CYTOLOGICAL AND BIOCHEMICAL CHANGES IN AGED AND OSMOPRIMED SEEDS OF CHILLI

(Capsicum annuum L.)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR
Kerala, India

1999

DECLARATION

I hereby declare that the thesis entitled **'Cytological and biochemical changes in aged and osmoprimed seeds of chilli (*Capsicum annuum* L.)'** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled '**Cytological and biochemical changes in aged and osmoprimed seeds of chilli (*Capsicum annuum* L.)**' is a record of research work done independently by **Ms. Thara Manoharan,** 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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ACKNOWLEDGEMENT

Before I say word of acknowledgement, I owe to bow my head before the **ALMIGHTY GOD** *whose unbounded rays of blessings always enshrined in my thoughts, deeds and so also bestowed with good healthy strength, confidence and self conscious.*

I am at a loss of words to express my profound sense of gratitude to Dr. K. Nandini, Assistant Professor, Department of Plant Breeding and Genetics, College of Horticulture and chairperson of my advisory committee for her invaluable guidance, ever willing help, perpetual support, constant encouragement and above all the understanding and enthusiasm rendered during the entire period of my work without which it would have been very difficult for me to prepare this thesis. I considered myself blessed for being guided by her.

With great respect, shall I express my extreme indebtedness and gratitude to Dr. K. Pushkaran, Professor and Head, Department of Plant Breeding and Genetics and member of my advisory committee for his meticulous help, forbearance, valuable suggestions and sustained interest given throughout my course, inspite of being very busy. I shall owe a deep sense of gratitude for that.

Heartfelt thanks are due to Dr. Samuel Mathew, Associate Professor, AMPRS, Odakali and member of my advisory committee for his whole-hearted co-

operation, cordial support and valuable suggestions during various stages of the study and preparation of the manuscript.

As a member of my Advisory Committee, Dr. Sudhams C. Babu, Dean, College of Forestry has shown keen interest in my research work. His willingness to help could never be forgotten.

No less is my gratefulness to Sri. S. Krishnan, Assistant Professor, Department of Agrl. Statistics for the immense help extended during the analysis of the data, constructive criticism and suggestions for improvement of the manuscript.

The help rendered by Dr. Achamma Cherian, Dr. V.S. Devadas, and Dr. Gopalakrishnan is thankfully acknowledged.

I sincerely thank Dr. V.K. Mallika, Associate Professor, CCRS for her co-operation in taking photographs which contributed much towards the completion of my thesis.

I place on record my deep sense of gratitude to Mrs. Amma and Sri. Roy M.D., Department of Plant Breeding and Genetics for their unlimited moral support throughout the preparation of the manuscript.

The co-operation and assistance offered by my friends Siji, Beejaya, Sona and Sheena are gratefully remembered.

The award of ICAR Junior Research Fellowship was extremely helpful and it is gratefully acknowledged.

I am thankful to Mrs. Joicy, for her patient and efficient service in the analysis of the data and the neat typing of the thesis.

I am in dearth of words to express my gratitudes, appreciation and indebtedness to my loving parents, brothers and sisters for their constant encouragement, untiring support and love showered on me. Without them, it would have been impossible to complete my study.

I owe the completion of this thesis to the indefinite patience and forbearance of my husband, who bore this rival love of mine with fond jealousy and also to my little kids Shilpa and Aswin, who silently bore their mothers eccentricities.

I affectionately dedicate this work to them.

Thara.

THARA MANOHARAN

To my little sweet hearts

Shilpa and Aswin

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Introduction

INTRODUCTION

Chilli (*Capsicum annuum* L.) the hot spice cum vegetable is cultivated throughout the world for its intrinsic qualities like pungency, flavour, appealing colour and nutritive value. Chilli has been a part of human diet since 7500 BC. Consumers especially in India have adapted well to chillies that they cannot complete their meal without a little of chilli. The power of chillies is so great that during 1978 - '79 when Korea faced a shortage of red chilli, it was feared that Korean government would fall if adequate supply of red chilli was not ensured.

India is the leading producer of chillies with an annual production of 8,50,000 MT (Murugan, 1998). The important chilli producing states are Andra Pradesh, Maharashtra, Tamil Nadu, Karnataka, West Bengal, Bihar and Assam. India is also, the largest exporter of red chillies. Estimated annual import of chilli in the world is one-lakh tonnes, which is 22.22 per cent of total spice import in the world. As a leading producer, India has the production figure of 9.45 lakh tonnes from an area of 9.565 lakh hectares, and it is expected to reach 15 lakh tonnes by 2000 AD India exports only 2.75 per cent to 7.50 per cent of its total production.. The main markets are USA, South East countries, Srilanka and Bangladesh.

Chilli is a diverse crop and is incorporated into majority of the world's business. Annual trade of chilli in the world is 55 to 65 thousand tonnes which is 16.7 % of the total spice trade in the world. Chilli is valued for its pungency, spice taste and aroma besides the appealing colour it adds to food. The two important chemical constituents of fruits are 'capsaicinoids' imparting pungency and 'carotenoid pigments' imparting colour.

Both ripe and unripe fruits of chilli are used for culinary purpose and it forms an important source of vitamin C. Of the five major spices, chilli ranks third next only to black pepper and cardamom. It is unique among all the spice crops, being the only source of capsaicin. The pungent principle capsaicin has significant physiological action and is used in many pharmaceutical preparations like balms, linaments and ointments for cold, sore throat and chest congestion. The oleoresin from high pungent chilli varieties is used as a counter irritant in lumbago, neuralgia, rheumatic disorders

and internally for tonic and carminative action. Chilli varieties with bright red colour and moderate pungency are used for flavouring food products like hot biscuits, ginger soft drinks and for chewing tobacco.

Chilli is propagated mainly through seeds. Vegetable seeds stored in gunny bags lose viability due to environmental and genetic factors and seed borne fungi. Under Indian conditions it is not feasible for farmers to provide ideal conditions for seed storage. Dry storage causes a gradual loss of viability and vigour. Lesions in the integrity of DNA and ribosomal RNA have been found to be the main causes of impaired transcription and protein synthesis leading to low viability of seeds Hence the availability of viable seeds in the succeeding sowing season has become a constraint. Loss of viability on storage also causes great economic loss to farmers. In vegetable crops, germination and seedling establishment are major constraints for a uniform crop, gap filling is neither economical nor a viable proposition and so the production of quality seeds and its safe storage is of paramount importance.

A variety of physiological treatments help to improve several environmental and genetical constraints. The importance of hydration and dehydration processes in improving seed germination is well established. Osmopriming has been identified as yet another technique which help the seed physiologically to improve germination and produce quality seedlings. Priming i.e., the pre imbibition of seeds in osmotic solutions can partly reverse the negative effects of ageing and may result in both accelerated germination rate and improved seedling uniformity (Taylor *et al.*, 1998). At the biochemical level, it has been reported that osmopriming increases the amount of RNA, DNA and protein synthesis which allow the seeds to advance pre germination processes and repair. However, osmopriming effects on chilli seeds are yet to be studied and needs testing in the context of constraints faced in handling chilli seeds. The present investigation was therefore undertaken with the following objectives.

1. To study the different types of cytological and biochemical changes in aged seeds of chilli
2. To investigate the effects of osmopriming in chilli seeds.
3. To study the feasibility of osmopriming as a technique in overcoming physiological and genetic deterioration of stored seeds.

Review of literature

REVIEW OF LITERATURE

This chapter reviews the relevant literature available in India and abroad on various aspects related to the present study.

2.1 Effect of seed Osmopriming on seed and seedling characters

2.1.1 Germination percentage

Priming, is a treatment of seeds in which they are hydrated sufficient to allow the preparative events for germination to take place but insufficiently hydrated to allow the radicles to emerge, making seedling emergence more predictable, advanced and more synchronized giving earlier growth. (Heydecker *et al.*, 1974).

Osmopriming celery seeds in PEG 6000, at 18^{0}C for 14 days showed significantly better seedling emergence even when sown 14 days later than untreated seeds. Plant development was also significantly improved, the effect lasting upto harvesting made 12, 15 and 18 weeks after sowing when plants from primed seeds had reached marketable size. (Rennick and Tiernan, 1978).

Brocklehurst *et al.* (1987) tried the technique of osmopriming of vegetable seeds to give more rapid and uniform germination and emergence on a wide range of species of family.

Saxena *et al.* (1987) conducted osmotic priming studies in tomato cv. Sioux, capsicum cv. Geram Jwala, cauliflower cv. Pusa Kataki and aurbergine cv. Pusa Kranti with PEG 6000. In all species the treatments increased germination and seedling growth compared with the controls. The best treatment for tomatoes was 12 days at 29 per cent PEG 6000 or 8 days at 32.4 per cent for capsicum 4 days at 29 per cent or 8 days at 32.4 per cent for cauliflower 8 days at 29 per cent or 4 days at 32.4 per cent and for aubergine 12 days at 29 per cent or 4 days at 32.4 per cent.

Yan (1987) found that Soyabean seeds immersed in 33 per cent poly ethylene glycol (PEG) 6000 solution at 10^{0}C for 72 h and then imbibed at 2 to 3^{0}C showed tolerance to this temperature for 60 days without reduction in viability.

Alvarado and Bradford (1987) reported priming tomato seeds for the first time in PEG at – 1.25 Mpa was effective as it was before storage and a second priming treatment of stored primed seeds was of some benefit, but did not entirely reversed the detrimental effects of high temperature storage.

Hassell and Kretchman (1987) noticed that soaking parsely seeds (cv. Forest green parsley) in water for 72 h to remove the inhibitor in the seed coat and seed priming with PEG 6000 increased yields.

According to Haingh and Barlow (1987), salt solution priming of tomato and carrot seeds were more beneficial to subsequent germination than PEG priming but salt solution priming of onion seeds was less beneficial than PEG priming.

Carpenter (1989) reported that priming seeds of *Salvia splendens* of three cultivars in a hypertonic osmotic solution of aerated poly ethylene glycol (PEG 8000) at -0.8 Mpa for 10 days at 15^{0}C improved germination in all cases.

Frett and Pill (1989) were of the opinion that the optimal priming treatment of seeds of Impatiens was -1.0 Mpa of poly ethylene glycol 8000 (PEG) at 25^{0}C for one week and primed seeds gave 80 per cent final germination and 11.5 days to 50 per cent germination, where as the respective values for untreated seeds were 50 per cent final germination and 18.1 days.

Tanne and Cantliffe (1989) reported that the percentage germination of celery seeds cv. Early belle was the highest when primed in PEG 8000 at -12.5 bar at 15^{0}C for 20 days.

Freshly harvested soyabean seeds on treatment with sodium chloride (0.25 %) for 6 h, washed, dried and stored for 12 months, increased germination percentage from 41 per cent in the control to 64 to 87 per cent and seedling vigour index from 656 to 1152 to 1862. (Sathiyamoorthy and Vivekanandan, 1989).

According to Niewnow *et al.* (1991) priming leek seeds for 7 days with -1.0 Mpa solution (PEG 600 and PEG 6000) gave results as good as priming for 14 d with 1.5 Mpa

PEG 6000 solution. Priming in filter paper was as effective as priming in bubble columns. But drying back after priming reduced the benefits derived from priming.

Cold tolerance, as measured by germination at 6^0C in soyabean genotypes I38 and I32 was increased by soaking in PEG during the early stages of germination (Li *et al.*, 1991).

Carpenter and Boucher (1991) reported that the optimum conditions for priming pansy seeds (cultivars Majestic Giant Yellow and Majestic Giant Red) were in aerated solutions of PEG 8000 at -1.0 MPa for 7 days at 15^0C.

A large-scale method of treating leek seeds cv. Guard in bubble column bioreactors using polyethylene glycol (PEG) -1.0 MPa for 7 days at 15^0C was investigated by Bujalski *et al.* (1991). All priming treatments increased percentage germination and shortened the germination time compared with untreated seeds.

According to Cordero *et al.* (1991), an absence of damage was observed in *Tecoma stans* seeds after a month of permanent soaking in PEG solutions of -1.0 and -1.5 MPa. The osmotic pretreatment improved and accelerated the initiation of germination.

Small and Gutter (1992) reported that the effect of thermodormancy was largely reduced by imbibing seeds at 40^0C in solutions of PEG 6000 and Na Cl (0.1 or 0.2 M). Despite similar water potentials of solutions Na Cl pretreatment was more effective.

Shen *et al.* (1992) concluded that osmoconditioning with polyethylene glycol (8000) at different concentrations and durations of treatments was of little value as a mean of improving germination of *Lathyrus sylvestris* seeds and performance of seedlings.

According to Chilembwe *et al.* (1992), priming commercially processed seeds of citrange cv. Carrizo, citrumelo cv. Swingle, mandarin cv. Cleopatra and sour orange in -0.6, -0.9 or -1.2 MPa solutions of PEG 6000 was not successful, as germination and emergence percentages were lower than from soaking in distilled water.

Parthasarathy *et al.* (1993) reported that on osmopriming *Phaseolus vulgaris* seeds cv. Arka Komal using polyethylene glycol (PEG 8000) at water potentials of 0, -0.25,

-0.75 and -1.25MPa, the highest germination (100 %) was obtained at the water potential of -1.25 MPa.

Rao and Phillips (1993) reported that in turnips cv. Purpletop and turnip x chinese cabbage hybrid cv. Tyfon, priming in polyethylene glycol (PEG-8000) increased seedling emergence over unprimed seeds by 75 and 53 per cents respectively.

Seed germination of spinach cv.. Jiroumaru was inhibited markedly at temperatures above 25^{0}C. Masuda and Konishi (1993) were of the opinion that Acid scarification followed by priming with poly ethylene glycol (PEG) 6000 solution (-1.3 Mpa for one week at 10^{0}C) increased germination percentage even at 30^{0}C to more than 80 per cent within 8 days after sowing.

