP @ 1 g kg^{-1} (1.19 g) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (1.47 g) were on par with T_{12}: CLP @ 1 g kg^{-1} (1.46 g) and T_6: FLP @ 1 g kg^{-1} (1.45 g) followed by T_6: FLP @ 1 g kg^{-1} (1.42 g), T_8: PLP @ 0.5 g kg^{-1} (1.42 g) which were on par with T_{11}: CLP @ 0.5 g kg^{-1} (1.39 g) recorded more fruit weight compared to control (1.12 g). The least fruit weight per plant was observed in T_9: PLP @ 1 g kg^{-1} (1.20 g) among the treated seeds.

4.4.8. Fruit yield per plant (g)

Compared to untreated seeds, fruit yield per plant of seeds treated with botanicals was higher. In Anugraha, normal grade treatments (Table 44) such as T_4: ALP @ 2 g kg^{-1} (315 g) were on par with T_7: FLP @ 2 g kg^{-1} (308 g) followed by T_3: ALP @ 1 g kg^{-1} (286 g) and T_{13}: CLP @ 2 g kg^{-1} (281 g) recorded maximum fruit yield per plant compared to control (200 g).The least fruit yield per plant was observed in T_{16}: NLP @ 2 g kg^{-1} (212 g) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_{11}: CLP @ 0.5 g kg^{-1} (372 g), T_6: FLP @ 1 g kg^{-1} (362 g) followed by T_5: FLP @ 0.5 g kg^{-1} (341 g) on par with T_7: FLP @ 2 g kg^{-1} (340 g) recorded maximum fruit yield per plant compared to control (200 g). The least fruit yield per plant was observed in T_{10}: PLP @ 2 g kg^{-1} (231 g) among the treated seeds.

In Ujwala, normal grade treatments (Table 44) seeds treated with T_2: ALP @ 0.5 g kg^{-1} (253 g), T_7: FLP @ 2 g kg^{-1} (238 g), T_{11}: CLP @ 0.5 g kg^{-1} (237 g) followed by T_{13}: CLP @ 2 g kg^{-1} (233 g) and T_{10}: PLP @ 2 g kg^{-1} (233 g) recorded maximum fruit yield per plant. The least fruit yield per plant was observed in T_{15}: NLP @ 1 g kg^{-1} (181 g) among the treated seeds. In nanopowder treatments (Table 45), seeds treated with T_5: FLP @ 0.5 g kg^{-1} (269 g),

T_{12}: CLP @ 1 g kg^{-1} (260 g) and T_7: FLP @ 2 g kg^{-1} (258 g) recorded maximum fruit yield per plant compared to control (165 g). The least fruit yield per plant was observed in T_9: PLP @ 1 g kg^{-1} (186 g) among the treated seeds.

Considering the yield attributes, it was clear that, in both varieties, botanicals such as arappu, custard apple and fenugreek were performing superior compared to neem and pungam, irrespective of the seed treatments and concentration of botanicals.

Discussion

5. DISCUSSION

Good quality seed is the key to successful agriculture and their use is an important factor for increased productivity. Storing of seeds is a serious problem in tropical and subtropical countries where high temperature and relative humidity greatly accelerate seed ageing resulting in loss of vigour and viability (Patil, 2000). Chilli is a high value low volume crop. In Kerala, owing to high temperature and high relative humidity the ageing process of the seed hastens and as a result, the viability of stored seeds reduces.

Seed deterioration is an irreversible process and the physiology of seed deterioration is not well understood (McDonald, 1999). Though, deterioration of seeds cannot be reversed, the rate of deterioration could be managed to certain extent by subjecting them to invigoration treatments (Basu, 1994). The maintenance of seed quality in storage depends upon initial seed quality, storage condition, seed moisture content and susceptibility to fungal attack. In order to preserve the seed quality and maintain high level of germination, seed treatments can be done to enhance the storability of seeds.

Currently, organic farming is gaining momentum in agriculture and in this scenario; seed treatment with botanicals to reduce the oxidative damage and to improve the viability and vigour of seeds assumes greater significance. Thus, standardization of a suitable seed invigoration treatment utilizing botanicals is of prime importance and useful to improve the germinability and field performance of chilli seeds.

Hence, studies were initiated to assess the impact of seed treatment with botanicals and to compare the efficacy of normal grade and nano size particles of botanicals on seedling vigour in chilli seed varieties Anugraha and Ujwala. The results obtained were statistically analyzed and critically discussed in this chapter.

5.1. Effects of botanical powders on seed quality and storability of seeds

Organic based materials have been used in seed treatments to invigorate seeds for a quite long time. In the present study, leaf powders of arappu *(Albizia amara)*, fenugreek *(Trigonella foenum-graecum)*, pungam (*Pongamia glabra)*, custard apple (*Anona squamosa)* and neem *(Azadirachta indica)* were used for invigorating chilli seeds. Plant products are known to contain various antioxidants that would quench free radical attack during seed ageing and a loss in such components would lead to the death of seeds. The antioxidants present in the plant products play a major role in improving the performance of the seeds (Ramya *et al.,* 2011).

5.2. Standardization of botanical seed treatments

Seeds with good physiological potential act as catalyst for all agricultural inputs. Invariably most crops require storage for one or more planting season, during which period the ageing is inevitable (Coolbear, 1995). Deterioration cannot be prevented completely, but can be delayed. Efforts are required to delay the process of deterioration in order to preserve the vigour and viability of seed until its fullest potential is exploited when sown in the field. In this aspect, products of plant origin called botanicals are being effectively used for maintaining the vigour and viability. Botanical seed treatments, a simple eco-friendly technique, would be of great advantage to reduce the problem in maintenance of seed quality as dry dressing of seeds with botanicals would significantly slowed down the seed deterioration and improve seed performance. This has been reported by many researchers like De *et al.*, (2004) in wheat; Rudrapal and Basu (2004) in french bean; Sengupta *et al.*, (2005) in onion; Kundagrami *et al.*, (2008) in rice.

Nanotechnology is an emerging science with vast potential applied in many fields including agriculture. It has several applications in seed technology, of which seed invigoration is one of them. The advantage of using nano sized particles for seed treatment isthat, because of their smaller size they can very well adhere to the seed surfaces especially in small seeds like chilli seeds. Their smaller size helps in easier penetration into the seeds thus enhancing the efficiency of the invigorants used. There are two approaches to produce nano sized particles and in the present study the top down approach was used. The size of the normal grade leaf powders used in the present study was subjected to high energy ball milling for size reduction. In order to confirm whether the leaf powders subjected to ball milling have indeed reached nanosize they were analysed in the particle size analyser. The nanosize expected for seed treatments ranges from 100 nm to 400 nm. In the present experiment, the mean size of synthesized nanopowders such as arappu leaf powder (ALP), fenugreek leaf powder (FLP), pungam leaf powder (PLP), custard apple leaf powder (CLP), and neem leaf powder (NLP) measured using particle size analyzer were 273 nm, 275 nm, 218 nm, 263 nm and 317 nm, respectively. In seed treatment, the nanoparticle size of the powders play a major role because they have greater permeability. The particle size distribution of nanopowders are given in Figures 1-5.

In order to get a more detailed idea regarding the shape and size of the particles used they were examined under Scanning Electron Microscope. The surface morphology of the nanopowders synthesized, before and after ball milling when examined under Scanning Electron Microscope revealed that, they were irregular in shape. After ball milling, the particle size of ALP, FLP, PLP, CLP and NLP got reduced from bulk particle size to nanoparticle size. It can be safely concluded that, ball milling process is sufficient to reduce the particle size to nano level. These nanoparticles forma uniform layer of botanicals over the seed coat and the active ingredients present in the powder may enter through cracks and crevices in the seed coat as suggested by Sengupta *et al.* (2005).

5.3. Influence of seed treatment with normal grade botanicals on seed quality parameters

5.3.1. Germination (%)

Germination is the most important indicator of seed quality and changes in seed germination may occur due to different treatments. In Anugraha, treatments with normal grade powders such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds retained maximum germination (69.58, 67.91 and 66.80, respectively) per cent at the end of twelve months of storage while the germination in control (untreated) was only 36.30 whereas, in Ujwala, treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds retained maximum germination (69.71, 68.84 and 68.37, respectively) per cent at the end of nine months of storage while the germination in control (untreated) was only 32.56. The increase in germination with botanical treatments was in conformity with the findings of Saraswathy (2003) and Albert (2004) in tomato, Vijayan (2005) in rice and Manimekalai (2006) in blackgram. Seed treatments with neem recorded lower germination among the treated seeds. All treatments were effective up to twelve months in Anugraha (Fig 6) and nine months in Ujwala (Fig 7).

Botanicals act as a catalyst for production of reactive oxygen species (ROS) in a slow and sustained manner for maintenance of seed viability. Botanical seed invigoration increases conversion of reserve nutritional material into mobile compounds and also invigorates the seeds by altering their physiological and biochemical nature resulting in better emergence of seedlings in blackgram (Manimekalai, 2006).

Lu *et al.* (1983) reported that the leaf powder of plants like arappu contains saponin like substance which acts as precursor of GA_3 under seed invigoration at low concentration

Fig 6: Effect of normal grade botanicals on retaining viability in Anugraha

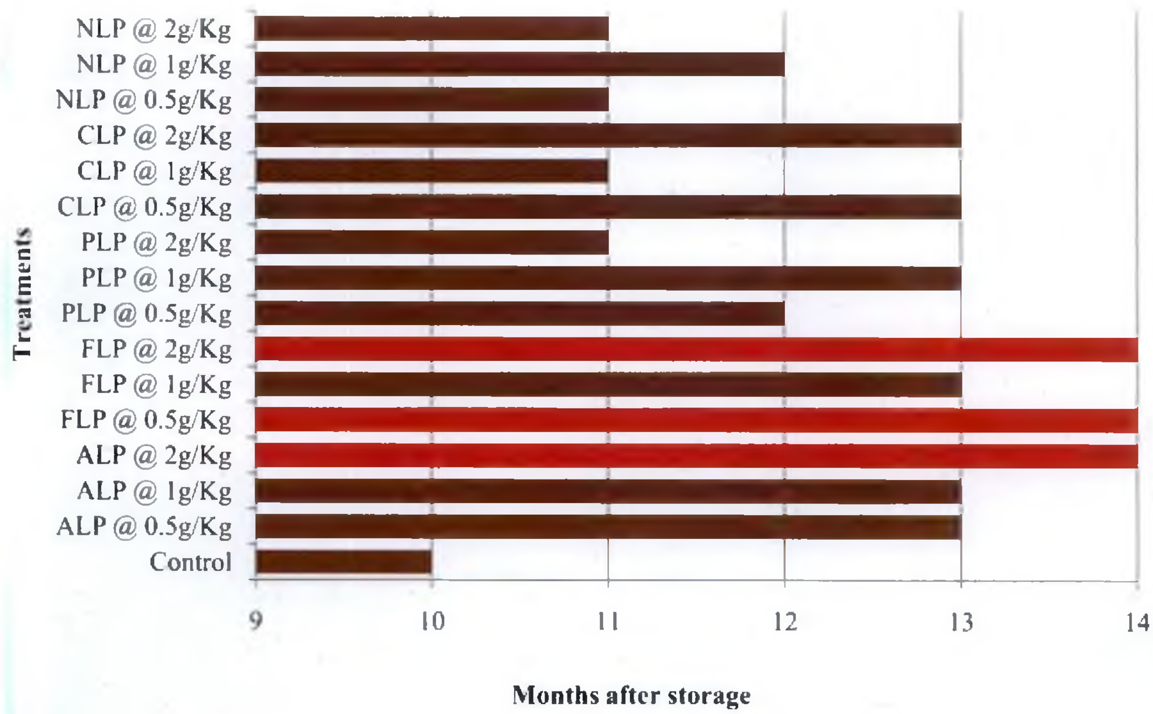
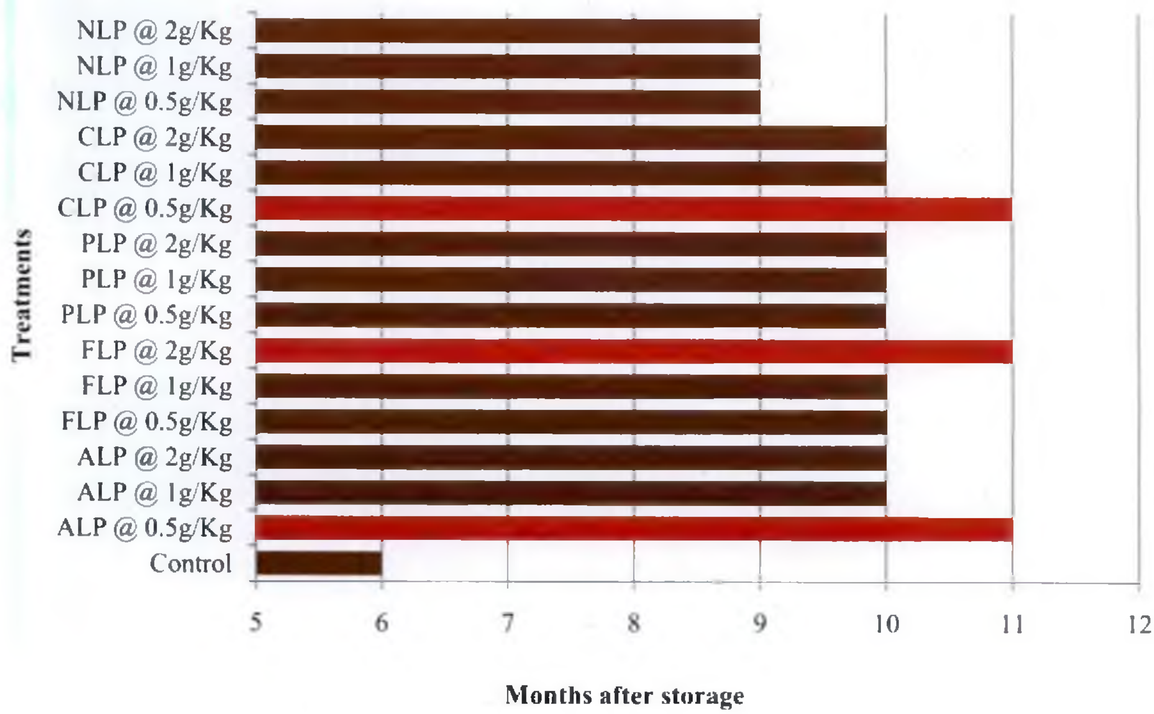


Fig 7: Effect of normal grade botanicals on retaining viability in Ujwala



and improve the performance of seed. The leaf powders of custard apple and fenugreek contains antioxidants that includes vitamins, minerals, carotenoids and polyphenols. These protect the seeds from harmful effect of free radicals and intend to terminate chain reactions by removing free radical intermediates and inhibit other oxidation reactions by being oxidized themselves (Butkhup and Samappito, 2011) and increased the performance of seeds.

Among the five botanicals used arappu leaf powder followed by fenugreek leaf powder at varying concentrations showed significantly superior results.

5.3.2. Seedling length (cm)

The seedling length would predict their subsequent growth and performance. In Anugraha, normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had longest shoot length (5.91 cm, 5.86 cm and 5.84 cm, respectively) compared to control (4.23 cm) at the end of twelve months of storage whereas, in Ujwala, treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds had longest shoot length (5.88 cm, 5.71 cm and 5.69 cm, respectively) compared to control (4.37 cm) at the end of nine months of storage as reported in sorghum by Devarani and Rangaswamy (1998).

Normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had longest root length (7.89 cm, 7.80 cm and 7.66 cm, respectively) compared to control (5.33 cm) at the end of twelve months of storage in Anugraha and treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds had longest root length (7.47 cm, 7.46 cm and 7.38 cm, respectively) compared to control (5.28 cm) at the end of nine months of storage in Ujwala. Similar results were reported in sorghum by Devarani and Rangaswamy (1998).

5.3.3. Seedling dry weight (mg)

The seedling dry weight is physiological manifestation of seed vigour largely influenced by the affluence of metabolites, growth regulating substances and enzyme activity (Heydecker, 1972).

In Anugraha, the normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds produced maximum dry weight (20.49 mg, 20.38 mg and 19.74 mg, respectively) compared to control (12.80 mg) at the end of twelve months of storage whereas, in Ujwala, treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds produced maximum dry weight (17.43 mg, 17.27 mg and 15.67 mg, respectively) compared to control (11.66 mg) at the end of nine months of storage. Similar results were reported by Layek *et al.* (2006) in gram. The decline in weight of seedlings might be due to hydrolysis of reserve metabolites, activation of endogenous enzymes and break down of food reserves over the period of storage as reported by Paramasivam (2005) in groundnut and Nisha (2006) in wheat.

5.3.4. Vigour Indices

The physiological performance of seeds depend on seedling length that ultimately is vigour. A decline in the seedling characters with advancement in storage period was reported by Vyakarnahal *et al.* (2007) and Baura *et al.* (2009) in chilli. Effect of botanical seed treatments led to an increase in seedling length and vigour index of treated seeds compared to control.

In Anugraha, the normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had higher vigour index I and vigour index II (961 and 1419, 917 and 1391, 914 and 1320, respectively) compared to control (349 and 466, respectively) at the end of twelve months of storage whereas, in Ujwala, treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds had higher vigour index I and vigour index II (863 and 1093, 849 and 1075, 830 and 997, respectively) compared to control (315 and 380, respectively) at the end of nine months of storage. The results were in conformity with Jegathambal (1996) in sorghum, Kavitha (2002) in blackgram and Suma (2005) in gingelly.

The physiologically active substances present in the botanical leaves might have activated the embryo and other associated structures which resulted in the absorption of more water due to the elasticity of cell wall and led to increased vigour index in sorghum as reported by Devarani and Rangaswamy, (1998). It is presumed that botanicals contain micronutrients, vitamins, antioxidants, polyphenols, and flavonoids which are conducive for improving seed vigour (Manimekalai, 2006 in black gram).

Among the five botanicals used arappu leaf powder followed by fenugreek leaf powder at varying concentrations showed significantly superior results in germination (%), seedling length (cm), seedling dry weight (mg) and seedling vigour.

5.3.5. Electrical conductivity (dSm^{-1})

Electrical conductivity of the seed leachate, a measure of membrane integrity is considered as a good index for seed viability (Mathews and Bradnock, 1968). Normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds produced minimum electrical conductivity (0.834 dSm^{-1}, 0.880 dSm^{-1} and 1.040 dSm^{-1}, respectively) compared to control (1.795 dSm^{-1}) at the end of twelve months of storage in Anugraha and treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} produced minimum electrical conductivity (0.149 dSm^{-1}, 0.197 dSm^{-1} and 0.220 dSm^{-1}, respectively) compared to control (0.423 dSm^{-1}) at the end of nine months of storage in Ujwala. The results were in conformity with the findings of Kavitha (2002) in black gram and Sundaralingam (2005) in rice.

Minimum value of electrical conductivity in the invigorated seeds are presumed to be due to quenching of free radicals which consequentially maintains the membrane integrity (Kavitha, 2002). The beneficial effect of fenugreek leaf powder and could be attributed to the presence of poly phenolics and flavonoids namely vitexin, tricin, naringenin and quercetin which act as a hydrogen donor and the OH^- scavenger (Kaviarasan *et al.*, 2007).

5.3.6. Dehydrogenase activity (OD)

Seeds treated with botanical powders expressed slight decrease in dehydrogenase activity over the period of storage. The activity of this enzyme was higher in the treated seeds than untreated seeds.

In Anugraha, the normal grade powder treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5g kg^{-1} of seeds produced maximum dehydrogenase activity (0.068, 0.059 and 0.058, respectively) compared to control (0.020) at the end of twelve months of storage whereas, in Ujwala, treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} of seeds produced maximum dehydrogenase activity (0.092, 0.086 and 0.078, respectively) compared to control (0.038) at the end of nine months of storage. Similar results have been reported in blackgram (Kavitha, 2002) and soybean (Anuja and Aneja, 2004).

The beneficial effect of custard apple and fenugreek leaf powder might be due to the presence of antioxidants (Neha Pandey and Dushyant Barve, 2011) and phenols and flavonoids (Annegowda *et al.*, 2010). Physiological deterioration of seed vigour might be the outcome of deterioration in the enzyme activity and seed composition (Begam, 2001).

Irrespective of the concentration of botanicals, arappu leaf powder followed by fenugreek leaf powder were very effective in maintaining membrane integrity as well as lipid peroxidation as evidenced by minimum values of electrical conductivity and higher dehydrogenase activity.

5.3.7. Seed microflora (%)

Maintenance of seed quality during storage is very much essential. Though the initial seed quality and storage environment are important to prolong the shelf life of seeds, invasion of fungal pathogen also play a major role in decreasing the viability of seed lot. Hence, pathogens play a major role in determining the storage life of seed with their shorter life span.

In cultivars of soybean, loss in seedling vigour was observed due to the seed infection (Krishnamurthy and Raveesha, 1996). Similarly Paul and Mishra (1994) in maize, Saxena and Karan (1991) in sesame and sunflower seeds and Kavitha (2007) in chilli reported that, seed infection increased with reduction in seed quality over the storage period.