Fujikura *et al.* (1993 b) suggested that osmopriming of aged seeds are slightly more effective than hydropriming at increasing germination and produced some increase in the very low percentage of normal seedlings which developed.

Corbineau *et al.* (1994) reported that a priming treatment of leek seeds cv. Premier at -15 bars of PEG 6000 for 7 to 10 days at 15^{0}C markedly increased germination at suboptiomal temperatures and the stimulatory effect persisted after drying and subsequent storage under silica gel for up to 15 months.

Mauromicale and Lerna (1994) reported that the beneficial effect of priming treatments using PEG were maintained over the six month storage period after treatment in case of *Oryzopsis miliaceae* (L.).

Experiments conducted by Binick *et al.* (1994) on priming carrot cv. Perfekoja and parsley cv. Berlinska seeds in PEG 6000 with prior soaking 0.2 M thiran, resulting in a significant improvement in percentage germination in both species compared with controls.

Cantliffe and Balla (1994) studied the effect of seed lots of carrot (cv. Orlando gold) collected from three separate locations. Seed priming was more effective in improving seed germination at 25^{0}C than at 15^{0}C, and was highly effective at a constant high temperature of 35^{0}C.

Mauromicale and Cavallaro (1995) evaluated the effect of osmotic priming of tomato seeds cultivar Rio Fuego and Sunny at water potentials of 0, -0.5, -0.7, -0.9, -1.1 and -1.3 MPa maintained by solutions of polyethylene glycol (PEG) 6000. Seed osmopriming increased germination percentage at low water potentials whereas the germination of untreated seeds was greatly inhibited.

2.1.2 Speed of germination

Ali *et al.* (1990) observed that osmo treatments of tomato and onion seeds at 8.6 and –11.9 bars respectively for a minimum of seven days produced rapid germination responses at 15^0C.

A comparison of priming agents for tomato and asparagus seeds primed for one week in -0.8 MPa PEG 8000 showed that priming did not affect percentage germination of tomato seeds but increased asparagus seed germination from 85 to 90 per cent (Frett *et al.*, 1991).

Belletti *et al* (1991) studied the effect of priming on seed germination of Ice land poppy at 10^0C, at treatment temperatures (10,15 and 20^0C) with PEG and NaCl. The results showed that most treatments reduced the average number of days for germination significantly with no immediate effects on viability.

Gray *et al.* (1991) in a comparison study of polyethylene glycol polymers, betaine and L-proline for priming vegetable seeds like onion, leek, carrot and celery found that priming in PEGs reduced mean germination time compared with untreated seeds by a similar time in each species and reduced the spread of germination times in leek and carrot but not in celery and onion.

The time for sugarbeet cv. WS – 88 to reach 50 per cent of maximum emergence in the greenhouse decreased linearly with increasing priming time (1 to 5 d) in 100, 200 and 300 g polyethylene glycol (PEG) per litre. Maximum emergence of primed seed was equal or superior to emergence from untreated seed throughout a six weeks storage period (Swensen and Murray, 1991).

Lanteri *et al.* (1993) concluded that osmotic pre conditioning of pepper seeds for 7, 14 and 21 days in polyethylene glycol (PEG) considerably reduced the time to 50 per cent germination, the mean germination time and the effect was proportional to the duration of the priming treatments. Besides the quantitative effect priming had a temporal influence on DNA synthetic activity.

In an experiment conducted by Dabrowska and Tulo (1993) to study the influence of different temperatures on germination of PEG 6000 treated tomato seeds of 12 early genotypes at 20^0C for seven days it was found that in all cases, PEG wet and PEG dry seeds showed higher germination rate at 25^0C than the control seeds and at other temperatures the genotypes showed varied behaviour.

According to Fujikura *et al.* (1993 c), hydropriming was found to improve rate of germination more effectively than osmopriming (-1.5 MPa PEG at 20^0C for one week) in case of cauliflower seeds.

High germination seed lots (common and cv. Bright star) and low-germination seed lots (common and cultivars Bright Star, White Swan and Branado) of *Echinacea purpurea*, evaluated by Wartidiningsih *et al.* (1994) for laboratory germination following osmotic priming in PEG 4000 increased early germination (3 days) at 27^0C of all seed lots and improved total (10 days) germination percentage of low-germination seed lots.

When seeds of rice cv. Zhejiascian 222 and Xiangweiyon 6 were treated with PEG 1000 for two days their resistance to imbibition dulling injury and germination rate significantly increased (Quin and Zheng, 1994).

Demir and Elis (1994) reported that priming in polyethylene glycol (PEG) 6000, -1.0 MPa 20^0C for seven days followed by drying or surface drying increased the rapidity of germination of capsicum cv. California Wonder seed lots harvested at different maturity levels.

Priming of pepper and tomato seeds in -1.1, -1.3 and -1.5 MPa polyethylene glycol (PEG) for 14 days reduced the mean time to germination. For both tomato and *Capsicum annuum*, the frequency of 4C signals was highest at the lowest PEG concentration (-1.1 MPa) (Lanteri *et al.*, 1994).

Effects of PEG osmoconditioning on germination power and seedling growth of sugarbeet seeds with different vigour (stored for different years) was investigated by Zhang *et al.* (1994) at three different PEG concentrations, two temperatures and three treatment times. The seed germination and germination rate were increased by PEG.

Yanmaz *et al.* (1994) reported that light was unnecessary for the priming process of carrot seeds and the speed of both germination and emergence was increased by all the priming treatments using PEG 6000 of -5 and -10 bar at 15^{0}C and 20^{0}C for 5, 10 and 20 days, of which the combination of 15^{0}C and -5 bar solution for 10 days gave the best improvement in speed and percentage.

According to Russo *et al.* (1994), seed osmopriming of eight regional ecotypes of sour orange in PEG 6000 of osmotic pressure -0.49, -0.90 and -1.10 MPa for 30 min and 24 h at 25^{0}C significantly improved the germination and emergence percentage and speed for most ecotypes.

Damato *et al.* (1994) observed osmotically primed seeds of Florence fennel cv. Locale di Bari at 10, 15 and 20^{0}C in PEG 8000 of 0, -9, -12 and -15 MPa for 6, 12 and 18 days prior to germination at 15, 25 and 35^{0}C. He found that the speed of germination after priming was similar with all three potentials and increasing priming temperature produced a trend of increasing germination speed.

Nasim *et al.* (1995) tested the germination performance of *Acacia nilotica* seeds at 37^{0}C and at room temperature before and after pretreatments at 20^{0}C using either pure distilled water or solutions of PEG 6000 and Na Cl for 20 days. Untreated controls showed weak germination profiles while the pretreatment effected the total number of seeds germinating and the spread of germination, but it did not generate any dramatic change in germination performance.

According to Rog *et al.* (1995), the germination percentage of PEG 8000 osmoprimed seeds of onion cv. Yellow and sugarbeet cv. WS 76 were 97 and 96 per cent compared to 89 per cent and 86 per cent respectively.

An investigation on the effects of PEG at -1.31 MPa for 0.5 to 3 days on the germination of *Lagenaria sciceraria* seeds compared with unprimed seeds showed that

priming in PEG increased percentage germination and decreased the mean time required for germination. (Keunchung *et al.*, 1996).

Quing *et al.* (1996) reported that freshly harvested tomato cv. Moneymaker seeds when osmotically primed for eight days in -1.0 Mpa PEG 6000 solution and dried to about six per cent water content for storage this so-called fresh PEG priming enhanced seed germination and improved seedling performance as compared with the untreated control

A comparison of osmotic and metric priming of broccoli seeds using polyethylene glycol (PEG 8000) at -1 per cent MPa and calcium silicate at -1.2 MPa was conducted by Jett *et al.* (1996). The results showed that metric and osmotic priming increased germination rate in the laboratory, green house and field

Seed osmopriming in PEG 6000 was investigated by Mauromicale and Cavallaro (1996) as a means of improving germination performance of three herbage grasses (*Festuca arundinacea* cv. Cigale, *Dactylis glomerata* cv. Lude and *Bromus catharticus* cv. Samson) primed seeds exhibited a significant increase in germination rate.

A study on the effects of priming tomato seeds (cultivars Yaungsoo and Wolkwang) in PEG at –0.75 MPa, for 4 days at 20^0C showed that seed germination was faster at 20^0C. Early growth of seedlings was slightly enhanced by seed priming (Jumsoom, *et al.*, 1996 a).

2.1.3 Uniformity in germination

According to Fleming and Lister (1984), priming Black spruce seeds with PEG increased the speed, vigour and uniformity of germination. The best treatment reduced the time to 50 per cent germination by 14, 3 or 5 days at 10^0C, 21^0C, or 32^0C respectively.

Seeds of tomato (cultivars VC 204 and 6203) primed in aerated polyethylene glycol 8000 germinated more rapidly than untreated seeds at 20 and 30^0C, seedlings from primed seeds in the field also emerged earlier and more uniformly than seedlings from untreated seeds, but priming did not affect the final germination percentage (Alvarado *et al*, 1987)

Priming onion seeds in bubble columns containing 50 g seed per litre of PEG (6000) solution using enriched air increased the percentage seed germination (89%) compared with untreated seeds (78%). The uniformity of germination was also increased in treated seeds (Bujalski *et al.*, 1989).

In a comparative study of two large scale seed priming techniques using aerated PEG 6000 solutions in bubble columns and by a non-osmotic priming technique in case of leek seed lots of high (91 %) and low (82 %) viability on sowing in the field both priming techniques gave earlier and more uniform emergence and higher levels of seedling emergence compared to untreated seeds (Gray *et al.*, 1990 a).

In a study Giulianini *et al.* (1992) found that osmotic priming of tomato seeds cv. Ventura and capsicum cv. Sangolia speeded up germination and improved uniformity but did not increase germination percentage even at the lowest temperature.

Leek seed germination is normally reduced at temperatures more than 25^0C. According to Parera and Cantliffe (1992) priming leek seeds cv. Verina with mannitol, polyethylene glycol (PEG) may promote early emergence at high temperature and improve stand uniformity for container transplant production.

A green house study undertaken by Rush (1992) in selected sugarbeet cultivars given priming treatments with -1.5 MPa Na Cl and -1.2 MPa polyethylene glycol (PEG 8000) showed that all priming treatments increased the rate and uniformity of seedling emergence and also reduced the incidence of pre emergence damping off in soils infested with *P. ultimum*.

In a series of field trials conducted by Mauromicale *et al.* (1994) on the emergence characteristics of osmoprimed seeds of summer squash (*Cucurbita pepo* L.) in PEG showed that there was a significant improvement in emergence from 72 per cent for the unprimed to 93 per cent for the primed seeds. It also increased the emergence speed and uniformity compared with control.

Jumsoom *et al.* (1996 b) reported that primed seeds of tomato (cv. Youngsoo and Wolkwang) in saline stress (0.6 and 1 % Na Cl) had a higher germination percentage than

unprimed seeds. Seed priming also reduced the time for 50 per cent germination and promoted rapid and uniform germination under adverse conditions.

2.1.4 Seedling vigour

According to Roberts (1986) loss of viability in storage is preceded by a wide range of symptoms, collectively contributing to loss of vigour, which can lead to decreased field emergence and poorer growth of plants resulting in poor final yield in crops sown at low resulting in poor final yield in crops sown at low density and harvested after a relatively short time.

In a comparative study between effect of pre-sowing seed treatment and pre-germination on capsicum emergence at different temperatures Ilamar *et al.* (1986) reported that seeds of the white fruited cv. Feherozon, treated with PEG and pregerminated at 22^{0}C were germinated at 16.5 - 21.0 in a growth chamber, PEG treatment advanced average emergence over the germination temperature range by 1.5 - 2.0 days where as pre germination by 3.5 days.

In a study to know the response of *Cicer milkvetch* seed to osmoconditioning Abernathy, (1987) found that an osmoconditioning regime of 8 to 10 days duration in 250 g PEG per kg water reduced mean germination time and naturally deteriorated seed lots responded positively to osmoconditioning.

Priming parsley seeds cv. Forest green in PEG 8000 solutions for 4.5 days at 25^{0}C improved earliness of germination at all test temperatures (5, 10 and 25^{0}C), with the largest improvement at the coolest temperature (Akers *et al.* 1987).

According to Pehap (1987), PEG treated *Picea abies* seeds germinated more quickly than control seeds.

According to Singh *et al.* (1988), in field trials with wheat seeds soaking in one per cent sodium chloride solution for 30 minutes increased the number of ear-bearing tillers per m row and gave grain yields of 4.45 t ha^{-1} compared with 4.03 t without seed treatment.

Alvarado and Bradford (1988 a) from their studies with tomato seeds (cultivars VC 204 and 6203) reported that priming stored control seeds for the first time in solutions of KNO_3 or PEG counteracted the adverse effects of storage and reduced the mean time to germination (T_{50}) by up to 53 per cent under laboratory conditions.

Alvarado and Bradford (1988 b) reported that priming tomato seeds in PEG 8000 of potentials (-1.25 MPa, 314g per kg of water) at 20^0C for seven days reduced the mean time to germination (T_{50}) by 41 per cent.

Osmopriming sugar beet seed in Na Cl or polyethylene glycol (PEG) solutions reduced *Pythium ultimum* pre-emergence damping off by 50 and 65 per cent respectively, compared with untreated seed when planted in naturally infested field soil (Osburn and Schroth, 1989).

Murray (1989) suggested that the initial seedling emergence of carrot seeds would be improved by PEG treatment, if the seeds were not over dried after osmoconditioning.

According to Gray (1994) the germination time is reduced after priming seeds with polyethylene glycol (PEG) for Impatiens, Salvia, Verbena and Petunia.