In both the varieties, seed infection per cent was high in untreated seeds compared to treated seeds. Untreated seeds recorded a high seed infection per cent (36.67) in Anugraha and (40.00) in Ujwala. Normal grade powder treatments in Anugraha revealed that, seed infection in ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 0.5 g kg^{-1} by blotter and agar method ranged between 13 to 17 and 16 to 20 per cent, (Fig 10) respectively whereas, in Ujwala, seed infection in ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1}, CLP @ 0.5 g kg^{-1} and ALP @ 2 g kg^{-1} ranged between 13 to 20 per cent and 16 to 20 per cent, (Fig 11) respectively. The storage fungi (Plate 4) observed were *Aspergillus* sp, *Pencillium* sp and *Alternaria* sp as reported by Wakil (2014) in sunflower.

In general, botanicals such as arappu leaf powder and fenugreek leaf powder recorded least seed infection per cent.

5.4. Influence of seed treatment with nano size botanicals on seed quality parameters

5.4.1. Germination (%)

The germination potential is the basic requirement for any seed. In Anugraha, treatments with normal grade powders such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds retained maximum germination (72.10, 70.08 and 68.84, respectively) per cent at the end of twelve months of storage while the germination in control (untreated) was only 36.30 whereas, in Ujwala, treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds retained maximum germination (64.56, 64.49 and 63.80, respectively) per cent at the end of nine months of storage while the germination in control (untreated) was only 32.56. Similar results were reported by Sasikala (1997) in cowpea and bhendi, Somasundaram (2003) and Sundaralingam (2005) in rice. Seed treatments with neem

Fig 10: Effect of normal grade botanicals on seed infection (%) in Anugraha

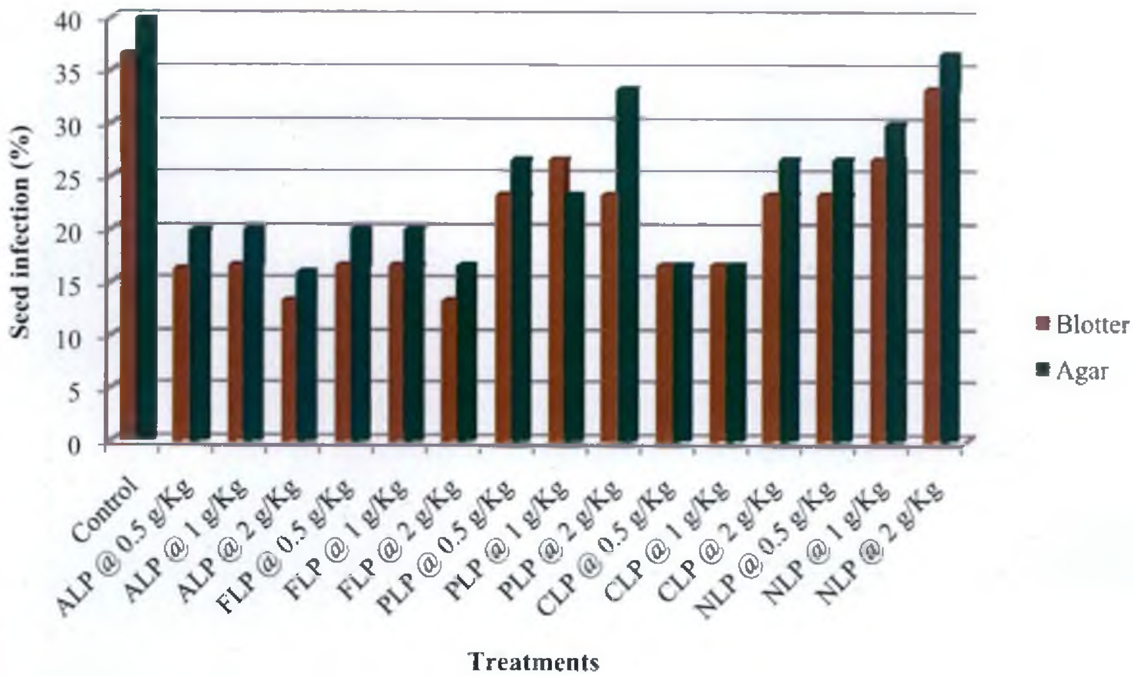
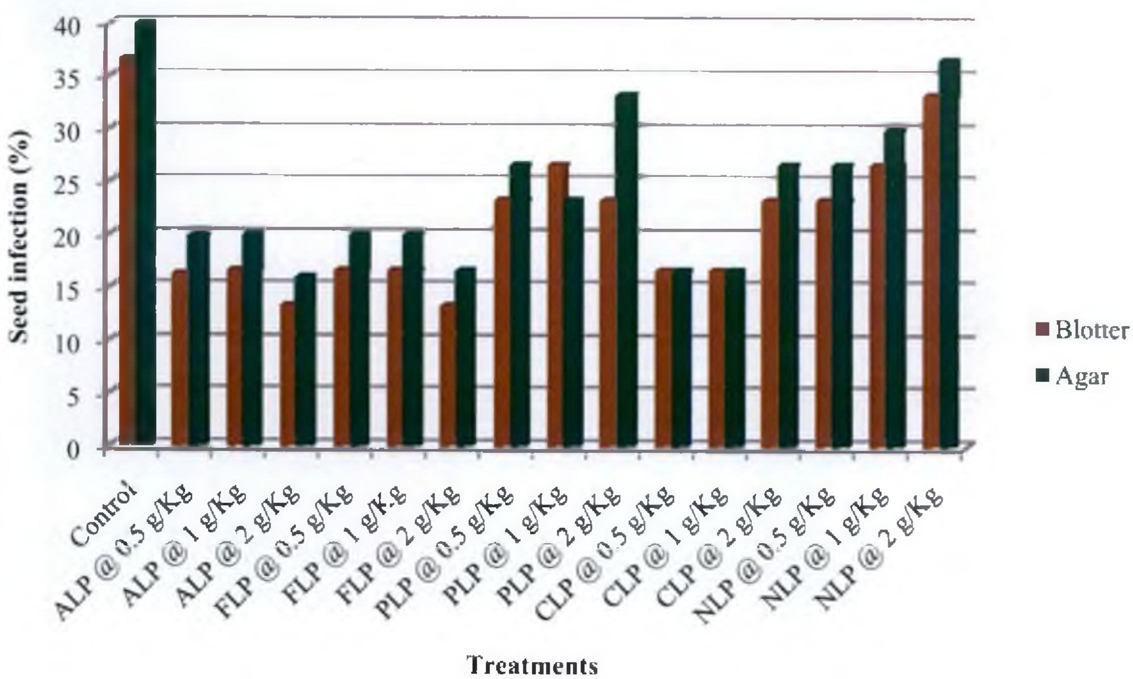


Fig 11: Effect of normal grade botanicals on seed infection (%) in Ujwala



recorded lower germination among the treated seeds. All treatments were effective up to twelve months in Anugraha (Fig 12) and nine months in Ujwala (Fig 13).

According to Baskar *et al.* (2007); Bukhari *et al.* (2008); Toppo *et al.* (2009) the reason might be that, leaves of CLP and FLP possess appreciable level of antioxidant content. Presence of thiamine, vitamin A, vitamin C and antioxidant activity of phenolic compound mainly in leaf powder of custard apple and fenugreek have played an important role as free radical scavengers, reducing agents, quenchers of singlet oxygen and complexes of metals and resulted in the improvement of germination over untreated seeds (Butkhup and Samappito, 2011).

Compared to normal grade powders, the improvement in germination per cent of seeds treated with nanopowders was high as in onion (Mythili, 2012), tomato (Vijiyalakshmi, 2012) and soybean (Hridya, 2013). The reason states that, the surface application of dry powders of normal grade on the outer surface of seed may facilitate a slow penetration of soluble materials through cracks and crevices during imbibition, whereas, nanopowders facilitate a faster penetration through cracks and crevices of seeds. That fast penetration of nanopowders might be due to activation of cells resulting in enhanced of mitochondrial activity leading to the formation of more energy compounds and vital biomolecules which are made available during the early phase of germination as reported by Renugadevi and Vijayageetha (2007) in cluster bean.

Among the five nano sized botanicals used custard apple leaf powder followed by fenugreek leaf powder at varying concentrations showed significantly superior results.

5.4.2. Seedling length (cm)

Root and shoot length of the seedlings is the manifestation of the physiological efficiency of seeds, which depends upon on the seed vigour (Heydecker, 1972).

In Anugraha, nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had longest shoot length (6.68 cm, 6.33 cm and 6.19 cm, respectively) compared to control (4.23 cm) at the end of twelve months of storage whereas, in Ujwala, treatments such as FLP @ 0.5 g kg^{-1} , CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds had longest shoot length (5.98 cm, 5.87 cm and 5.84 cm, respectively) compared to control (4.37 cm) at the end of nine months of storage. Similar results were reported by Somasundaram (2003) and Sundaralingam (2005) in rice.

Fig 12: Effect of nano size botanicals on retaining viability in Anugraha

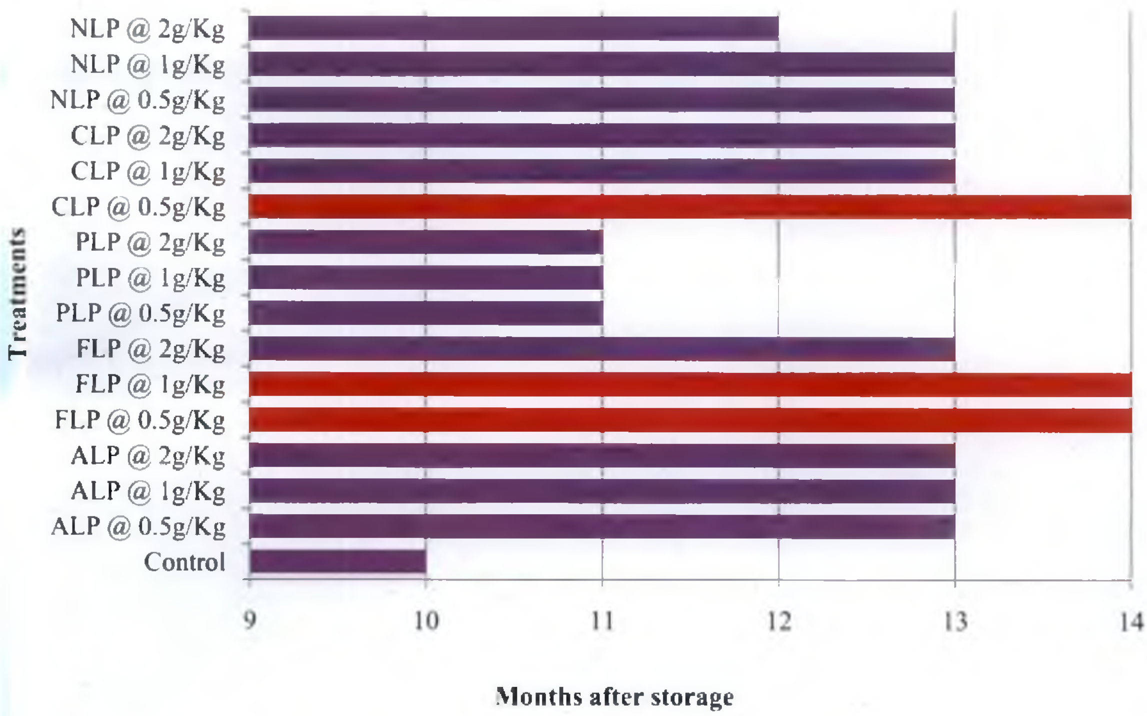
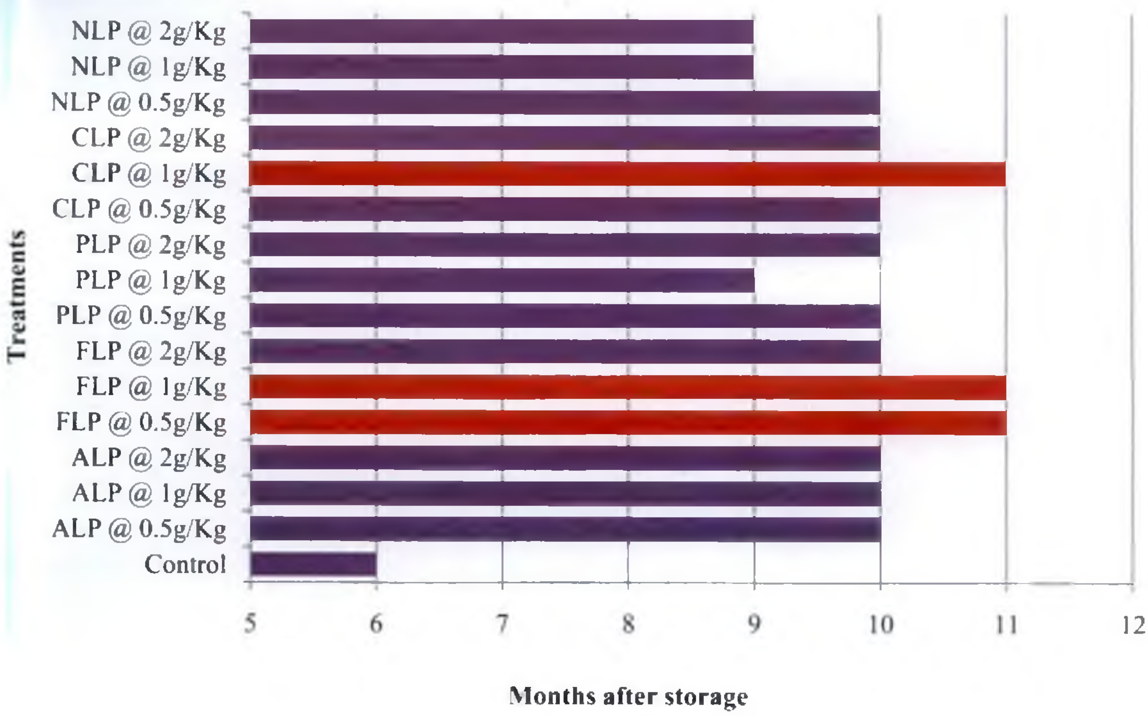


Fig 13: Effect of nano size botanicals on retaining viability in Ujwala



Nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had longest root length (8.19 cm, 7.93 cm and 7.77 cm, respectively) compared to control (5.33 cm) at the end of twelve months of storage in Anugraha and treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds had longest root length (7.57 cm, 7.53 cm and 7.51 cm, respectively) compared to control (5.28 cm) at the end of nine months of storage in Ujwala. Similar results were reported by Somasundaram (2003) and Sundaralingam (2005) in rice.

5.4.3. Seedling dry weight (mg)

The dry weight of the seedlings is the manifestation of physical and physiological vigour (Heydecker, 1973).

In Anugraha, nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds produced maximum dry weight (20.83 mg, 20.79 mg and 19.80 mg, respectively) compared to control (12.80 mg) at the end of twelve months of storage whereas, in Ujwala, treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds produced maximum dry weight (17.38 mg, 17.24 mg and 17.22 mg, respectively) compared to control (11.66 mg) at the end of nine months of storage. Similar results were reported by Somasundaram (2003) and Sundaralingam (2005) in rice, Baura *et al.* (2009) in chilli.

5.4.4. Vigour Indices

Seedling growth in terms of root and shoot has been regarded as a good index to measure the vigour of seeds (Abdul-Baki and Anderson, 1973). Seed vigour decreases with increase in storage period as reported in Vyakarnahal *et al.* (2007) and Baura *et al.* (2009) in chilli.

In Anugraha, nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds had higher vigour index I and vigour index II (1072 and 1503, 1011 and 1473, 964 and 1358 respectively) compared to control (349 and 466, respectively) at the end of twelve months of storage whereas, in Ujwala, treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds had higher vigour index I and vigour index II (862 and 1125, 853 and 1107, 852 and 1082, respectively) compared to control (315 and 380 respectively) at the end of nine months of storage.

The reason might be that, custard apple leaf powder contains alkaloids of aporphine, corydine (Bhakuni *et al.*, 1972), roemerine (Morita *et al.*, 2000) and fenugreek leaf powder contains phenols and flavonoids (Annegowda *et al.*, 2010), polyphenolic content, antioxidant and antibacterial activity (Ramya *et al.*, 2011) which might have enhanced the metabolic activity of the seeds during germination and ultimately the vigour.

Considering the particle size, impact of nanopowder in improving the vigour index was higher compared to normal grade powders (Fig 18 and 19) which have been confirmed with the earlier reports of Rudrapal and Basu (2004) in french bean; Mythili (2012) in onion and Vijayalakshmi (2012) in tomato. Antioxidants are the substances when present in low concentration, effectively protects the cell membrane against the oxidative damage induced by oxidants (Rajagopal, 2001). The secondary metabolites of plants are the potential source of natural antioxidants (Walton and Brown, 1999) which slowed down the deterioration of seeds and resulted in increased seedling growth.

Among the five botanicals used custard apple leaf powder followed by fenugreek leaf powder at varying concentrations showed significantly superior results in germination (%), seedling length (cm), seedling dry weight (mg) and seedling vigour.

5.4.5. Electrical conductivity (dSm^{-1})

Botanical leaf powders also expressed pronounced effect on electrical conductivity. In general, electrical conductivity of seed leachate was lesser in the treated seeds compared to control.

Nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds produced minimum electrical conductivity (0.864 dSm^{-1}, 0.897 dSm^{-1} and 1.044 dSm^{-1}, respectively) compared to control (1.795 dSm^{-1}) at the end of twelve months of storage in Anugraha and treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds produced minimum electrical conductivity (0.747 dSm^{-1}, 0.780 dSm^{-1} and 0.844 dSm^{-1}, respectively) compared to control (1.138 dSm^{-1}) at the end of nine months of storage in Ujwala. The results are in conformity with the findings of earlier reports (Pandey and Brave, 2011; Bose *et al.*, 2011 and Toppo *et al.*, 2009). However, cells are encoded with detoxifying enzymes and antioxidant compounds that could scavenge free radicals (Bernal-Lugo *et al.*, 2000; Shelar, 2007). This is the reflection of seed deterioration due to impairment of membrane as suggested by Villiers (1973).

Considering the particle size, it was seen that, electrical conductivity of seed leachate in seeds treated with nanopowder was minimum compared to normal grade powders. The present study clearly establishes that deterioration in the membrane system of the seeds can

Fig 18: Impact of normal grade and nanopowder botanicals on seed quality parameters in Anugraha