A study conducted by Cavallaro *et al.* (1994) on the effects of osmoconditioning with PEG 6000 on emergence characteristics of tomato (*Lycopersicon esculentum* Mill.) significantly decreased the mean time of emergence (MTE).

2.1.5 Seedling abnormality

According to Armstrong and Donald (1992), osmoconditioning of soyabean seeds with PEG without an intervening air drying treatment resulted in normal seedling development and increased plumule and radicle length and weight while soaking soyabean seeds with water resulted in abnormal seedling development. Electrical conductivity of osmoconditioned seeds increased following air-drying.

Lui *et al.* (1994) observed that osmotic priming of tomato cv. Moneymaker seeds for 4 to 20 days using PEG 6000 improved the germination rate slightly and increased root length but had no significant effect on percentage germination. Where as hydro priming for longer periods resulted in abnormal seedlings. They explained that the visible injury to

the radicle which led to abnormal seedling development often occurred upon dehydration during embryo growth where as this injury did not occur with osmotic priming.

According to Maude *et al.* (1994), all those priming treatments in leek seeds which increased the effectiveness of priming using PEG 6000 caused increased numbers of abnormal seedlings after storage.

2.2 Effect of osmopriming on biochemical characters

2.2.2 Enzyme activity and protein

According to Bray *et al.* (1989), differences in germination performances of leek seeds were reflected in differences in rates of protein biosynthesis of embryo tissue during germination and osmopriming treatments abolished these differences and furthermore induced high levels of protein biosynthesis in embryo tissue.

According to Wang and Zhao (1990) treatment with 20 per cent PEG for 48 h markedly increased the vigour of soyabean seeds stored for one year, increased germination percentage, germination index, vigour index, acid phosphatase activity, ATP level and field emergence whereas electrical conductivity decreased giving similar values to those of fresh seeds.

According to Davison *et al.* (1991), loss of vigour in leek seed lots was accompanied by the appearance of damaged ribosomal (r) RNA in quiescent embryo tissue. Polyethylene glycol osmopriming treatments of such low vigour seed permitted replacement of the damaged r RNA over seven days priming period and such seeds exhibited the capacity for much higher levels of protein synthesis than unprimed seeds at equivalent stages of imbibition.

Davison and Bray (1991) identified that during osmopriming of leek several polypeptides were synthesized at higher levels than during germination and also two polypeptides whose synthesis appeared to be specific to germination.

According to Vazquez *et al.* (1991) loss of viability and vigour in maize cv. Chalqueno was proposed due to damage of DNA metabolism.

Bino *et al.* (1992) opined that the beneficial effects of priming tomato seeds on seedling performance were associated with the action of replicative DNA synthetic processes prior to germination.

Bray *et al.* (1993) showed that osmopriming corrected the defects in the protein and DNA synthetic activities of low vigour leek seeds and permited replacement of damaged ribosomal RNA. A replicative and repair type DNA synthesis occurs in both nucleus and mitochondrion of leek embryo tissue during priming and continues into germination.

An investigation done by Fujikura *et al.* (1993 a) on the effects of controlled deterioration and osmopriming on germination showed that three types of changes in protein synthesis (vigour related, osmopriming related and aging related) were observed in vivo labelling of radicle tips. One of the vigour related protein was found to be specific to processes preceding visible germination.

Zhang *et al.* (1993) reported that seed treatment of five soyabean cultivars with polyethylene glycol decreased the lipoxygenease activity in the hypocotyl of seedlings and increased the hypocotyl protein content by 9.69 to 35.29 per cent. It was suggested that the decrease in lipoxygenase activity was related to the increase in protein content.

Osmotic priming of aged (one year old) onion seeds of cv. Punjab Red – 48 in PEG 8000 on filter paper and incubation at 20 ± 1^{0}C in darkness for three and five days showed that it did not affect the percentage germination but markedly improved the germination rate and also root and shoot growth. Surface dried primed seeds showed greater response (Basra *et al.*, 1994). They also concluded that priming induced invigoration of aged seeds was related to enhanced accumulation of putrescine, spermidine and to a lesser extent of spermine.

According to Ru *et al.* (1995) pre treated seeds of mung beans (*Vigna radiata*) in -1.6 MPa PEG 6000 solution for 20 h when germinated in 20 ml of 15 per cent and 20 per cent PEG 6000 at 28^{0}C in the dark, shortened the time of seed imbibition, increased germination rate in 20 per cent PEG solution, increased stability in hypocotyl cell membranes, decreased electrolyte exosmosis from seeds, increased the content of soluble protein and activities of peroxidase, catalase and phenylalanine ammonia-lyase.

2.2.2 Leachate EC

Doijode (1988) reported that there was excessive leaching of soluble sugars and free amino acids from deteriorating tomato seeds.

Pandey (1988) was of the opinion that priming aged *Phaseolus vulgaris* cv. Selection – 9 seeds reduced leakage of electrolyte and UV absorbing substances and improved the vigour of seeds aged for up to three years. The effect being greatest on seeds aged for two years and declined thereafter. It is suggested that there exists a critical state of deterioration beyond which loss in viability cannot be restored.

According to Agrawal (1990) in orthodox seeds an increase in protease activity may be the responsible for decrease in activities of other enzymes during storage. Besides leaching of water soluble sugars and leucine -14C increased with seed deterioration. He explained this due to membrane deterioration during seed storage. These changes preceded the loss in germination.

Normah and Chin (1991) reported that there was an increase in leachate conductivity of rubber seeds as duration of storage increased. Loss of membrane integrity was suggested as one of the causes of seed deterioration during storage.

Osmopriming soyabean seeds in 40 per cent polyethylene glycol (PEG) showed that the vigour index was 28.1 to 35.7 which was significantly higher than 14.0 in untreated controls. The treatments significantly reduced water adsorption and electrolyte leakage (mainly soluble sugar and amino acids). The pre treatments were effective in improving seed vigour only when the seed deterioration did not damage the repairing system (Meng and Li, 1992).

Basra *et al.* (1994) were of the opinion that osmotic priming of aged onion cv.Punjab Red –48 seeds with 25 per cent PEG 8000 for five days reduced electrolyte leakage as well as lipid peroxidation in seeds implying the activation of membrane repair processes. They also showed that the responses to priming in terms of changes in the levels of antioxidants and scavenging enzymes were greater in unaged than in aged seeds.

Paula *et al.* (1994) studied the changes in electrolyte leakage from sunflower cv. Perodovik subjected to different storing temperatures. Significant correlations with germination percentage were obtained for EC determination using one and two volts and this technique was concluded as a good indicator of loss of membrane integrity from deteriorated seeds within a sunflower seed lot.

According to Trawatha *et al.* (1995), seeds lots of soyabeans cv. Century, Pennyrile and Pharoh stored at 20, 30 and 40^{0}C, sampled periodically and tested for seed germination and vigour showed that conductivity of seed leachates increased about two fold during storage for all cultivars.

2.2 Effect of osmopriming on cytological characters

2.2.1 Mitotic studies and chromosomal aberrations

Results of ageing of isolated embryos and endosperms of durum wheat indicated that both aged embryos and endosperms produced mutagenic substances capable of inducing nuclear damage in the form of aberrant anaphases and chromatid and chromosome breaks in the radicle meristem, and age induced damage in embryo was not a consequence of endosperm aging (Floris and Anguillesi, 1974).

Harrison and Perry (1976) reported that respiration rate, dehydrogenase and diastase activities of germinating deteriorated barley seeds were less than those of non deteriorated and the integrity of cell membranes was affected. They also opined that the principal site of deterioration which affected seedling growth lay in the embryo.

Mozaffari and Gahan (1978) reported that mitotic activity was found to decline with age in root apices of maizes, pea and *Vicia faba*. Besides this there was higher levels of spontaneous chromosome aberration on aging of the root apex.

Chauhan and Swaminathan (1984) reported that the progeny of aged seeds of soyabean and barley showed a marked decrease in mitotic index and chromosomal aberrations of various types increased at both mitotisis and meiosis, resulting in a significant loss of pollen viability as the ageing advanced.

The results of a research conducted by Rotn (1986) on the frequency of chromosome aberrations in *Capsicum annuum* L. seeds selected to different aging treatments showed that the highest percentages of cells without aberrations were found with the least severe treatment, which also caused least loss in viability.

Rao and Roberts (1989) reported that meiotic chromosomal abnormalities observed in lettuce plants grown from aged seeds increased with decrease in viability of the seed lot. Univalents, fragments and a few cases of precocious segregation was observed at metaphase I. Abnormalities found at anaphases I and II included dicentric bridges with or without fragments, acentric fragments and lagging chromosomes and chromatids.

Gray *et al.* (1990) reported that seeds of carrot, onion and leek when soaked in water and in PEG 6000 solutions of nominal osmotic potentials of -0.5, -1.0, -1.5, -2.0, -3.0 and -4.0 MPa for 28 days, he got linear relationship between response to priming and seed moisture content of each species. Priming increased embryo volume by 43 per cent and cell number per embryo by 100 per cent in carrots but had no effect in leek and onion.

Ashraf and Bray (1993) reported that constant low levels of DNA synthesis occur on leek seed embryos during osmopriming treatment in polyethylene glycol. After one day of germination following priming, enhanced levels of both replicative and repair type DNA synthesis was detected in nuclear and mito chondria in the absence of detectable cell division.

Post storage humidification treatments conducted on pea cv. Kelvedon Wonder showed that 16^0C was the optimum temperature for the humidification of aged seeds. There was generally a considerable decrease in each type of chromosomal aberration after humidification treatments, greatest reduction being observed in chromatid type aberrations (Sivritepe and Dourado, 1994).

Dimitrov (1994) observed chromosomal aberrations on metaphase chromosomes in the first and second mitosis of primary root cells from artificially aged seeds of *Crepis capillaris*.

An investigation conducted by Saracco *etal.* (1995) on the influence of priming induced nuclear replication activity on storability of pepper (*Capsicum annuum* L.) seeds

showed that priming at - 1.1 MPa for 10 days induced almost 40 per cent of nuclei in the embryo root tips to enter the synthetic phase of nuclear division.

According to Garcia *et al.* (1995), osmopriming maize seeds in PEG 6000 at –1.7 MPa improved germinability when osmotic agent was removed. At the biochemical level, embryo axes from osmoprimed seeds could incorporate precursors into all three types of macro molecules (DNA, RNA and proteins) which induced synthesis at much higher levels. Mitotic figures appeared several hours earlier in germinated osmoprimed root tissues than in non osmoprimed tissues.

Ageing of tomato seeds (cv.Lerica) resulted in a significant decrease in seed quality as evidenced by decreases in total germination, percentage of normal seedlings and the uniformity of germination. Cytological analysis showed that decrease in seed quality by aging correlated well with the increase in percentage aberrant anaphases in the root tips of the seedlings (Van *et al.*, 1995)

According to Sivritepe and Dourado (1995), post storage priming treatments at 16^0C with PEG 8000(-0.5, -1.0 and -1.2 MPa) for 3, 5 and 7 days increased final germination and decreased the mean germination time and the frequency of age induced damage. They also suggested that the critical moisture content that facilitates repair of chromosomal damage in pea seeds is likely to be between 32 and 46 per cent.

Van *et al.* (1996) reported that osmopriming tomato seeds strongly increased the percentage of nuclei with replicated DNA in the embryonic root tip, indicating initiation of the cell cycle and progression towards the G_2 phase.

Bino *et al.* (1996) found that during imbibition of tomato seeds in PEG solution there was an increase in cells entering in the synthetic phase of nuclear division leading to doubling of the chromosomal material.

Coello and Ramos (1996) inferred that during the germination of artificially deteriorated maize embryo axes, total DNA polymerase activity decreased by around 50 per cent when compared with activity in non-deteriorated axes. This decrease in activity was related to protein degradation during germination.

Lanteri *et al.* (1992) observed that osmopriming *Capsicum annuum* seeds on filter paper wetted with PEG 6000 for one to two weeks in the dark considerably reduced germination time without affecting germination percentage. They opined that improved seed performance following osmopriming may be partially correlated with the activity of replicative DNA synthetic processes.

Lanteri *et al.* (1996) studied the effect of osmoconditioning with PEG 6000 solution at osmotic potential –1.1 and -1.5 MPa on aged damaged seeds of capsicum cv. Corno di Toro for 6, 10 and 14 days. The effect of osmoconditioning on germination of aged seeds depended on the degree of seed deterioration. The activation of under replication by osmoconditioning appeared to be influenced by the level of seed deterioration.

Materials and methods

MATERIALS AND METHODS

The experiment designed to fulfill the objectives set in 'Cytological and biochemical changes in aged and osmoprimed seeds of chilli (*Capsicum annuum* L.) was conducted during the year 1997 to 1998 in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara.

3.1 Materials

3.1.1 Plant material and chemicals

The seeds of chilli (*Capsicum annum* L.) varieties Jwalasakhi and Ujwala purchased from College of Agriculture, Vellayani and College of Horticulture, Vellanikkara respectively were used for this study. The seeds were kept under ambient storage conditions in 250 gauge polythene cover. The important details of the varieties are given here under.

Features	Jwalasakhi	Ujwala
Parentage	Selection from the cross Vellanochi x Pusa Jwala,	Introduction from Japanese material CA 219
Centre of release	College of Agriculture, Vellayani, Kerala Agricultural University	College of Horticulture, Vellanikkara, Kerala Agricultural University
Fruit characterisites	sulphury green, long succulent fruits	highly pungent, erect, borne in clusters, 9 to 10 fruits per cluster, characterised by high oleoresin content (24 %)
Resistance to diseases	tolerant to little leaf and leaf spot diseases.	resistant to bacterial wilt

The chemicals used for osmopriming treatments include polyethylene glycol 6000 and sodium chloride.

3.1.2 Equipments used

i. Digital conductivity meter	CM – 180, Elico Pvt. Ltd.
ii. Spectrophotometer	Mini spec, SL 171, Elico Pvt. Ltd.
iii. BOD incubator	NSW India, Narang Scientific works Pvt. Ltd.
iv. Ordinary microscope	Ernst Leitz Wetzlar
v. Microscope	Leitz BIOMED

3.1.3 Treatments

At each month 74 treatment combination comprising factorial combinations of two varieties, two chemicals, four concentrations and four durations were tried continued upto ten months. The control treatments include untreated and distilled water treated seeds.

Sl. No.	Factors	Levels	Code
(i)	Variety	(a) Jwalasakhi	V_1
		(b) Ujwala	V_2
(ii)	Chemical	(a) Polyethylene glycol (PEG - 6000)	H_2
		(b) Sodium chloride (Na Cl)	H_1
(iii)	Concentration	(a) –1.00 MPa	C_1
		(b) –1.50 MPa	C_2
		(c) –1.75 MPa	C_3
		(d) –2.00 MPa	C_4
(iv)	Duration	(a) 12 hr	D_1
		(b) 24 hr	D_2
		(c) 36 hr	D_3
		(d) 48 hr	D_4

1 Chilli plant var. Jwalasakhi

2 Chilli plant var. Ujwala

3.1.4 Design

The experiment was conducted in Completely Randomised Design with three replications.

3.2 Methodology

3.2.1 Seed Osmopriming

Random samples were drawn from the seedlots at monthly interval upto 10 months of storage and subjected to osmopriming treatments. Seed priming was carried out on filter paper wetted with PEG 6000 and Na Cl at osmotic potentials 1.0 MPa, -1.5 MPa, -1.75 MPa and –2.0 MPa for durations 12, 24, 36 and 48 hours respectively at 20°C. The concentrations of PEG 6000 was calculated according to Michel and Kaufmann (1973) and Na Cl according to Hillel (1980). After priming seeds were washed with running tap water to remove the osmotic agent and surface dried. The osmoprimed seeds were tested for various seed quality parameters.

3.3 Observations

3.3.1 Seed and seedling characters

(i) Germination percentage

A total number of 3 x 25 osmoprimed seeds selected at random were placed in sterilized sand medium and allowed to germinate under ambient conditions. The seedlings were watered daily. The seedlings were evaluated on the fourteenth day after sowing (final count day) and the total number of seedlings were recorded. The mean number of seedlings were recorded. The mean number of seedlings produced to the total number of seeds sown was expressed as germination percentage.

(ii) Root length of seedling

At the end of the germination test period i.e. on the final count day, five normal seedlings were carefully uprooted at random from the test sample and measured the root length and computed the mean. The length between collar and tip of the root was measured as root length and expressed in centimeter (cm).

(iii) Shoot length of seedling

From the sample after measuring root length, the length between collar and tip of the leaf was measured in centimeter and the mean value was recorded as shoot length.

(iv) Root / shoot ratio

It is calculated as the ratio of mean root length to the shoot length.

(v) Uniformity in germination

Treatments recording 50 per cent germination on the seventh day (first count day) after sowing were considered as uniform.

(vi) Vigour index of seedling

Vigour index was computed adapting the following formula (Abdul - Baki and Anderson, 1970).

Vigour index = Germination percentage x Mean length of seedling

where, Length of seedling = root length + shoot length

(v) Seedling abnormalities

Seedlings lacking the essential structures like well developed and intact root system, hypocotyl, plumule and one or two cotyledons according to the species are abnormal seedlings (ISTA, 1985).

The percentage of abnormal seedlings are expressed as percentage by number of total seedlings. The percentage calculated to the (normal) nearest whole number.

3.3.2 Biochemical aspects

(i) Dehydrogenase enzyme activity

Dehydrogenase activity was measured as per the procedure suggested by Kittock and Law (1986). Three replicates of 20 seeds were soaked in distilled water overnight to allow imbibition. The seeds were cut longitudinally on next day and placed in 10 ml. of 0.5 per cent tetrazolium solution taken in a petridish for four hours for the development of

red coloured formazan. The excess tetrazolium solution was decanted and the seeds were washed thoroughly with distilled water. Red coloured formazan was extracted using 20 ml methyl cellosolve (2 - methoxyethanol) by soaking the cotyledons for 22 hours until the cotyledons became colourless. The red coloured methyl cellosolve extract was made upto 20 ml and absorbance was read at 480 nm using spectrophotometer (Mini spec. SL 171).

(ii) Estimation of protein

Protein content of osmoprimed seeds was estimated by Lowry's method (Lowry *et al.*, 1951)

Reagents

A. 2 % sodium carbonate in 0.1 N sodium hydroxide
B. 0.5 % copper sulphate in 1 % potassium sodium tartrate
C. Alkaline copper solution : Mixed 50 ml A and 1 ml B prior to use
D. Folin – ciocalteau Reagent

Protein solution

Weighed accurately 50 mg bovine serum albumin, dissolved in distilled water and made upto 50 ml in a standard flask.

Working standard

Diluted 10 ml of the stock solution to 50 ml with distilled water in a standard flask. One ml of this solution contains 200 µg protein.

Seed extract

Seed (0.5 g) was extracted with 10 ml of extraction buffer (pH 7) by grinding in a precooled mortar and pestle. The homogenised material was centrifuged at 18000 rpm for 15 minutes. The supernatent solution was used for the estimation of protein.

Procedure

Pipetted out 0.2, 0.4, 0.6, 0.8 and 1 ml of working standard solutions into a series of test tubes and 0.1 ml and 0.2 ml of the sample extract in two other test tubes. Made up the volume to 1 ml with distilled water in all the test tubes. A tube with one ml. of water served as the blank. Added 5 ml of reagent C to each tube including blank, mixed well and allowed to stand for 10 minutes. Then added 0.5 ml of reagent and mixed well and kept for 30 minutes at room temperature in dark. The blue colour which developed was read at 660 nm in spectrophotometer. A standard graph was drawn by plotting the OD values against concentration. The amount of protein in the sample was calculated from the standard graph and expressed as mg per g sample.

(iii) Electrical conductivity of seed leachate

Electrical conductivity of seed leachate was measured by the method suggested by (Presley, 1958). Three replicates of twenty five seeds were taken and washed with distilled water to remove all dirt, soil or chemicals. The seeds were soaked in 20 ml of distilled water for four hours by stirring the contents occasionally. The seed leachate was decanted and seeds were repeatedly washed with distilled water. The extract was pooled filtered and made up to 50 ml with distilled water. The electrical conductivity of seed leachate was measured using a digital conductivity meter. The electrical conductivity of seed leachate was expressed in mmhos cm^{-1}.

3.3.3 Cytological studies

Mitotic studies of the two chilli varieties were carried out using root tip squash method.

(i) Fixation

The roots of germinating chilli seeds were excised between 10 to 10.15 a.m. The tip of roots were white in colour. The roots were blotted between folds of filter paper and fixed in the fixative for 24 hours. The fixed material was stored in refrigerator.

Carnoy's fluid was used for fixing chilli roots. This was prepared by mixing one part of glacial acetic acid, 3 parts chloroform and 6 parts ethyl alcohol.

(ii) Staining

The fixed roots were thoroughly washed in running water to remove traces of fixative. After washing, the roots were blotted between folds of filter paper. They were then hydrolysed using 1 N HCl at 60^0C for six to seven minutes in a water bath. The hydrolysed roots were washed with three to four changes of water in a petridish. Washed roots were blotted between folds of filter paper and stained.

Acetocarmine two per cent was used for the mitotic studies in the present investigation. The stain was prepared by heating 100 ml of 45 per cent acetic acid in a conical flask until boiling. Then two grams of carmine powder was added to it with constant stirring. Boiling was continued for two to three minutes until the dye got dissolved and the colour changed to grape red. The stain was cooled at room temperature, filtered and stored in a glass stoppered bottle (Sharma and Sharma, 1980).

(iii) Slide preparation

After staining, the root tips were taken out from the stain and put on a slide along with a drop of stain. The tip portion with high meristematic activity which attained characteristic magenta colour was collected and the remaining portion was discarded. A cover slip was placed carefully over the root tip avoiding air bubbles. Gentle tapping was done over the cover slip using the blunt end of a glass rod. Then it was put between folds of filter paper and hand pressed using index finger. After pressing, the slide was warmed slightly over a spirit lamp and allowed to cool. Alternate warming and cooling was repeated three to four times. Again, the slide was placed between thick folds of filter paper and hand pressed. The slides thus prepared were sealed with nailpolish to prevent entry of air bubbles and mitotic cells were examined. Microphotograps were taken using Leitz BIOMED microscop, with automatic photocontrol unit, WILD MPS 28.

(iv) Mitotic index

Two to three random fields from each slide were scanned for scoring dividing and nondividing cells in all the treatments and controls. The dividing cells included those showing any stage of cell division, such as prophase, metaphase, anaphase and telophase. Mitotic index was calculated using the formula,

$$\text{Mitotic index (MI)} = \frac{\text{Number of dividing cells}}{\text{Total number of cells scored}} \times 100$$

(v) Scoring of chromosomal aberrations

The slides prepared from the root tips of the treated and control experiments were scanned thoroughly for various types of abnormalities in different stages of cell division.

3.4 Statistical analysis

Statistical analysis of the data was done in computer using MSTATC package in factorial completely randomised design.

Results

RESULTS

The results obtained in the present investigation "Cytological and biochemical changes in aged and osmoprimed seeds of chilli (*Capsicum annuum* L.)" are given below in various sections.

4.1 Seedling characters

4.1.1 Germination percentage

The mean data on germination percentage in chilli varieties Jwalasakhi and Ujwala are given in Table 1a and 1b.

It is clearly evident from the overall mean values for germination that in the absolute control where no treatment were given to the seeds the germination per cent drastically reduced to 52 or below from third month onwards and seeds not at all germinated during ninth and tenth month. This effect was appreciably reduced by osmopriming in general.

When seeds were treated with water the germination per cent could be improved considerably over absolute control, even the seeds germinated to the tune of 13 per cent (Jwalasakhi) and 20 per cent (Ujwala) in the ninth month and 12 per cent (Jwalasakhi) and 16 per cent (Ujwala) in the tenth month. Further more than 50 per cent germination could be achieved up to fourth month. In general 12 hour water treatment is sufficient for the variety Jwalasakhi while 36 to 48 hour treatment was found to be better in case of Ujwala.

Application of chemicals specifically sodium chloride was found to be the better in improving germination of the seeds at various months over that of water treatment. Interestingly germination could be retained more than 50 per cent up to tenth month of storage due to chemical treatments at variable concentrations.

The main effects of variety, chemical, concentration, duration of treatment and period of storage on germination are given in Table 2

Variety Ujwala showed significantly higher germination per cent (58.54) than the variety Jwalasakhi (55.31). The chemical sodium chloride significantly improved germination per cent (59.10) compared to PEG (54.75). The concentration of the chemicals tried i.e. -1.0 MPa, -1.5 MPa, -1.75 MPa and -2.00 MPa imparted significant