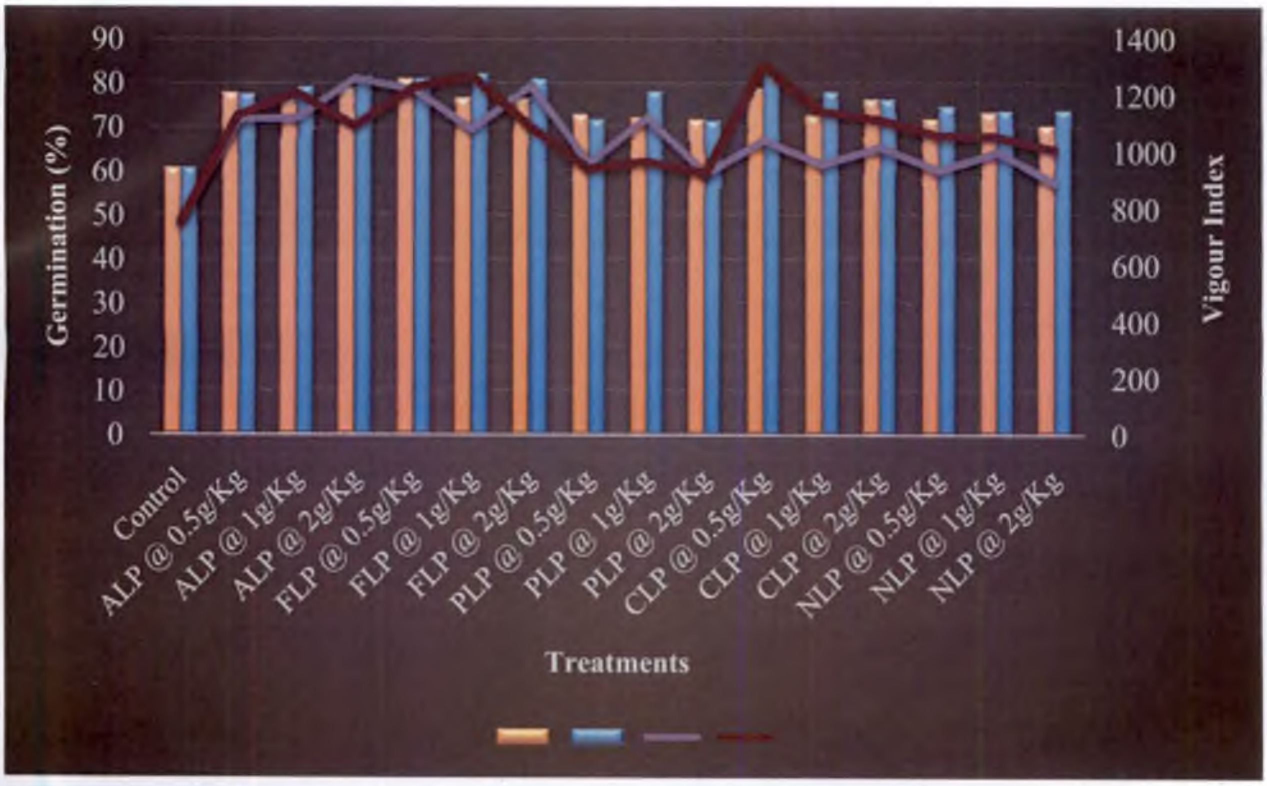
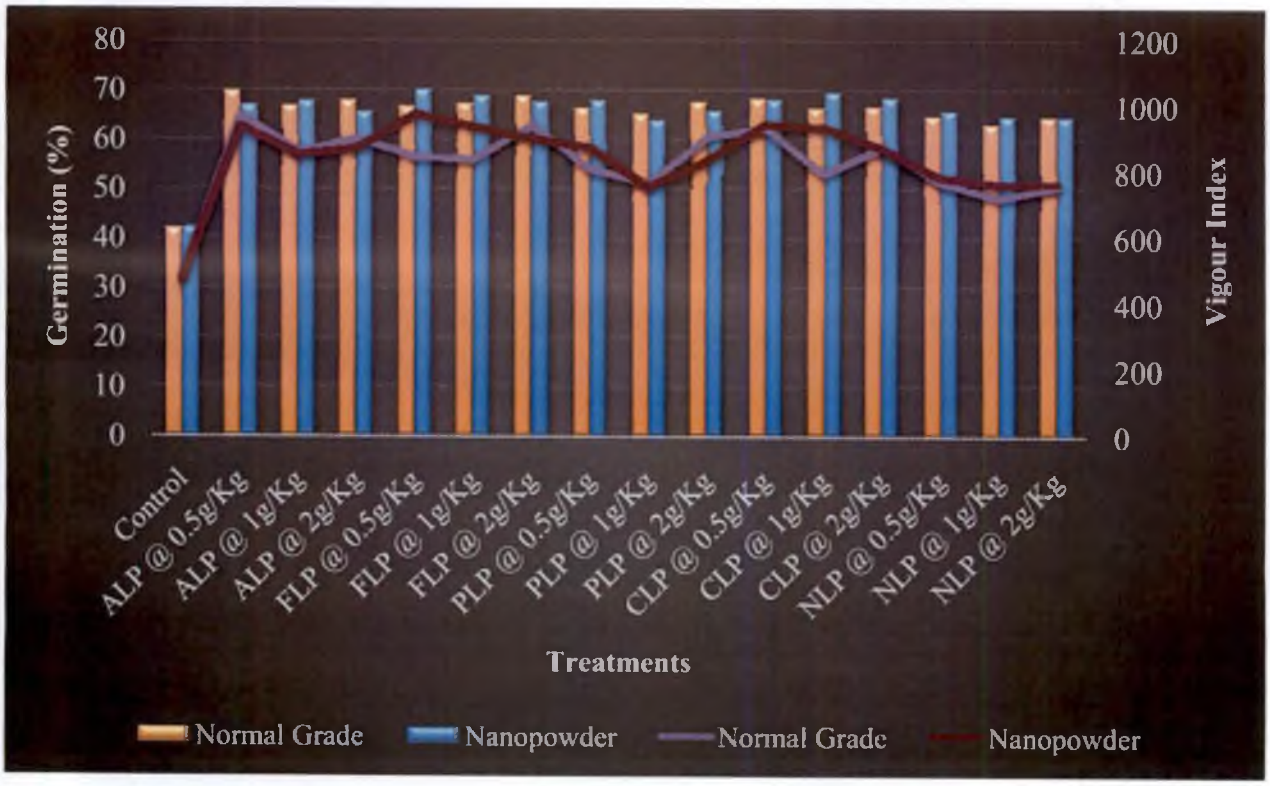


Fig 19: Impact of normal grade and nanopowder botanicals on seed quality parameters in Ujwala



be reduced by nanopowder treatments. The nanopowders such as custard apple and fenugreek had the lowest scavenging activities of 58 per cent and 56 per cent respectively (Mythili, 2012).

5.4.6. Dehydrogenase activity (OD)

In general, decline in the activity of enzymes was evident with advances in seed storage period due to basic changes that the enzyme undergo within themselves which lowered both the energy and food supply to the germinating seed causing reduction in germination with advances in storage. It was clear that, dehydrogenase activity in seeds treated with nanopowder was higher compared to normal grade powders.

In Anugraha, nanopowder treatments such as CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} of seeds produced maximum dehydrogenase activity (0.080, 0.067 and 1.059, respectively) compared to control (0.020) at the end of twelve months of storage whereas, in Ujwala, treatments such as FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1} and FLP @ 1 g kg^{-1} of seeds produced maximum dehydrogenase activity (0.107, 0.091and 0.083, respectively) compared to control (0.038) at the end of nine months of storage. Similar results were reported in groundnut (Krishnashyla, 2014) and soybean (Hridya, 2013). Pallavi *et al.* (2003) observed that the absorbance of dehydrogenase enzyme decreases as the period of storage increased in sunflower. Verma *et al.* (2003) observed that, the dehydrogenase activity reduced as the ageing progressed and found to be the lowest after four years of storage in *Brassica* sp.

Irrespective of the concentration of botanicals, custard apple leaf powder followed by fenugreek leaf powder were very effective in maintaining membrane integrity as well as lipid peroxidation as evidenced by minimum values of electrical conductivity and higher dehydrogenase activity.

5.4.7. Seed microflora (%)

Healthy seeds are a basic requirement for the successful cultivation of any crop. Seeds are known to carry a wide range of microorganisms on the surface as well as inside the seed which become active at the advent of favorable conditions. These cause considerable damage and may be the reason for deterioration and reduction in storage potential of the seed. Seed treatments with botanicals reduce the qualitative and quantitative losses besides maintaining the quality of seed for longer period.

Loss in seedling vigour was observed due to the seed infection in cultivars of soybean (Krishnamurthy and Raveesha, 1996). Similarly Paul and Mishra (1994) in maize, Saxena and Karan (1991) in sesame and sunflower seeds and Kavitha (2007) in chilli reported that, seed infection increased with reduction in seed quality over the storage period.

In both the varieties, seed infection per cent was high in untreated seeds compared to treated seeds. Untreated seeds recorded a high seed infection per cent in Anugraha (36.67) and Ujwala (40.00).

Nanopowder treatments (Fig 16) in Anugraha revealed that, seed infection in CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1}, FLP @ 0.5 g kg^{-1} and ALP @ 1 g kg^{-1} by blotter and agar method ranged between 10 to 17 and 13 to 20 per cent, respectively whereas, in Ujwala, seed infection in FLP @ 0.5 g kg^{-1}, CLP @ 0.5 g kg^{-1}, CLP @ 1 g kg^{-1} and FLP @ 1 g kg^{-1} ranged between 10 to 17 and 13 to 20 per cent, (Fig 17) respectively. The storage fungi (Plate 4) observed were *Aspergillus* sp, *Pencillium* sp and *Alternaria* sp as reported by Wakil (2014) in sunflower.

In general, botanicals such as custard apple leaf powder and fenugreek leaf powder recorded least seed infection per cent.

5.5. Impact of botanical seed treatments on field performance

Keeping in view of the advantages realized in storage experiments by botanicals on maintenance of vigour and viability, studies were carried out to evaluate the field performance of seeds. Good quality seed with rapid and uniform field emergence is an essential prerequisite for increased yield, quality and ultimately profit to the farmers. Uniformity and percentage seedling emergence of direct seeded crops have a major impact on final yield and quality. Slow emergence results in weaker seedlings, which are prone to diseases (Osburn and Schroth, 1989). Various pre-sowing or prestorage seed treatments have been practiced to reduce the time between sowing and seedling emergence. Seed invigoration has become a common seed treatment method to increase the rate and uniformity of seedling emergence.

In the present study, the positive effects witnessed on physiological parameters of treated seeds, had an impact on productivity, as observed through an increase in number of fruits, fruit weight per plant and fruit yield per plant in treated and untreated seeds as reported by Kausar *et al.* (2009) in sunflower.