Table 1a. Effect of osmopriming on germination percentage in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	86.67	80.67	72.00	62.00	46.67	43.33	42.67	36.00	30.67	36.00	32.00
$V_1H_1C_1D_2$	81.33	77.33	68.00	58.67	48.00	34.67	45.33	36.00	33.33	37.33	32.00
$V_1H_1C_1D_3$	81.33	72.00	62.67	49.33	53.33	57.33	46.67	45.33	42.67	37.33	40.00
$V_1H_1C_1D_4$	84.00	77.33	77.33	64.00	72.00	68.00	61.33	60.00	44.00	54.67	46.67
$V_1H_1C_2D_1$	77.33	69.33	68.00	54.67	58.67	49.33	53.33	48.00	44.00	48.00	50.67
$V_1H_1C_2D_2$	82.67	78.67	80.00	64.00	60.00	52.00	57.33	57.33	58.67	44.00	22.67
$V_1H_1C_2D_3$	82.67	77.33	72.00	68.00	61.33	60.00	58.67	54.67	46.67	40.00	32.00
$V_1H_1C_2D_4$	80.00	74.67	72.00	62.67	54.67	46.67	54.67	53.33	53.33	36.00	42.67
$V_1H_1C_3D_1$	78.67	74.67	72.00	58.67	56.00	53.33	53.33	48.00	49.33	53.33	48.00
$V_1H_1C_3D_2$	85.33	81.33	73.33	62.67	60.00	56.00	49.33	57.33	60.00	45.33	33.33
$V_1H_1C_3D_3$	81.33	76.00	76.00	73.33	64.00	57.33	52.00	50.67	48.00	50.67	50.67
$V_1H_1C_3D_4$	80.00	72.00	65.33	57.33	57.33	42.67	48.00	48.00	46.67	37.33	37.33
$V_1H_1C_4D_1$	86.67	74.67	77.33	78.67	69.33	68.00	65.33	60.00	50.67	52.00	49.33
$V_1H_1C_4D_2$	76.00	61.33	53.33	53.33	52.00	58.67	48.00	41.33	41.33	36.00	25.33
$V_1H_1C_4D_3$	81.33	70.67	56.00	57.33	52.00	52.00	48.00	50.67	56.00	44.00	42.67
$V_1H_1C_4D_4$	85.33	81.33	68.00	49.33	57.33	45.33	50.67	40.00	48.00	48.00	38.67
$V_1H_2C_1D_1$	92.00	89.33	76.00	68.00	62.67	65.33	62.67	56.00	49.33	33.33	29.33
$V_1H_2C_1D_2$	81.33	77.33	72.00	58.67	64.00	48.00	52.00	49.33	32.00	26.67	10.67
$V_1H_2C_1D_3$	78.67	72.00	68.00	54.67	53.33	46.67	45.33	44.00	42.67	46.67	48.00
$V_1H_2C_1D_4$	80.00	65.33	54.67	48.00	46.67	38.67	33.33	37.33	37.33	33.33	29.00
$V_1H_2C_2D_1$	76.00	66.67	58.67	56.00	48.00	52.00	41.33	32.00	29.33	20.67	19.00
$V_1H_2C_2D_2$	89.33	82.67	65.33	54.67	60.00	57.33	53.33	52.00	46.67	34.67	24.00
$V_1H_2C_2D_3$	85.33	74 67	68.00	57.33	60.00	61.33	54.67	54.67	44.00	38.67	10.67
$V_1H_2C_2D_4$	84.00	80.00	70.67	62.67	60.00	56.00	57.33	53.33	54.67	54.67	49.33
$V_1H_2C_3D_1$	81.33	77.33	64.00	57.33	50.67	46.67	50.67	49.33	50.67	36.00	21.33
$V_1H_2C_3D_2$	80.00	72.00	66.67	60.00	56.00	49.33	52.00	46.67	38.67	38.67	24.00
$V_1H_2C_3D_3$	78 67	76.00	66.67	64.00	54.67	52.00	50.67	48.00	46.67	40.00	33.33
$V_1H_2C_3D_4$	85.33	77.33	70.67	64.00	52.00	52.00	52.00	48.00	44.00	34.67	13.33
$V_1H_2C_4D_1$	85.33	73.33	69.33	60.00	52.00	48.00	46.67	46.67	45.33	32.00	20.00
$V_1H_2C_4D_2$	80.00	73.33	68.00	61.33	61.33	65.33	52.00	49.33	46.67	32.00	6.67
$V_1H_2C_4D_3$	80.00	72.00	69.33	60.00	50.67	37.33	38.67	40.00	36.00	28.00	16.00
$V_1H_2C_4D_4$	85.33	77.33	72.00	60.00	52.00	54.67	46.67	46.67	50.67	33.33	29.33
V_1O	81.33	76.00	52.00	40.00	38.67	40.00	25.33	21.33	16.00	0.00	0.00
V_1WD_1	89.33	86.67	65.33	56.00	52.00	42.67	42.67	37.33	28.00	13.33	12.00
V_1WD_2	78.67	70.67	57.33	48.00	38.67	28.00	33.33	25.33	24.00	10.67	0.00
V_1WD_3	82.67	77.33	68.00	56.00	49.33	48.00	36.00	24.00	14.67	8.00	6.00
V_1WD_4	80.00	74.67	64.00	46.67	44.00	41.33	33.33	20.00	12.00	8.00	8.00
CD	7.97	10.14	7.96	10.22	8.35	9.90	7.72	7.44	8.85	11.82	9.88

Table 1b. Effect of osmopriming on germination percentage in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	92.00	89.33	82.00	64.00	62.67	57.33	46.67	44.00	36.00	33.33	24.00
$V_2H_1C_1D_2$	82.67	78.67	74.67	62.67	56.00	56.00	50.67	46.67	40.00	48.00	33.33
$V_2H_1C_1D_3$	90.67	88.00	76.00	66.67	64.00	61.33	61.33	54.67	45.33	37.33	36.00
$V_2H_1C_1D_4$	81.33	77.33	68.00	64.00	58.67	57.33	57.33	50.67	49.33	48.00	42.67
$V_2H_1C_2D_1$	82.67	76.00	70.67	62.67	56.00	49.33	44.00	46.67	44.00	46.67	50.67
$V_2H_1C_2D_2$	98.67	92.00	82.67	72.00	62.67	53.33	53.33	46.67	45.33	45.33	45.33
$V_2H_1C_2D_3$	97.33	92.00	85.33	65.33	60.00	54.67	49.33	50.67	53.33	36.00	30.67
$V_2H_1C_2D_4$	94.67	89.33	77.33	70.67	65.33	60.00	58.67	56.00	56.00	52.00	52.00
$V_2H_1C_3D_1$	93.33	89.33	81.33	72.00	64.00	60.00	58.67	57.33	65.33	52.00	49.33
$V_2H_1C_3D_2$	88.00	82.67	73.33	65.33	62.67	64.00	52.00	48.00	36.00	37.33	30.67
$V_2H_1C_3D_3$	86.67	81.33	76.00	64.00	57.33	49.33	50.67	50.67	50.67	44.00	44.00
$V_2H_1C_3D_4$	90.67	89.33	82.67	76.00	64.00	70.67	64.00	56.00	65.33	56.00	46.67
$V_2H_1C_4D_1$	89.33	81.33	69.33	62.67	57.33	52.00	53.33	49.33	52.00	44.00	37.33
$V_2H_1C_4D_2$	86.67	86.67	81.33	64.00	60.00	56.00	52.00	50.67	52.00	42.67	37.33
$V_2H_1C_4D_3$	82.67	78.67	70.67	64.00	60.00	50.67	53.33	48.00	49.33	44.00	42.67
$V_2H_1C_4D_4$	84.00	80.00	72.00	66.67	60.00	50.67	50.67	48.00	42.67	44.00	42.67
$V_2H_2C_1D_1$	88.00	82.67	72.00	62.67	52.00	53.33	49.33	48.00	11.00	40.00	36.00
$V_2H_2C_1D_2$	88.00	84.00	68.00	61.33	54.67	50.67	49.33	44.00	38.67	40.00	36.00
$V_2H_2C_1D_3$	88.00	78.67	72.00	61.33	58.67	52.00	48.00	46.67	45.33	44.00	42.67
$V_2H_2C_1D_4$	88.00	84.00	81.33	73.33	69.33	65.33	56.00	52.00	45.33	44.00	30.67
$V_2H_2C_2D_1$	96.00	93.33	89.33	72.00	61.33	50.67	53.33	52.00	50.67	42.67	33.33
$V_2H_2C_2D_2$	93.33	85.33	76.00	66.67	57.33	48.00	48.00	46.67	38.67	42.67	20.67
$V_2H_2C_2D_3$	90.67	88.00	81.33	68.00	57.33	52.00	50.67	50.67	45.33	44.00	45.33
$V_2H_2C_2D_4$	84.00	74.67	65.33	58.67	56.00	45.33	49.33	50.67	48.00	56.00	45.33
$V_2H_2C_3D_1$	82.67	82.67	70.67	65.33	54.67	49.33	49.33	46.67	41.33	33.33	25.33
$V_2H_2C_3D_2$	92.00	92.00	78.67	68.00	53.33	52.00	49.33	50.67	49.33	37.33	29.33
$V_2H_2C_3D_3$	76.00	72.00	61.33	54.67	49.33	46.67	44.00	40.00	34.67	38.00	0.00
$V_2H_2C_3D_4$	88.00	88.00	72.00	64.00	64.00	65.33	52.00	46.67	46.67	44.00	28.00
$V_2H_2C_4D_1$	88.00	81.33	69.33	65.33	56.00	49.33	48.00	50.67	45.33	44.00	37.33
$V_2H_2C_4D_2$	86.67	81.33	64.00	60.00	56.00	54.67	48.00	46.67	46.67	36.00	20.00
$V_2H_2C_4D_3$	77.33	64.00	56.00	52.00	48.00	48.00	38.67	32.00	32.67	26.67	20.00
$V_2H_2C_4D_4$	88.00	84.00	78.67	65.33	58.67	49.33	50.67	46.67	46.67	32.00	25.33
V_2O	82.67	78.67	49.33	34.67	33.33	28.00	16.00	4.00	2.67	0.00	0.00
V_2WD_1	86.67	85.33	64.00	56.00	52.00	52.00	44.00	36.00	18.67	20.00	16.00
V_2WD_2	93.33	90.67	68.00	52.00	44.00	29.33	30.67	28.00	26.67	9.33	8.00
V_2WD_3	92.00	89.33	64.00	62.67	52.00	37.33	38.67	25.33	29.33	9.33	5.33
V_2WD_4	96.00	94.67	69.33	54.67	53.33	46.67	46.67	42.67	28.00	9.33	13.33
CD	7.97	10.14	7.96	10.22	8.35	9.90	7.72	7.44	8.85	11.82	9.88

Table 2 Main effects of Variety, Chemical, Concentration, Duration and Period of storage on germination, vigour index and root shoot ratio

a. Variety

Variety	Germination	Vigour index	Root shoot ratio
V_1	55.31	366.26	0.341
V_2	58.54	413.23	0.332
CD	0.60	3.81	0.005

b. Chemical

Chemical	Germination	Vigour index	Root shoot ratio
H_1	59.10	395.58	0.341
H_2	54.75	383.92	0.333
CD	0.60	3.81	0.003

c. Concentration

Concentration	Germination	Vigour index	Root shoot ratio
C_1	56.20	383.73	0.326
C_2	58.43	397.77	0.332
C_3	57.85	396.52	0.339
C_4	55.25	381.09	0.350
CD	0.69	5.39	0.005

d. Duration

Duration	Germination	Vigour index	Root shoot ratio
D_1	57.23	390.12	0.336
D_2	56.35	387.84	0.334
D_3	55.61	382.97	0.336
D_4	58.54	398.18	0.341
CD	0.69	5.39	0.005

e. Period of storage

Month	Germination	Vigour index	Root shoot ratio
M_0	85.15	687.16	0.378
M_1	79.28	611.20	0.360
M_2	71.45	533.48	0.355
M_3	62.53	448.27	0.333
M_4	57.56	398.82	0.335
M_5	53.75	354.46	0.330
M_6	51.00	324.75	0.328
M_7	48.35	294.52	0.318
M_8	44.80	259.31	0.339
M_9	40.45	218.68	0.317
M_{10}	31.89	158.56	0.307
CD	0.97713	0.945	0.008

Table 3a Effect of osmopriming on uniformity in germination (%) in chilli variety Jwalasakhi