Fig 16: Effect of nano size botanicals on seed infection (%) in Anugraha

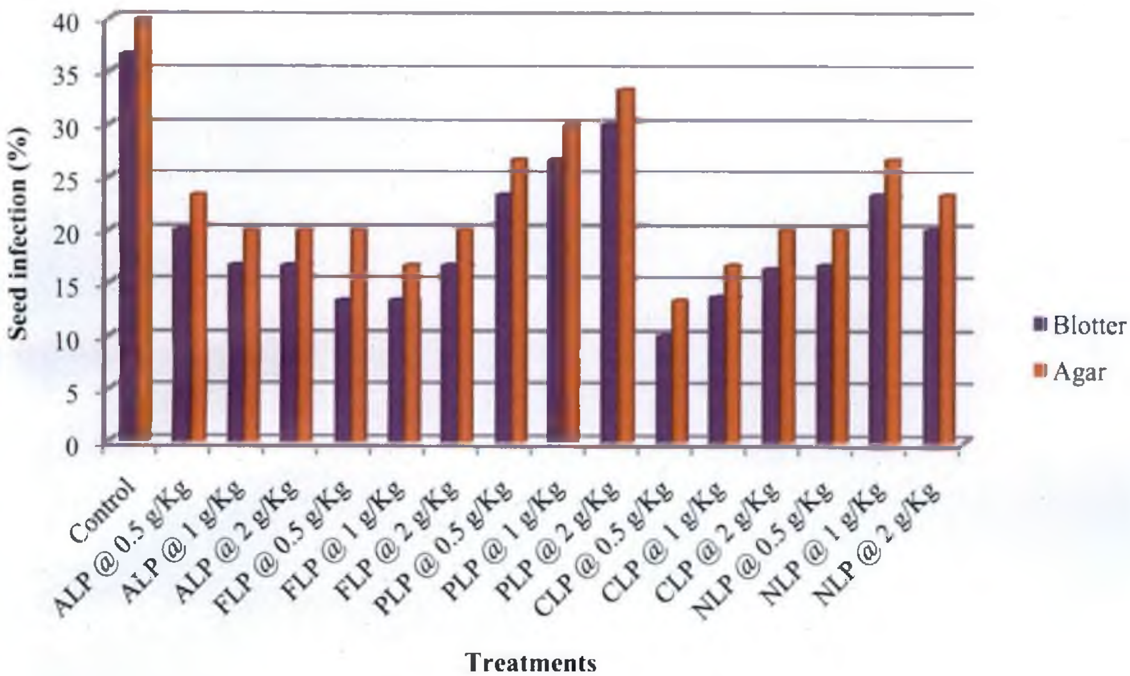
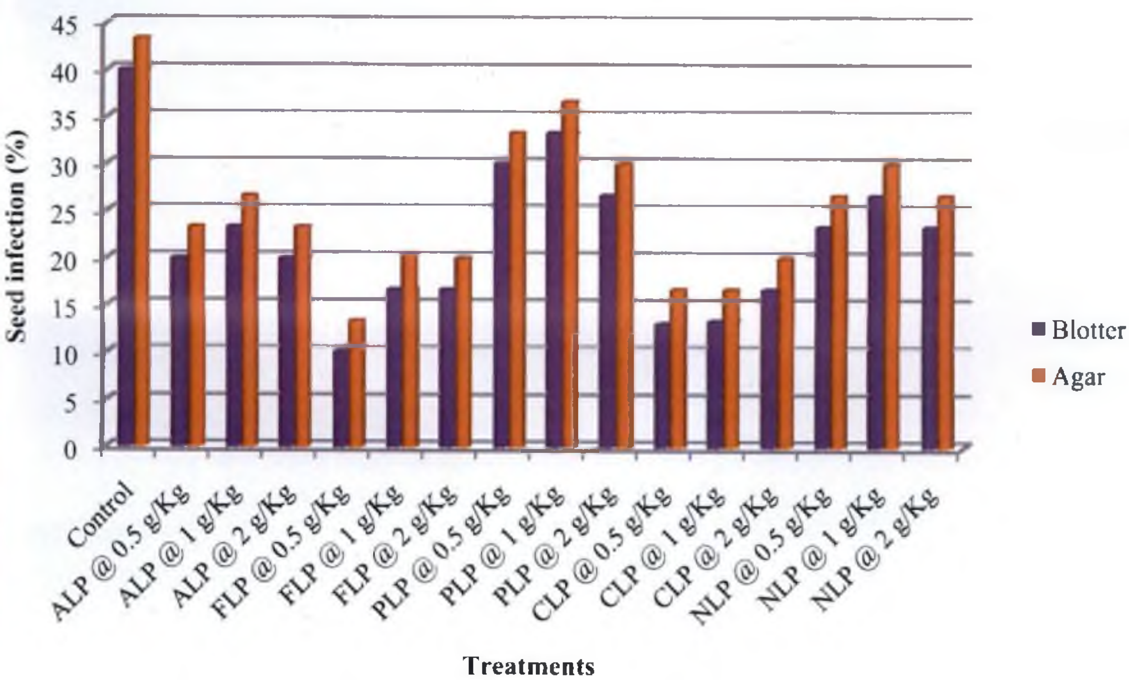


Fig 17: Effect of nano size botanicals on seed infection (%) in Ujwala



5.5.1. Plant height (cm)

Seed treatments with botanicals (both normal grade and nanopowders) were found to have a favorable effect on plant height. In Anugraha, among the treatments with normal grade powders treatments ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1}, and FLP @ 0.5 g kg^{-1} were superior in recording a plant height 82.0 cm, 81.1 cm and 80.0 cm respectively whereas in nanopowder treatments, seeds treated with CLP @ 0.5 g kg^{-1} (86.0 cm), FLP @ 1 g kg^{-1} (83.6 cm) and FLP @ 0.5 g kg^{-1} (81.4 cm) were superior by producing taller plants compared to control (68.0 cm). In Ujwala, normal grade treatments such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g $kg^{-1}$and CLP @ 0.5 g kg^{-1} was superior in recording a plant height of 80.9 cm, 80.1 cm and 80.0 cm, respectively whereas in nanopowder treatments, FLP @ 0.5 g kg^{-1} (81.8 cm), CLP @ 1 g kg^{-1} (81.1 cm) and FLP @ 1 g kg^{-1} (80.5 cm) were superior by producing taller plants compared to control (70.0 cm).

Considering the height of plants, it was observed that, nanopowder treatments had slightly increased plant height compared to normal grade powder treatments. Plant height of treated seeds was high than control. Among the botanicals, custard apple followed by fenugreek and arappu flowered earlier than the control irrespective of the seed treatments and concentrations. Similar results were reported in blackgram (Sathish, 2013), tomato (Vijiyalakshmi, 2012).

5.5.2. Days to 50% flowering (days)

Significant differences were observed among the seed treatments on days to flowering (50%). In Anugraha, the effect of normal grade and nanopowder treatments revealed significant difference in flowering compared to control. The normal grade treatments, such as ALP @ 2 g kg^{-1} and FLP @ 2 g kg^{-1} produced the flowers (82 days) whereas nanopowder treatments such as CLP @ 0.5 g kg^{-1} and FLP @ 1g kg^{-1} produced flowers earlier (79 days) while there was a delay in the control (87 days).

In Ujwala, the effect of normal grade and nanopowder treatments revealed significant difference in flowering compared to control. Normal grade treatments, such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1} and CLP @ 0.5 g kg^{-1} produced flowers (80, 81 and 82 days, respectively) whereas in nanopowder treatments, effect of seed treatments revealed significant difference in flowering earlier than control. Among the treatments, seed treated with FLP @ 0.5 g kg^{-1}, CLP @ 1 g kg^{-1} and FLP @ 1 g kg^{-1} produced the flowers earlier (78, 79 and 81 days, respectively) while there was a delay in the control (88 days).

Considering the days to flowering, the overall mean of normal grade treatments showed flowering (84 days) and nanopowder treatments showed earlier flowering (82 and 83 days) compared to control (87 and 88 days) in Anugraha and Ujwala respectively. It was observed that, nanopowder treatments flowered earlier than the normal grade powder treatments. Among the botanicals, custard apple followed by fenugreek and arappu flowered earlier than the control irrespective of the seed treatments and concentrations. Similar results were reported in blackgram (Sathish, 2013), tomato (Vijiyalakshmi, 2012).

5.5.3. Fruit length and girth (cm)

In Anugraha, normal grade powder treatments, ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} produced longer fruits and increased fruit girth (7.2 cm ; 2.7 cm, 7.0 cm ; 2.6 cm and 7.0 cm ; 2.6 cm, respectively) whereas in nanopowder treatments, CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} produced longer fruits and increased fruit girth (7.4 cm ; 2.9 cm, 7.2 cm ; 2.9 cm and 7.1 cm ; 2.8 cm, respectively) compared to control (6.1 cm ; 1.9 cm, respectively).

In Ujwala, the normal grade powder treatments, such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1} and CLP @ 0.5 g kg^{-1} produced longer fruits, increased fruit girth (7.2 cm ; 3.2 cm, 7.1cm ; 3.2 cm and 7.0 cm ; 3.1 cm, respectively) whereas in nanopowder treatments, seeds treated with FLP @ 0.5 g kg^{-1}, CLP @ 1 g kg^{-1} and FLP @ 1 g kg^{-1} produced longer fruits, increased fruit girth (7.3 cm; 3.3 cm, 7.2 cm; 3.1 cm and 7.1 cm; 3.0 cm, respectively) compared to control (6.0 cm ; 2.2 cm, respectively).

Fruit length and girth of treated seeds was more compared to control. Comparing the seed treatments with botanicals (both normal grade and nanopowders), a slight increase in fruit girth and fruit length of nanopowders was observed in both the varieties.

5.5.4. Number of fruits and fruit weight per plant (g)

In Anugraha, the normal grade powders treatments such as ALP @ 2 g kg^{-1}, FLP @ 2 g kg^{-1} and FLP @ 0.5 g kg^{-1} produced more number of fruits and increased fruit weight (210 ; 1.50 g, 208 ; 1.48 g and 202 ; 1.42 g, respectively) whereas in the case of nanopowders, seeds treated with CLP @ 0.5 g kg^{-1}, FLP @ 1 g kg^{-1} and FLP @ 0.5 g kg^{-1} produced more number of fruits and increased fruit weight (237 ; 1.57 g, 235 ; 1.53 g and 223 ; 1.53 g, respectively) compared to control (165 ; 1.16 g, respectively).

In Ujwala, seeds treated with normal grade powders such as ALP @ 0.5 g kg^{-1}, FLP @ 2 g kg^{-1} and CLP @ 0.5 g kg^{-1} produced more number of fruits and increased fruit weight

(178 ; 1.42 g, 174 ; 1.37 g and 173 ; 1.37 g, respectively) whereas in nanopowder treatments, seeds treated with FLP @ 0.5 g kg^{-1}, CLP @ 1 g kg^{-1} and FLP @ 1 g kg^{-1} produced more number of fruits and fruit weight (184 ; 1.47 g, 183 ; 1.46 g and 183 ; 1.45 g, respectively) compared to control (147 ; 1.12 g, respectively).

Maximum number of fruits and their weight were recorded in treated seeds than untreated seeds. Comparing the seed treatments with botanicals (both normal grade and nanopowders), a slight increase in number of fruits and their weight of nanopowders was observed in both the varieties. Similar results were reported in tomato (Vijiyalakshmi, 2012) and rice (Vijayan, 2005).

5.5.5. Fruit yield per plant (g)

Fruit yield per plant was higher in treated seeds compared to control. In Anugraha, normal grade treatments (Fig 20) such as ALP @ 2 g kg^{-1} (315 g), FLP @ 2 g kg^{-1} (309 g) and FLP @ 0.5 g kg^{-1} (295 g) recorded maximum fruit yield per plant whereas in nanopowder treatments (Fig 21), such as CLP @ 0.5 g kg^{-1} (372 g), FLP @ 1 g kg^{-1} (362 g) and FLP @ 0.5 g kg^{-1} (341 g) recorded maximum fruit yield per plant compared to control (191 g). The pronounced yield increase imposed by botanical treatments are in conformity with the reports of Albert (2004) in tomato, Sundaralingam (2005), Vijayan (2005) in rice, Manimekalai (2006) in blackgram and Vijayalakshmi (2012) in tomato.

In Ujwala, normal grade treatments (Fig 20) such as ALP @ 0.5 g kg^{-1} (253 g), FLP @ 2 g kg^{-1} (240 g) and CLP @ 0.5 g kg^{-1} (237 g) recorded maximum fruit yield per plant whereas in nanopowder treatments (Fig 21), seeds treated with FLP @ 0.5 g kg^{-1} (270 g), CLP @ 1 g kg^{-1} (267 g) and FLP @ 1 g kg^{-1} (258 g) recorded maximum fruit yield per plant compared to control (165 g). The positive effect of botanical seed treatments for improved yield was also reported by Sabir-Ahamed (1999) in blackgram, Sasikala (1997) in cowpea and bhendi, Jegathambal (1996) in sorghum, Kavitha (2002) in blackgram, Somasundaram (2003) in maize, sunflower and greengram.

The improvement in field emergence by organically treated seeds might be due to activation of cells during soaking which resulted in enhancement of mitochondrial activity leading to the formation of more energy compounds and vital bio molecules which were made available during the early phase of germination as reported by Manimekalai (2006) in blackgram. The reduction in yield of untreated seeds could be assigned to lack of vigour as reported by

Fig 20: Impact of normal grade botanicals on fruit yield per plant in Anugraha and Ujwala

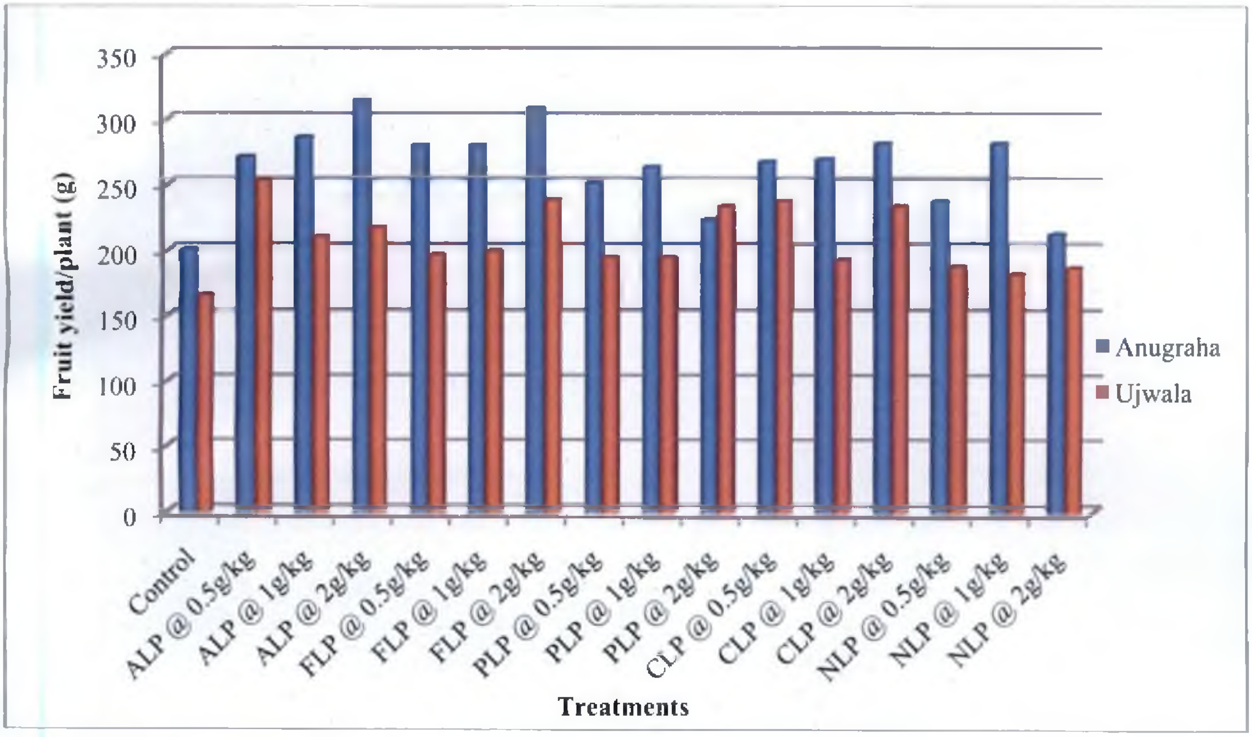
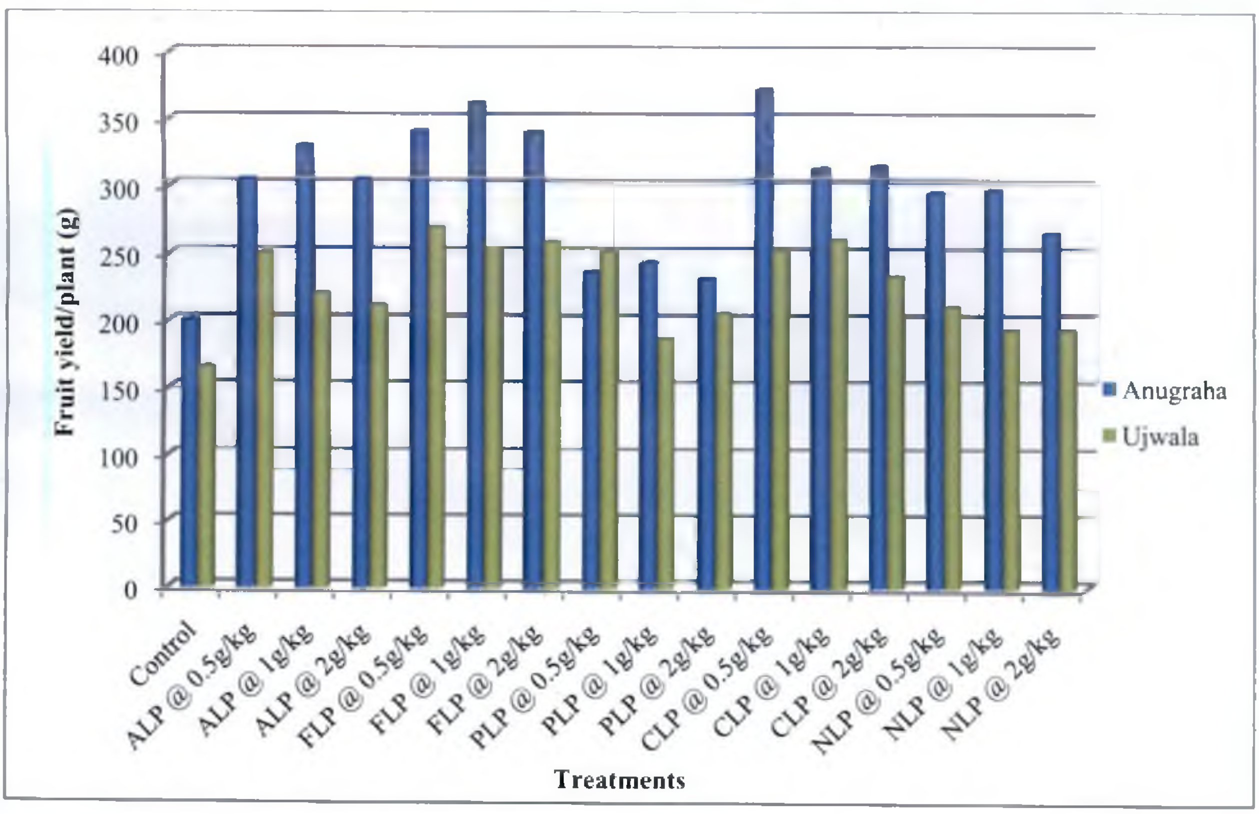


Fig 21: Impact of nano size botanicals on fruit yield per plant in Anugraha and Ujwala



Harrison, (1966); Perry, (1977) in barely; Tekrony and Egli, (1977) in soybean; Ramamoorthy and Basu, (1997) in groundnut.

The comparative results of normal grade powders and nanopowders of the botanicals indicated that, nanopowders showed increased performance of seed quality parameters and slowed down the process of seed deterioration thus maintaining the biochemical constituents of seeds. A similar result of storage study was observed in field performance also. The influence of seed invigoration treatments were positive on all attributes towards yield increase such as plant height (cm), number of fruits per plant, fruit weight per plant (g), fruit length (cm), fruit girth (cm) and fruit yield per plant (g).

The overall results of botanical seed treatments with ALP, FLP, PLP, CLP and NLP at three concentrations *viz.,* 0.5, 1 and 2 g kg^{-1} revealed that, Anugraha seeds treated with normal grade powder such as ALP @ 2 g $kg^{-1}$and nanopowders such as CLP @ 0.5 g kg^{-1} were found to be best treatments than other treatments and control. Ujwala seeds treated with normal grade powder such as ALP @ 0.5 g kg^{-1} and nanopowder such as FLP @ 0.5 g kg^{-1} were found to be best treatments compared to other treatments and control. A similar trend of the above mentioned laboratory result was seen in field performance also. In general, effects of normal grade powders (ALP, FLP, PLP, CLP and NLP) on seed quality parameters during storage as well as field performance were little lower compared to nanopowders (ALP, FLP, PLP, CLP and NLP).

The findings of the present study reveals, the effect of pre-storage seed treatment with botanicals of normal grade powders and nanopowders. The seed invigoration treatments have proved beneficial during storage and confirmed their efficacy under field conditions also. Irrespective of the varieties and concentration of botanicals, among the normal grade treatments, arappu (*Albizia amara*) was the best treatment, whereas in nanopowder treatments, custard apple (*Anona squamosa*) and fenugreek (*Trigonella foenum-graecum*) were the best treatments. In general, custard apple followed by fenugreek and arappu were the best botanicals for seed treatment. The outcome of this study is valuable for farmers as well as seed industries. The utilization of botanical leaf powders may be a feasible approach to increase the germination, vigour, storability. It tends to reduce consumption of chemical substances in agriculture that results in environmental pollution.

FUTURE LINE OF WORK

The present investigation is an indication of further research exploration in establishing relationship between botanicals and seed quality improvement in a detailed manner.

Critical elucidation is required on the mode of action of crude plant materials or mechanism of entry of active ingredients of crude plant materials through invigoration treatment for maintaining viability. Studies can be extended to the utilizations of other locally available botanicals.

Varietal differences in response to the botanical treatments were noticed and hence studies may be initiated on other varieties to arrive at the correct botanical suitable for corresponding varieties.

The present study is focused completely on only leaf powders of botanicals. Hence, the study can be conducted on seed and fruit powders of botanicals.

The present work paves way for the usage of inorganic nanoparticles in enhancing seed quality so that a comparison can be made on beneficial effects of organic and inorganics.

The scope of the present study was restricted to ambient conditions. Hence, the effect of botanicals under controlled atmospheric condition, and the interaction can be studied.

The present work concentrates on dry dressing of leaf powders and their effects whereas it can be made an elaborative study on different mode of invigoration treatments such as wet forms, pelleting, priming, and others.

Summary

6. SUMMARY

The present investigation was undertaken at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University, Thrissur to elucidate the effect of normal grade and nano size botanical leaf powders on the storage potential of chilli seeds as well as to study the field performance of these botanical seed treatments.

The salient findings of the study are summarized below:

6.1. Impact of seed treatment with normal grade botanicals

Seeds treated with normal grade powders showed better performance compared to untreated seeds in all the seed quality and biochemical parameters.

In Anugraha, treated seeds maintained more than 60 per cent (minimum seed certification standards), till the twelfth month (60.84) of storage whereas the untreated control could retain MSCS only up to the ninth month (64.32). Among the treatments, maximum germination per cent, vigour index, dehydrogenase activity and lower electrical conductivity was recorded in T_4: ALP @ 2 g kg^{-1} (69.58, 961, 0.068 and 0.834 dSm^{-1}, respectively) compared to control (36.30, 349, 0.020 and 1.795 dSm^{-1} respectively).