Treatments	0		1		2		3		4		5		6		7		8		9		10	
	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day
$V_1H_1C_1D_1$	86.67	86.67	80.67	80.67	72.00	72.00	62.00	62.00	46.67	46.67	73.33	73.33	42.67	42.67	36.00	36.00	30.67	30.67	36.00	36.00	32.00	32.00
$V_1H_1C_1D_2$	81.33	81.33	77.33	77.33	68.00	68.00	58.67	58.67	48.00	48.00	34.67	34.67	45.33	45.33	36.00	36.00	33.33	33.33	37.33	37.33	32.00	32.00
$V_1H_1C_1D_3$	81.33	81.33	72.00	72.00	62.67	62.67	49.33	49.33	53.33	53.33	57.33	57.33	46.67	46.67	45.33	45.33	42.67	42.67	37.33	37.33	40.00	40.00
$V_1H_1C_1D_4$	84.00	84.00	77.33	77.33	77.33	77.33	64.00	64.00	72.00	72.00	68.00	68.00	61.33	61.33	60.00	60.00	44.00	44.00	54.67	54.67	46.67	46.67
$V_1H_1C_2D_1$	77.33	77.33	69.33	69.33	68.00	68.00	54.67	54.67	58.67	58.67	49.33	49.33	53.33	53.33	48.00	48.00	44.00	44.00	48.00	48.00	50.67	50.67
$V_1H_1C_2D_2$	82.67	82.67	78.67	78.67	80.00	80.00	64.00	64.00	60.00	60.00	52.00	52.00	57.33	57.33	57.33	57.33	58.67	58.67	44.00	44.00	22.67	22.67
$V_1H_1C_2D_3$	82.67	82.67	77.33	77.33	72.00	72.00	68.00	68.00	61.33	61.33	60.00	60.00	58.67	58.67	54.67	54.67	46.67	46.67	40.00	40.00	32.00	32.00
$V_1H_1C_2D_4$	80.00	80.00	74.67	74.67	72.00	72.00	62.67	62.67	54.67	54.67	46.67	46.67	54.67	54.67	53.33	53.33	53.33	53.33	36.00	36.00	42.67	42.67
$V_1H_1C_3D_1$	78.67	78.67	74.67	74.67	72.00	72.00	58.67	58.67	56.00	56.00	53.33	53.33	53.33	53.33	48.00	48.00	49.33	49.33	53.33	53.33	48.00	48.00
$V_1H_1C_3D_2$	85.33	85.33	81.33	81.33	73.33	73.33	62.67	62.67	60.00	60.00	56.00	56.00	49.33	49.33	57.33	57.33	60.00	60.00	45.33	45.33	33.33	33.33
$V_1H_1C_3D_3$	81.33	81.33	76.00	76.00	76.00	76.00	73.33	73.33	64.00	64.00	57.33	57.33	52.00	52.00	50.67	50.67	48.00	48.00	50.67	50.67	50.67	50.67
$V_1H_1C_3D_4$	80.00	80.00	72.00	72.00	65.33	65.33	57.33	57.33	57.33	57.33	42.67	42.67	48.00	48.00	48.00	48.00	46.67	46.67	37.33	37.33	37.33	37.33
$V_1H_1C_4D_1$	86.67	86.67	74.67	74.67	77.33	77.33	78.67	78.67	69.33	69.33	68.00	68.00	65.33	65.33	60.00	60.00	50.67	50.67	52.00	52.00	49.33	49.33
$V_1H_1C_4D_2$	76.00	76.00	61.33	61.33	53.33	53.33	53.33	53.33	52.00	52.00	58.67	58.67	48.00	48.00	41.33	41.33	41.33	41.33	36.00	36.00	25.33	25.33
$V_1H_1C_4D_3$	81.33	81.33	70.67	70.67	56.00	56.00	57.33	57.33	52.00	52.00	52.00	52.00	48.00	48.00	50.67	50.67	56.00	56.00	44.00	44.00	42.67	42.67
$V_1H_1C_4D_4$	85.33	85.33	81.33	81.33	68.00	68.00	49.33	49.33	57.33	57.33	45.33	45.33	50.67	50.67	40.00	40.00	48.00	48.00	48.00	48.00	38.67	38.67
$V_1H_2C_1D_1$	92.00	92.00	89.33	89.33	76.00	76.00	68.00	68.00	62.67	62.67	65.33	65.33	62.67	62.67	56.00	56.00	49.33	49.33	33.33	33.33	29.33	29.33
$V_1H_2C_1D_2$	81.33	81.33	77.33	77.33	72.00	72.00	58.67	58.67	64.00	64.00	48.00	48.00	52.00	52.00	49.33	49.33	32.00	32.00	26.67	26.67	10.67	10.67
$V_1H_2C_1D_3$	78.67	78.67	72.00	72.00	68.00	68.00	54.67	54.67	53.33	53.33	46.67	46.67	45.33	45.33	44.00	44.00	42.67	42.67	46.67	46.67	48.00	48.00
$V_1H_2C_1D_4$	80.00	80.00	65.33	65.33	54.67	54.67	48.00	48.00	46.67	46.67	38.67	38.67	33.33	33.33	37.33	37.33	37.33	37.33	33.33	33.33	29.00	29.00
$V_1H_2C_2D_1$	76.00	76.00	66.67	66.67	58.67	58.67	56.00	56.00	48.00	48.00	52.00	52.00	41.33	41.33	32.00	32.00	29.33	29.33	20.67	20.67	19.00	19.00
$V_1H_2C_2D_2$	89.33	89.33	82.67	82.67	65.33	65.33	54.67	54.67	60.00	60.00	57.33	57.33	53.33	53.33	52.00	52.00	46.67	46.67	34.67	34.67	24.00	24.00
$V_1H_2C_2D_3$	85.33	85.33	74.67	74.67	68.00	68.00	57.33	57.33	60.00	60.00	61.33	61.33	54.67	54.67	54.67	54.67	44.00	44.00	38.67	38.67	10.67	10.67
$V_1H_2C_2D_4$	84.00	84.00	80.00	80.00	70.67	70.67	62.67	62.67	60.00	60.00	56.00	56.00	57.33	57.33	53.33	53.33	54.67	54.67	54.67	54.67	49.33	49.33
$V_1H_2C_3D_1$	81.33	81.33	77.33	77.33	64.00	64.00	57.33	57.33	50.67	50.67	46.67	46.67	50.67	50.67	49.33	49.33	50.67	50.67	36.00	36.00	21.33	21.33
$V_1H_2C_3D_2$	80.00	80.00	72.00	72.00	66.67	66.67	60.00	60.00	56.00	56.00	49.33	49.33	52.00	52.00	46.67	46.67	38.67	38.67	38.67	38.67	24.00	24.00
$V_1H_2C_3D_3$	78.67	78.67	76.00	76.00	66.67	66.67	64.00	64.00	54.67	54.67	52.00	52.00	50.67	50.67	48.00	48.00	46.67	46.67	40.00	40.00	33.33	33.33
$V_1H_2C_3D_4$	85.33	85.33	77.33	77.33	70.67	70.67	64.00	64.00	52.00	52.00	52.00	52.00	52.00	52.00	48.00	48.00	44.00	44.00	34.67	34.67	13.33	13.33
$V_1H_2C_4D_1$	85.33	85.33	73.33	73.33	69.33	69.33	60.00	60.00	52.00	52.00	48.00	48.00	46.67	46.67	46.67	46.67	45.33	45.33	32.00	32.00	20.00	20.00
$V_1H_2C_4D_2$	80.00	80.00	73.33	73.33	68.00	68.00	61.33	61.33	61.33	61.33	65.33	65.33	52.00	52.00	49.33	49.33	46.67	46.67	32.00	32.00	6.67	6.67
$V_1H_2C_4D_3$	80.00	80.00	72.00	72.00	69.33	69.33	60.00	60.00	50.67	50.67	37.33	37.33	38.67	38.67	40.00	40.00	36.00	36.00	28.00	28.00	16.00	16.00
$V_1H_2C_4D_4$	85.33	85.33	77.33	77.33	72.00	72.00	60.00	60.00	52.00	52.00	54.67	54.67	46.67	46.67	46.67	46.67	50.67	50.67	33.33	33.33	29.33	29.33
V_1O	41.33	81.33	37.33	76.00	22.67	52.00	14.67	40.00	13.33	38.67	13.33	40.00	13.33	25.33	6.67	21.33	10.00	16.00	0.00	0.00	0.00	0.00
V_1WD_1	46.67	89.33	45.33	86.67	29.33	65.33	20.00	56.00	14.67	52.00	18.67	42.67	12.00	42.67	6.67	37.33	5.30	28.00	3.00	13.33	0.33	12.00
V_1WD_2	41.33	78.67	40.00	70.67	29.33	57.33	22.67	48.00	12.00	38.67	8.00	28.00	12.00	33.33	4.00	25.33	3.00	24.00	2.00	10.67	0.00	0.00
V_1WD_3	44.00	82.67	41.33	77.33	30.67	68.00	24.00	56.00	17.33	49.33	13.33	48.00	10.60	36.00	6.67	24.00	4.33	14.67	2.00	8.00	0.33	6.00
V_1WD_4	42.67	80.00	37.33	74.67	29.33	64.00	20.00	46.67	18.67	44.00	18.67	41.33	37.30	33.33	5.30	20.00	2.00	12.00	1.60	8.00	0.33	8.00

Table 3b. Effect of osmopriming on uniformity in germination (%) in chilli variety Ujwala

Treatments	0		1		2		3		4		5		6		7		8		9		10	
	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day
$V_2H_1C_1D_1$	92.00	92.00	89.33	89.33	82.00	82.00	64.00	64.00	62.67	62.67	57.33	57.33	46.67	46.67	44.00	44.00	36.00	36.00	33.33	33.33	24.00	24.00
$V_2H_1C_1D_2$	82.67	82.67	78.67	78.67	74.67	74.67	62.67	62.67	56.00	56.00	56.00	56.00	50.67	50.67	46.67	46.67	40.00	40.00	48.00	48.00	33.33	33.33
$V_2H_1C_1D_3$	90.67	90.67	88.00	88.00	76.00	76.00	66.67	66.67	64.00	64.00	61.33	61.33	61.33	61.33	54.67	54.67	45.33	45.33	37.33	37.33	16.00	16.00
$V_2H_1C_1D_4$	81.33	81.33	77.33	77.33	68.00	68.00	64.00	64.00	58.67	58.67	57.33	57.33	57.33	57.33	50.67	50.67	49.33	49.33	48.00	48.00	42.67	42.67
$V_2H_1C_2D_1$	82.67	82.67	76.00	76.00	70.67	70.67	62.67	62.67	56.00	56.00	49.33	49.33	44.00	44.00	46.67	46.67	44.00	44.00	46.67	46.67	50.67	50.67
$V_2H_1C_2D_2$	98.67	98.67	92.00	92.00	82.67	82.67	72.00	72.00	62.67	62.67	53.33	53.33	53.33	53.33	46.67	46.67	45.33	45.33	45.33	45.33	45.33	45.33
$V_2H_1C_2D_3$	97.33	97.33	92.00	92.00	85.33	85.33	65.33	65.33	60.00	60.00	54.67	54.67	49.33	49.33	50.67	50.67	53.33	53.33	36.00	36.00	30.67	30.67
$V_2H_1C_2D_4$	94.67	94.67	89.33	89.33	77.33	77.33	70.67	70.67	65.33	65.33	60.00	60.00	58.67	58.67	56.00	56.00	56.00	56.00	52.00	52.00	52.00	52.00
$V_2H_1C_3D_1$	93.33	93.33	89.33	89.33	81.33	81.33	72.00	72.00	64.00	64.00	60.00	60.00	58.67	58.67	57.33	57.33	65.33	65.33	52.00	52.00	49.33	49.33
$V_2H_1C_3D_2$	88.00	88.00	82.67	82.67	73.33	73.33	65.33	65.33	62.67	62.67	64.00	64.00	52.00	52.00	48.00	48.00	36.00	36.00	37.33	37.33	30.67	30.67
$V_2H_1C_3D_3$	86.67	86.67	81.33	81.33	76.00	76.00	64.00	64.00	57.33	57.33	49.33	49.33	50.67	50.67	50.67	50.67	50.67	50.67	44.00	44.00	44.00	44.00
$V_2H_1C_3D_4$	90.67	90.67	89.33	89.33	82.67	82.67	76.00	76.00	64.00	64.00	70.67	70.67	64.00	64.00	56.00	56.00	65.33	65.33	56.00	56.00	46.67	46.67
$V_2H_1C_4D_1$	89.33	89.33	81.33	81.33	69.33	69.33	62.67	62.67	57.33	57.33	52.00	52.00	53.33	53.33	49.33	49.33	52.00	52.00	44.00	44.00	37.33	37.33
$V_2H_1C_4D_2$	86.67	86.67	86.67	86.67	81.33	81.33	64.00	64.00	60.00	60.00	56.00	56.00	52.00	52.00	50.67	50.67	52.00	52.00	42.67	42.67	37.33	37.33
$V_2H_1C_4D_3$	82.67	82.67	78.67	78.67	70.67	70.67	64.00	64.00	60.00	60.00	50.67	50.67	53.33	53.33	48.00	48.00	49.33	49.33	44.00	44.00	42.67	42.67
$V_2H_1C_4D_4$	84.00	84.00	80.00	80.00	72.00	72.00	66.67	66.67	60.00	60.00	50.67	50.67	50.67	50.67	48.00	48.00	42.67	42.67	44.00	44.00	42.67	42.67
$V_2H_2C_1D_1$	88.00	88.00	82.67	82.67	72.00	72.00	62.67	62.67	52.00	52.00	53.33	53.33	49.33	49.33	48.00	48.00	11.00	11.00	40.00	40.00	36.00	36.00
$V_2H_2C_1D_2$	88.00	88.00	84.00	84.00	68.00	68.00	61.33	61.33	54.67	54.67	50.67	50.67	49.33	49.33	44.00	44.00	38.67	38.67	40.00	40.00	36.00	36.00
$V_2H_2C_1D_3$	88.00	88.00	78.67	78.67	72.00	72.00	61.33	61.33	58.67	58.67	52.00	52.00	48.00	48.00	46.67	46.67	45.33	45.33	44.00	44.00	42.67	42.67
$V_2H_2C_1D_4$	88.00	88.00	84.00	84.00	81.33	81.33	73.33	73.33	69.33	69.33	65.33	65.33	56.00	56.00	52.00	52.00	45.33	45.33	44.00	44.00	30.67	30.67
$V_2H_2C_2D_1$	96.00	96.00	93.33	93.33	89.33	89.33	72.00	72.00	61.33	61.33	50.67	50.67	53.33	53.33	52.00	52.00	50.67	50.67	42.67	42.67	33.33	33.33
$V_2H_2C_2D_2$	93.33	93.33	85.33	85.33	76.00	76.00	66.67	66.67	57.33	57.33	48.00	48.00	48.00	48.00	46.67	46.67	38.67	38.67	42.67	42.67	20.67	20.67
$V_2H_2C_2D_3$	90.67	90.67	88.00	88.00	81.33	81.33	68.00	68.00	57.33	57.33	52.00	52.00	50.67	50.67	50.67	50.67	45.33	45.33	44.00	44.00	45.33	45.33
$V_2H_2C_2D_4$	84.00	84.00	74.67	74.67	65.33	65.33	58.67	58.67	56.00	56.00	45.33	45.33	49.33	49.33	50.67	50.67	48.00	48.00	56.00	56.00	45.33	45.33
$V_2H_2C_3D_1$	82.67	82.67	82.67	82.67	70.67	70.67	65.33	65.33	54.67	54.67	49.33	49.33	49.33	49.33	46.67	46.67	41.33	41.33	33.33	33.33	25.33	25.33
$V_2H_2C_3D_2$	92.00	92.00	92.00	92.00	78.67	78.67	68.00	68.00	53.33	53.33	52.00	52.00	49.33	49.33	50.67	50.67	49.33	49.33	37.33	37.33	29.33	29.33
$V_2H_2C_3D_3$	76.00	76.00	72.00	72.00	61.33	61.33	54.67	54.67	49.33	49.33	46.67	46.67	44.00	44.00	40.00	40.00	34.67	34.67	38.00	38.00	20.00	20.00
$V_2H_2C_3D_4$	88.00	88.00	88.00	88.00	72.00	72.00	64.00	64.00	64.00	64.00	65.33	65.33	52.00	52.00	46.67	46.67	46.67	46.67	44.00	44.00	28.00	28.00
$V_2H_2C_4D_1$	88.00	88.00	81.33	81.33	69.33	69.33	65.33	65.33	56.00	56.00	49.33	49.33	48.00	48.00	50.67	50.67	45.33	45.33	44.00	44.00	37.33	37.33
$V_2H_2C_4D_2$	86.67	86.67	81.33	81.33	64.00	64.00	60.00	60.00	56.00	56.00	54.67	54.67	48.00	48.00	46.67	46.67	46.67	46.67	36.00	36.00	20.00	20.00
$V_2H_2C_4D_3$	77.33	77.33	64.00	64.00	56.00	56.00	52.00	52.00	48.00	48.00	48.00	48.00	38.67	38.67	32.00	32.00	32.67	32.67	26.67	26.67	20.00	20.00
$V_2H_2C_4D_4$	88.00	88.00	84.00	84.00	78.67	78.67	65.33	65.33	58.67	58.67	49.33	49.33	50.67	50.67	46.67	46.67	46.67	46.67	32.00	32.00	25.33	25.33
V_2O	41.33	82.67	36.00	76.67	25.33	49.33	21.33	34.67	11.33	33.33	10.67	28.00	6.67	16.00	0.33	4.00	0.00	2.67	0.00	0.00	0.00	0.00
V_2WD_1	52.00	86.67	44.00	85.33	33.33	64.00	22.67	56.00	18.67	52.00	14.67	52.00	8.00	44.00	6.67	36.00	6.67	18.67	5.33	20.00	4.00	16.00
V_2WD_2	53.33	93.33	46.67	90.67	37.33	68.00	25.33	52.00	18.67	44.00	9.33	29.33	10.67	30.67	5.33	28.00	5.33	26.67	1.67	9.33	1.30	8.00
V_2WD_3	50.67	92.00	46.67	89.33	33.33	64.00	19.33	62.67	14.67	52.00	9.33	37.33	12.00	38.67	5.33	25.33	5.33	29.33	2.00	9.33	0.00	5.33
V_2WD_4	54.66	96.00	52.00	94.67	33.33	69.33	22.67	54.67	13.33	53.33	10.67	46.67	12.00	46.67	9.33	42.67	4.00	28.00	2.00	9.33	4.00	13.33

variations in germination. The highest germination percentage (58.43) was recorded by C_2 (-1.5 MPa) and lowest C_4 (-2.0 MPa). The osmopriming treatment duration selected also differed significantly with D_4 (48 hour) registering the highest germination percentage (58.54). As time elapsed from the first month to tenth month of storage the germination percentage remarkably reduced from 85.5 in the first month to 31.88 showing the germination being reduced below 80 per cent from the second month onwards.