In Ujwala, the germination per cent as per the minimum seed certification standards was retained till ninth month (61.68) of storage for treated seeds, whereas, it was only up to fifth month (63.80) for untreated seeds. Among the treatments, maximum germination per cent, vigour index, dehydrogenase activity and lower electrical conductivity was recorded in T_2: ALP @ 0.5 g kg^{-1} (64.10, 863, 0.092 and 0.149 dSm^{-1}, respectively) compared to control (36.56, 315, 0.038 and 0.423 dSm^{-1}, respectively).

The superiorly performing botanical in both varieties, irrespective of the concentration of arappu (*Albizia amara*).

6.1.1. Impact of seed microflora on normal grade botanical seed treatments

In the present study, Anugraha seeds treated with normal grade powder i.e., ALP @ 2 g kg^{-1} (13.33) of seeds recorded minimum seed infection per cent than control (36.67) whereas, in Ujwala treated with normal grade powder i.e., ALP @ 0.5 g kg^{-1} of seeds recorded minimum seed infection per cent (13.33) compared to other treatments and control (40.00). The seed microflora were observed at the end of twelfth and ninth month of storage in Anugraha and Ujwala. The seed storage fungi observed were *Aspergillus niger, Aspergillus flavus, Pencillium* sp and *Alternaria sp.*

6.2. Impact of seed treatment with nano size botanicals

Seeds treated with nanopowders showed better performance compared to untreated seeds in all seed quality and biochemical parameters.

In Anugraha, treated seeds maintained more than 60 per cent (minimum seed certification standards), till twelfth month (63.11) of storage whereas the untreated control could retain MSCS only up to ninth month (64.32). Among the treatments, germination per cent, vigour index, dehydrogenase activity and lower electrical conductivity was recorded in T_{11}: CLP @ 0.5g kg^{-1} (72.10, 1072, 0.080 and 0.864 dSm^{-1}, respectively) compared to control (36.30, 349, 0.020 and 1.795 dSm^{-1}, respectively).

In Ujwala, the germination per cent as per the minimum seed certification standards was retained till ninth month (61.76) of storage for treated seeds, whereas, it was only up to fifth month (63.80) for untreated seeds. Among the treatments, germination per cent, vigour index, dehydrogenase activity and lower electrical conductivity was recorded in T_5: FLP @ 0.5g kg^{-1} (64.56, 862, 0.107 and 0.747 dSm^{-1}, respectively) compared to control (36.56, 315, 0.020 and 1.138 dSm^{-1}, respectively).

The superiorly performing botanicals in both varieties, irrespective of the concentration of botanicals was fenugreek (*Trigonella foemm-graecum*) and custard apple (*Anona squamosa*).

6.2.1. Impact of seed microflora on nano size botanical seed treatments

In the present study, Anugraha seeds treated with nanopowder i.e., CLP @ 0.5 g kg^{-1} (10.00) of seeds recorded minimum seed infection per cent than other treatments and control (36.67) whereas, in Ujwala treated with nanopowder i.e., FLP @ 0.5 g kg^{-1} of seeds recorded minimum seed infection per cent (10.00) compared to control (40.00).The seed microflora were observed at the end of twelfth and ninth month of storage in Anugraha and Ujwala. The seed storage fungi observed were *Aspergillus niger, Aspergillus flavus, Pencillium* sp and *Alternaria sp.*

6.2.2. Field performance of seed treatment with botanicals

The performance of treated seeds was better compared to untreated seeds. In Anugraha, among the normal grade powders, fruit yield per plant was higher in ALP @ 2 g kg^{-1} (315 g) whereas, in nanopowder treatments, higher fruit yield per plant was seen in CLP @ 0.5 g kg^{-1} (372 g) compared to control (200 g).

In Anugraha, among the normal grade powders, fruit yield per plant was higher in ALP @ 0.5g kg^{-1} (253 g) whereas, in nanopowder treatments, higher fruit yield per plant was seen in FLP @ 0.5 g kg^{-1} (269 g) compared to control (165 g).

Among the performance of nanopowder botanicals throughout the storage period as well as field performance of chilli seeds, custard apple (*Anona squamosa*) and fenugreek (*Trigonella foenum-graecum*) was found to be the best treatment, irrespective of the varieties and concentration of botanical leaf powder. In case of normal grade botanicals throughout the storage period as well as field performance of chilli seeds, arappu (*Albizia amara*) was found to be the best treatment.

The superiorly performing botanical seed treatment was selected on the basis of all seed quality parameters (high germination per cent; seedling vigour; viability and low electrical conductivity) and yield attributes. Hence, it is clearly evident from the present study that, performance of seed invigoration with nanopowder treatments were better compared to normal grade powder treatments. Both seed treatments performed better than untreated (control). In general, botanicals such as custard apple, fenugreek and arappu were the best botanicals suitable for seed invigoration treatments.

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Appendix

Appendix

Details of varieties Ujwala and Anugraha

Details	Ujwala	Anugraha
Year of release	1996	2003
Station of release	Kerala Agricultural University	Kerala Agricultural University
Parentage	CA 219-1-19-6 (SPS)	Ujwala x Pusa jwala
Special character	Bacterial wilt resistant	Bacterial wilt resistant
Pungency	High	Medium
Fruit	Medium long erect	Long pendant
Sourced from	Agricultural Research Station, Mannuthy, Thrissur	Department of Olericulture, College of Horticulture , Vellanikkara

Abstract

Seed treatment with botanicals to enhance seedling vigour in chilli (*Capsicum annuum* L.)

BY

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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was undertaken at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur to elucidate the effects of botanicals and compare the efficacy of normal grade and nanopowder botanicals on seedling vigour in chilli. The study consisted of three experiments such as seed treatment with normal grade botanicals, seed treatment with nanopowder botanicals and field performance of seeds treated with botanicals in two varieties Anugraha and Ujwala. The study involved five commonly used botanicals namely *viz*., arappu (*Albizia amara*), fenugreek (*Trigonella foenum-graecum*), pungam (*Pongamia glabra*), custard apple (*Anona squamosa)* and neem (*Azadirachta indica*). Preparation of powders involved collection and shade drying of the above mentioned leaves followed by grinding in mixer grinder and sieving to get a uniform particle size. These normal grade powders were used in experiment one. These finely ground powders were further synthesized using High Energy Ball milling and characterized using Particle Size Analyser (PSA), Scanning Electron Microscope (SEM) to reduce the particle size to nano dimension. These nanopowders were used in experiment two. Chilli seeds were pre-treated with each of the normal grade and nanopowders mentioned above in each of the following three doses, 0.5 g kg^{-1}, 1 g kg^{-1} and 2 g kg^{-1} of seeds. The treated seeds along with the untreated (control) were packed in 400 gauge polyethylene bags and stored in the ambient conditions. Observations on seed quality parameters were recorded as per ISTA standards at monthly intervals.

In both the varieties tested, irrespective of the particle size of the botanicals used, seed treatments with botanicals had a favourable impact on seed viability and seedling vigour over the period of storage. In variety Anugraha, treated seeds enhanced the viability of seeds for twelve months compared to ten months in case of untreated seeds. However, viability in untreated and treated

seeds of variety Ujwala was retained for six and nine months respectively. Seeds of variety Anugraha stored better than that of Ujwala.

Considering the impact of seed treatment with normal grade botanicals, on seed quality parameters, arappu @ 2 g kg^{-1}, fenugreek @ 2 g kg^{-1}, and fenugreek @ 0.5 g kg^{-1} were superior to other treatments in variety Anugraha, whereas, arappu @ 0.5 g kg^{-1}, fenugreek @ 2 g kg^{-1} and custard apple @ 0.5 g kg^{-1} were found to be superior in variety Ujwala. In case of seed treatment with nanopowder botanicals, it was evident that, in variety Anugraha, custard apple @ 0.5 g kg^{-1}, fenugreek @ 1 g kg^{-1}, and fenugreek @ 0.5 g kg^{-1}, were superior, whereas, in variety Ujwala, fenugreek @ 0.5 g kg^{-1}, custard apple @ 1 g kg^{-1}, and fenugreek @ 1 g kg^{-1} were superior. Seeds treated with treatments mentioned above had registered high germination, seedling vigour, dehydrogenase activity and low electrical conductivity throughout the storage period. Microflora infection per cent was found to be lower in treated seeds than in untreated control. The seed storage fungi observed were *Aspergillus niger, Aspergillus flavus, Pencillium* sp and *Alternaria* sp.

A similar trend was observed in the field performance of treated seeds. In variety Anugraha, fruit yield per plant was high when treated with nano powder treatments such as custard apple @ 0.5 g kg^{-1}, fenugreek @ 1 g kg^{-1}, and fenugreek @ 0.5 g kg^{-1}. The fruit yield per plant in these treatments was 372 g, 362 g and 341 g, respectively. Treatments with normal grade botanical treatments such as arappu @ 2 g kg^{-1}, fenugreek @ 2 g kg^{-1} and fenugreek @ 0.5 g kg^{-1} also resulted in higher fruit yield per plant. The fruit yield per plant of 315 g, 295.4 g and 269.9 g, were realised from these treatments respectively. In variety Ujwala, the fruit yield per plant was high when treated with nanopowder botanical treatments such as fenugreek @ 0.5 g kg^{-1}, custard apple @ 1 g kg^{-1} and fenugreek @ 1 g kg^{-1}. The fruit yield per plant in these treatments was 270 g, 267 g and 258 g, respectively. Treatments with normal grade botanical treatments such as arappu @ 0.5 g kg^{-1}, fenugreek @ 2 g kg^{-1}, custard apple @ 0.5 g kg^{-1}

also resulted in higher fruit yield per plant. The fruit yield per plant of 253 g, 238 g and 237 g, were realised from these treatments respectively.

It was observed that, treatments with nanopowders enhanced seed quality better than the normal grade powders. In general, seeds treated with botanicals such as fenugreek (*Trigonella foenum-graecum*), custard apple (*Anona squamosa)* and arappu (*Albizia amara*) performed better than the others. Among the normal grade powder treatments, arappu was found to be the best treatment, whereas, custard apple and fenugreek were found to be best among seeds treated with nanopowders. The storage life of treated seeds of variety Anugraha retained for twelve months compared to ten months in case of untreated control. In case of variety Ujwala, viability can be retained upto nine months compared to six months untreated control. Hence, the present study indicates that, viability and seedling performance can be enhanced by treating the chilli seeds with normal grade botanicals like arappu, fenugreek or nanopowders like custard apple and fenugreek.