4.1.2 Uniformity in germination

The mean data on uniformity in germination of chilli varieties Jwalasakhi and Ujwala are presented in Table 3a and 3b.

When no treatment was given for germination, the time for 50 per cent germination was delayed beyond seven days. Water treatment could not considerably enhance early germination compared to absolute control except in the months of 7, 8, 9 and 10.

Both the varieties completed 50 per cent of its germination within seven days of its sowing irrespective of the chemicals tried and its various concentrations. This trend was maintained in case of all storage time i.e. one to ten months.

4.1.3 Vigour index (VI)

The mean data on vigour index given in Table 4a and 4b showed that the vigour index for absolute control is significantly lower than that for chemical and water treated seeds at all the months of storage. Both the varieties recorded progressive and significant reduction in vigour index values as the time elapsed from one to ten months of storage.

When seeds were treated with water alone or chemicals the vigour index improved significantly over the absolute control. Water treated seeds recorded statistically similar vigour index as that of chemical treatments for the first three months for both the varieties. After that chemical treated seeds put up higher vigour index significantly above that of water treated seeds. In most of the months both the chemicals i.e. sodium chloride and PEG induced statistically similar vigour index. However for the variety Ujwala sodium chloride was found to be more advantageous and for Jwalasakhi, PEG.

Table 4a. Effect of osmopriming on vigour index in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	591.67	583.33	424.53	339.33	280.00	221.87	191.73	180.93	180.67	170.00	130.67
$V_1H_1C_1D_2$	642.67	517.87	441.73	373.07	301.60	186.67	215.87	185.07	184.67	172.53	131.73
$V_1H_1C_1D_3$	658.80	457.47	410.80	252.53	428.27	319.73	278.80	241.80	206.00	164.40	173.33
$V_1H_1C_1D_4$	738.13	561.87	543.20	405.60	455.07	376.67	337.07	273.73	210.40	252.13	185.07
$V_1H_1C_2D_1$	662.27	492.27	448.80	349.87	331.47	295.87	305.07	256.40	229.47	249.20	226.27
$V_1H_1C_2D_2$	592.00	562.40	514.93	391.07	354.00	348.67	296.47	313.33	297.33	206.62	79.20
$V_1H_1C_2D_3$	709.73	614.67	455.87	419.47	372.40	348.40	273.07	271.33	258.13	189.73	93.87
$V_1H_1C_2D_4$	586.53	556.80	505.73	417.33	342.27	295.07	322.40	298.27	295.20	178 53	176.80
$V_1H_1C_3D_1$	589.07	589.73	536.53	414.40	358.40	336.00	328.53	277.20	316.40	271.33	221.73
$V_1H_1C_3D_2$	643.47	604.67	544.93	449.60	350.13	354.80	324.80	322.80	304.93	222.67	150.13
$V_1H_1C_3D_3$	615.47	544.27	481.73	618.40	392.27	351.67	320.80	304.53	245.33	244.00	234.67
$V_1H_1C_3D_4$	612.53	521.60	460.13	399.47	372.13	307.87	303.20	283.07	235.07	187.73	156.53
$V_1H_1C_4D_1$	688.27	537.87	553.87	547.20	524.13	432.80	409.87	362.00	224.53	239.33	218.80
$V_1H_1C_4D_2$	587.73	429.20	372.27	367.60	313.07	349.60	294.40	232.13	189.07	183.33	121.07
$V_1H_1C_4D_3$	607.20	528.53	409.20	403.33	343.20	334.13	305.60	291.47	282.67	224 67	201.73
$V_1H_1C_4D_4$	622.13	577.20	455.33	324.27	425.73	296.00	321.20	242.80	262.53	248.40	184.13
$V_1H_2C_1D_1$	770.00	693.87	573.20	496.40	449.47	413.47	439.60	373.47	318.80	194.27	164.27
$V_1H_2C_1D_2$	672.00	598.13	542.40	476.80	447.73	319.20	350.27	332.13	197.87	166.27	61.87
$V_1H_2C_1D_3$	648.40	554.13	523.60	390.00	380.67	336.27	310.93	295.73	280.27	287.33	283.20
$V_1H_2C_1D_4$	670.67	511.33	409.73	318.80	314.67	266.80	222.93	242.40	235.07	205.60	146.93
$V_1H_2C_2D_1$	604.13	500.80	442.00	337.87	325.60	348.80	272.80	207.20	146.93	107.87	79.20
$V_1H_2C_2D_2$	720.40	625.60	477.87	394.40	407.07	393.73	355.47	341.47	294.00	209.60	136.27
$V_1H_2C_2D_3$	703.20	579.20	522.80	361.87	408.27	452.00	384.53	360.93	285.73	222.53	60.53
$V_1H_2C_2D_4$	658.00	605.20	520.53	475.80	401.73	387.73	380.53	341.47	329.47	326.13	283.47
$V_1H_2C_3D_1$	637.60	593.33	499.07	433.73	349.07	311.33	321.33	316.27	314.13	208.67	116.80
$V_1H_2C_3D_2$	646.27	553.07	513.60	428.00	397.33	326.53	339.33	282.67	236.93	222.93	129.33
$V_1H_2C_3D_3$	630.13	582.67	500.00	469.33	356.00	334.53	315.73	294.40	284.27	235.87	184.53
$V_1H_2C_3D_4$	675.47	587.47	526.00	443.60	366.93	347.87	341.47	302.13	283.47	209.07	74.93
$V_1H_2C_4D_1$	681.60	562.67	511.20	430.27	351.87	310.67	297.07	286.27	268.93	186.53	107.87
$V_1H_2C_4D_2$	613.87	564.67	509.87	433.47	423.47	450.93	348.40	307.60	276.80	181 20	32.40
$V_1H_2C_4D_3$	646.00	551.47	533.73	421.60	334.93	252.40	253.07	249.33	219.47	153.33	81.20
$V_1H_2C_4D_4$	666.67	587.60	542.53	423.47	339.47	351.87	298.27	290.00	295.33	172.13	146.93
V_1O	656.40	602.93	359.60	257.60	212.93	212.00	122.67	92.27	66.67	0.00	0.00
V_1WD_1	735.33	684.40	494.67	397.73	274.53	246.00	223.33	175.40	121.60	48.80	36.00
V_1WD_2	658.53	572.53	439.20	348.40	236.53	154.13	174.13	119.87	101.07	34.27	0.00
V_1WD_3	672.53	610.67	529.87	390.00	297.47	271.07	188.80	107.47	66.40	36.13	8.53
V_1WD_4	642.00	610.67	471.60	328.60	306.53	246.40	185.60	93.87	50.93	30.00	22.93
CD	116.73	83.50	66.72	78.90	72.18	63.33	52.12	55.50	58.89	95.65	55.59

Table 4b. Effect of osmopriming on vigour index in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	758.00	700.13	617.67	462.80	432.27	397.60	296.40	259.33	216.00	192.80	114.13
$V_2H_1C_1D_2$	676.53	620.67	564.53	455.47	393.20	385.93	320.53	301.87	238.40	267.33	170.00
$V_2H_1C_1D_3$	773.60	713.20	572.13	511.73	469.20	425.33	415.20	338.93	275.73	201.87	193.00
$V_2H_1C_1D_4$	683.73	634.53	528.27	482.00	436.13	409.07	390.00	327.73	296.80	276.80	224.00
$V_2H_1C_2D_1$	664.80	598.53	536.80	461.60	403.33	345.47	296.53	299.73	233.87	256.80	256.00
$V_2H_1C_2D_2$	838.67	726.80	642.27	537.13	457.33	375.20	352.40	295.73	265.87	247.47	238.67
$V_2H_1C_2D_3$	791.87	732.53	662.53	496.67	479.73	399.07	337.07	330.93	342.93	210.13	164.00
$V_2H_1C_2D_4$	794.67	687.07	570.67	541.33	487.73	428.53	398.80	364.00	368.00	306.80	286.27
$V_2H_1C_3D_1$	749.60	699.60	620.67	544.00	469.60	428.40	374.53	339.87	387.60	304.93	269.87
$V_2H_1C_3D_2$	744.67	669.87	575.07	498.67	455.33	450.53	339.60	294.80	220.93	220.27	170.27
$V_2H_1C_3D_3$	716.93	653.33	593.07	492.67	454.13	358.80	339.60	318.13	317.87	273.60	242.00
$V_2H_1C_3D_4$	545.93	717.73	628.13	559.73	479.20	507.47	427.07	366.27	403.07	322.13	246.80
$V_2H_1C_4D_1$	731.87	645.33	536.27	469.87	379.07	360.53	353.73	344.53	298.27	250.53	193.33
$V_2H_1C_4D_2$	716.13	690.13	623.33	475.87	425.47	403.60	352.93	337.73	303.87	234.00	190.53
$V_2H_1C_4D_3$	708.13	647.87	553.60	488.80	449.60	361.47	375.20	318.27	290.93	243.47	225.33
$V_2H_1C_4D_4$	697.33	634.67	549.73	497.73	409.20	346.00	330.67	301.07	270.67	254.13	220.00
$V_2H_2C_1D_1$	727.60	652.80	605.07	455.33	369.60	349.07	327.47	302.67	62.77	236.00	195.73
$V_2H_2C_1D_2$	718.67	668.40	508.80	451.73	389.73	347.73	320.67	277.33	231.33	230.53	198.13
$V_2H_2C_1D_3$	738.67	584.93	556.53	456.00	437.33	372.27	302.00	284.53	272.00	247.60	228.53
$V_2H_2C_1D_4$	721.73	664.27	617.87	537.73	476.00	446.13	347.20	325.73	261.73	238.80	164.13
$V_2H_2C_2D_1$	774.93	725.47	673.20	515.20	423.07	333.00	339.47	315.47	290.80	234.67	160.67
$V_2H_2C_2D_2$	774.67	682.67	582.67	509.07	418.67	320.67	304.13	281.33	227.74	231.60	89.60
$V_2H_2C_2D_3$	758.67	706.80	634.67	517.07	378.27	338.80	319.20	308.80	248.67	233.20	217.73
$V_2H_2C_2D_4$	696.93	618.67	490.00	434.00	388.27	302.00	311.33	310.27	272.00	241.07	200.53
$V_2H_2C_3D_1$	675.20	647.33	522.80	473.20	384.80	310.93	315.73	270.40	244.53	176.00	119.33
$V_2H_2C_3D_2$	775.73	751.33	608.40	505.20	370.00	351.87	310.80	303.87	279.87	226.13	143.73
$V_2H_2C_3D_3$	662.40	554.00	461.87	406.40	344.27	304.80	283.07	237.07	183.47	114.13	89.60
$V_2H_2C_3D_4$	712.53	671.60	556.53	469.60	409.47	426.53	315.20	273.87	273.60	251.20	143.33
$V_2H_2C_4D_1$	768.53	681.47	554.27	476.80	462.00	318.93	327.73	309.33	270.93	257.33	202.13
$V_2H_2C_4D_2$	722.13	631.73	494.93	452.27	435.47	384.27	338.80	295.47	272.80	200.53	111.73
$V_2H_2C_4D_3$	634.80	507.60	434.27	386.67	339.87	319.60	239.73	205.20	116.00	96.25	89.60
$V_2H_2C_4D_4$	730.67	665.07	630.13	458.93	418.40	315.87	320.40	248.53	256.27	180.40	130.53
V_2O	644.93	613.47	372.93	236.27	202.93	157.87	74.00	17.87	12.67	0.00	0.00
V_2WD_1	688.80	660.87	486.93	414.15	314.93	305.08	227.07	180.80	132.40	82.53	80.27
V_2WD_2	732.27	704.63	491.33	355.20	236.67	203.33	156.27	144.67	117.60	277.73	32.67
V_2WD_3	744.40	732.40	482.53	397.73	386.67	197.33	204.53	122.67	135.07	40.67	66.67
V_2WD_4	788.80	750.67	535.47	371.07	284.67	274.27	229.60	206.00	140.27	168.53	63.33
CD	116.73	83.50	66.72	78.90	72.18	63.33	52.12	55.50	58.89	95.65	55.59

Table 5a. Effect of osmopriming on root shoot ratio in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	0.367	0.377	0.360	0.340	0.330	0.347	0.437	0.337	0.337	0.293	0.380
$V_1H_1C_1D_2$	0.363	0.377	0.390	0.410	0.397	0.457	0.360	0.407	0.420	0.323	0.357
$V_1H_1C_1D_3$	0.350	0.353	0.370	0.370	0.337	0.353	0.400	0.367	0.490	0.300	0.463
$V_1H_1C_1D_4$	0.357	0.363	0.383	0.367	0.370	0.310	0.333	0.327	0.373	0.387	0.477
$V_1H_1C_2D_1$	0.420	0.393	0.380	0.333	0.307	0.320	0.313	0.287	0.357	0.337	0.347
$V_1H_1C_2D_2$	0.413	0.420	0.407	0.323	0.400	0.330	0.333	0.327	0.433	0.297	0.307
$V_1H_1C_2D_3$	0.383	0.383	0.357	0.330	0.330	0.330	0.343	0.283	0.327	0.313	0.357
$V_1H_1C_2D_4$	0.393	0.400	0.377	0.357	0.353	0.400	0.373	0.303	0.353	0.370	0.380
$V_1H_1C_3D_1$	0.383	0.380	0.367	0.367	0.350	0.360	0.363	0.333	0.420	0.340	0.290
$V_1H_1C_3D_2$	0.397	0.403	0.370	0.350	0.343	0.347	0.393	0.300	0.370	0.357	0.290
$V_1H_1C_3D_3$	0.360	0.370	0.377	0.341	0.370	0.343	0.377	0.323	0.400	0.330	0.310
$V_1H_1C_3D_4$	0.403	0.390	0.343	0.350	0.320	0.340	0.370	0.340	0.427	0.373	0.340
$V_1H_1C_4D_1$	0.383	0.390	0.360	0.350	0.353	0.367	0.360	0.340	0.367	0.390	0.377
$V_1H_1C_4D_2$	0.380	0.380	0.393	0.353	0.290	0.307	0.347	0.330	0.457	0.417	0.360
$V_1H_1C_4D_3$	0.393	0.377	0.380	0.340	0.387	0.367	0.373	0.300	0.360	0.390	0.337
$V_1H_1C_4D_4$	0.407	0.380	0.367	0.380	0.407	0.333	0.350	0.340	0.463	0.450	0.407
$V_1H_2C_1D_1$	0.410	0.387	0.397	0.340	0.410	0.377	0.377	0.327	0.277	0.250	0.250
$V_1H_2C_1D_2$	0.390	0.387	0.370	0.303	0.247	0.273	0.267	0.230	0.253	0.233	0.207
$V_1H_2C_1D_3$	0.370	0.380	0.373	0.297	0.283	0.310	0.277	0.287	0.290	0.267	0.240
$V_1H_2C_1D_4$	0.380	0.377	0.337	0.273	0.287	0.277	0.273	0.253	0.250	0.257	0.210
$V_1H_2C_2D_1$	0.377	0.363	0.360	0.330	0.387	0.313	0.300	0.303	0.283	0.270	0.243
$V_1H_2C_2D_2$	0.387	0.367	0.303	0.310	0.373	0.310	0.300	0.313	0.303	0.270	0.243
$V_1H_2C_2D_3$	0.440	0.363	0.377	0.333	0.363	0.340	0.320	0.303	0.303	0.277	0.247
$V_1H_2C_2D_4$	0.357	0.397	0.340	0.337	0.307	0.323	0.310	0.297	0.277	0.297	0.257
$V_1H_2C_3D_1$	0.370	0.363	0.353	0.343	0.333	0.323	0.313	0.297	0.337	0.267	0.273
$V_1H_2C_3D_2$	0.357	0.357	0.463	0.303	0.317	0.320	0.307	0.297	0.287	0.273	0.247
$V_1H_2C_3D_3$	0.397	0.393	0.340	0.350	0.270	0.340	0.327	0.333	0.307	0.280	0.247
$V_1H_2C_3D_4$	0.370	0.370	0.327	0.260	0.320	0.313	0.313	0.323	0.323	0.273	0.243
$V_1H_2C_4D_1$	0.357	0.360	0.323	0.323	0.253	0.347	0.323	0.327	0.313	0.300	0.267
$V_1H_2C_4D_2$	0.363	0.367	0.333	0.293	0.300	0.380	0.323	0.317	0.290	0.280	0.313
$V_1H_2C_4D_3$	0.373	0.377	0.367	0.297	0.280	0.357	0.337	0.317	0.293	0.283	0.277
$V_1H_2C_4D_4$	0.370	0.360	0.340	0.320	0.337	0.340	0.317	0.327	0.323	0.343	0.310
V_1O	0.367	0.353	0.300	0.303	0.370	0.297	0.293	0.333	0.330	*	*
V_1WD_1	0.367	0.363	0.327	0.283	0.297	0.273	0.320	0.335	0.397	0.373	0.270
V_1WD_2	0.340	0.343	0.320	0.290	0.273	0.280	0.295	0.317	0.347	0.373	*
V_1WD_3	0.340	0.347	0.307	0.267	0.257	0.310	0.345	0.337	0.463	0.333	0.247
V_1WD_4	0.330	0.330	0.300	0.270	0.283	0.297	0.345	0.320	0.337	0.370	0.407
CD	0.051	0.051	0.051	0.051	0.088	0.051	0.051	0.051	1.102	0.072	0.088

* No germination

Table 5b. Effect of osmopriming on root shoot ratio in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	0.390	0.343	0.323	0.310	0.287	0.283	0.273	0.267	0.243	0.280	0.290
$V_2H_1C_1D_2$	0.337	0.337	0.313	0.317	0.280	0.293	0.280	0.283	0.253	0.273	0.253
$V_2H_1C_1D_3$	0.333	0.333	0.323	0.337	0.230	0.293	0.293	0.293	0.370	0.290	0.277
$V_2H_1C_1D_4$	0.353	0.360	0.343	0.347	0.320	0.320	0.293	0.287	0.333	0.293	0.277
$V_2H_1C_2D_1$	0.360	0.353	0.347	0.340	0.303	0.297	0.287	0.270	0.273	0.270	0.250
$V_2H_1C_2D_2$	0.350	0.363	0.353	0.350	0.310	0.287	0.293	0.283	0.313	0.300	0.287
$V_2H_1C_2D_3$	0.380	0.357	0.353	0.357	0.397	0.310	0.307	0.297	0.327	0.287	0.260
$V_2H_1C_2D_4$	0.377	0.353	0.357	0.370	0.333	0.320	0.323	0.303	0.350	0.300	0.290
$V_2H_1C_3D_1$	0.353	0.367	0.357	0.360	0.323	0.320	0.310	0.310	0.290	0.323	0.300
$V_2H_1C_3D_2$	0.353	0.360	0.350	0.340	0.293	0.303	0.307	0.297	0.307	0.320	0.297
$V_2H_1C_3D_3$	0.347	0.353	0.343	0.333	0.377	0.300	0.293	0.293	0.353	0.333	0.320
$V_2H_1C_3D_4$	0.400	0.360	0.337	0.340	0.437	0.323	0.297	0.313	0.310	0.310	0.317
$V_2H_1C_4D_1$	0.367	0.353	0.333	0.340	0.273	0.297	0.290	0.303	0.310	0.340	0.373
$V_2H_1C_4D_2$	0.377	0.360	0.343	0.343	0.257	0.293	0.280	0.290	0.267	0.253	0.267
$V_2H_1C_4D_3$	0.363	0.327	0.320	0.313	0.323	0.287	0.293	0.290	0.290	0.320	0.273
$V_2H_1C_4D_4$	0.380	0.343	0.330	0.337	0.290	0.297	0.290	0.323	0.370	0.337	0.277
$V_2H_2C_1D_1$	0.387	0.357	0.350	0.320	0.303	0.293	0.290	0.293	0.313	0.303	0.257
$V_2H_2C_1D_2$	0.360	0.350	0.337	0.323	0.313	0.303	0.280	0.313	0.283	0.263	0.337
$V_2H_2C_1D_3$	0.370	0.357	0.347	0.333	0.333	0.307	0.303	0.323	0.320	0.313	0.320
$V_2H_2C_1D_4$	0.373	0.360	0.360	0.343	0.313	0.377	0.310	0.303	0.280	0.263	0.250
$V_2H_2C_2D_1$	0.383	0.363	0.350	0.317	0.327	0.320	0.337	0.320	0.337	0.287	0.243
$V_2H_2C_2D_2$	0.347	0.333	0.323	0.353	0.353	0.343	0.327	0.313	0.330	0.300	0.323
$V_2H_2C_2D_3$	0.373	0.343	0.340	0.350	0.363	0.317	0.340	0.323	0.297	0.317	0.323
$V_2H_2C_2D_4$	0.340	0.343	0.317	0.337	0.323	0.343	0.327	0.347	0.350	0.353	0.253
$V_2H_2C_3D_1$	0.353	0.333	0.313	0.330	0.380	0.313	0.333	0.340	0.383	0.377	0.333
$V_2H_2C_3D_2$	0.343	0.337	0.337	0.337	0.283	0.310	0.313	0.347	0.371	0.333	0.290
$V_2H_2C_3D_3$	0.337	0.340	0.330	0.360	0.340	0.353	0.377	0.334	0.337	0.290	0.310
$V_2H_2C_3D_4$	0.440	0.363	0.350	0.330	0.330	0.373	0.333	0.370	0.430	0.473	0.400
$V_2H_2C_4D_1$	0.457	0.393	0.370	0.280	0.530	0.373	0.427	0.417	0.397	0.380	0.397
$V_2H_2C_4D_2$	0.507	0.377	0.367	0.303	0.480	0.417	0.440	0.407	0.437	0.367	0.437
$V_2H_2C_4D_3$	0.383	0.367	0.387	0.320	0.360	0.340	0.373	0.443	0.427	0.357	0.390
$V_2H_2C_4D_4$	0.370	0.397	0.403	0.280	0.363	0.360	0.360	0.347	0.390	0.380	0.350
V_2O	0.377	0.343	0.353	0.240	0.320	0.380	0.313	0.303	0.430	*	*
V_2WD_1	0.360	0.357	0.280	0.300	0.273	0.410	0.423	0.360	0.457	0.487	0.383
V_2WD_2	0.363	0.363	0.307	0.240	0.263	0.347	0.383	0.453	0.447	0.503	0.470
V_2WD_3	0.367	0.350	0.353	0.233	0.420	0.377	0.410	0.407	0.497	0.427	0.413
V_2WD_4	0.380	0.367	0.380	0.257	0.260	0.367	0.397	0.350	0.423	0.437	0.470
CD	0.051	0.051	0.051	0.051	0.088	0.051	0.051	0.051	1.102	0.072	0.088

* No germination

Table 6a. Effect of osmopriming on seedling abnormalities (%) in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_1D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_1D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_1D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_2D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_2D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_2D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_2D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_3D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_3D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_3D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_3D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_4D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_4D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_4D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_1C_4D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_1D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_1D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_1D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_1D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_2D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_2D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_2D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_2D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_3D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_3D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_3D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_3D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_4D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_4D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_4D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_1H_2C_4D_4$	0	0	0	0	0	0	0	0	0	0	0
V_1O	0	0	0	0	0	0	0	0	52	*	*
V_1WD_1	0	0	0	0	0	0	0	0	35	100	100
V_1WD_2	0	0	0	0	0	0	0	0	26	100	*
V_1WD_3	0	0	0	0	0	0	0	0	30	100	100
V_1WD_4	0	0	0	0	0	0	0	0	40	100	100

* No germination

Table 6b. Effect of osmopriming on seedling abnormalities (%) in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_1D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_1D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_1D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_2D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_2D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_2D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_2D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_3D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_3D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_3D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_3D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_4D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_4D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_4D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_1C_4D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_1D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_1D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_1D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_1D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_2D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_2D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_2D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_2D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_3D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_3D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_3D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_3D_4$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_4D_1$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_4D_2$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_4D_3$	0	0	0	0	0	0	0	0	0	0	0
$V_2H_2C_4D_4$	0	0	0	0	0	0	0	0	0	0	0
V_2O	0	0	0	0	0	0	0	0	35	*	*
V_2WD_1	0	0	0	0	0	0	0	0	10	100	100
V_2WD_2	0	0	0	0	0	0	0	0	20	100	100
V_2WD_3	0	0	0	0	0	0	0	0	25	100	100
V_2WD_4	0	0	0	0	0	0	0	0	30	100	100

* No germination

The main effects of variety, chemical, concentration, duration of treatment and period of storage on vigour index are given in Table 2.

Variety Ujwala showed significantly high vigour index (413.23) than the variety Jwalasakhi (366.26). Among chemicals sodium chloride gave the highest mean vigour index of 395.57 compared to PEG (383.92). Among the concentrations of the chemicals tried C_2 (-1.5 MPa) and C_3 (-1.75 MPa) differed significantly from C_1 (-1.0 MPa) and C_4 (-2.0 MPa). The highest value for vigour index (397.77) was registered by concentration C_2 (-1.5 MPa). The treatment duration, 48 hours registered the highest value for vigour index. Fresh seeds showed maximum vigour index (687.16) and that at tenth month showed the least (158.56). Vigour index progressively reduced as the time elapsed from one to ten months.

4.1.4 Root - shoot ratio

The overall mean values for root shoot ratio calculated from the observations on root length and shoot length on fourteenth day are given in Table 5a and 5b.

In case of both the varieties seeds without any treatment i.e., the absolute control showed a statistically lower root shoot ratio compared to chemically treated seeds, but a root shoot ratio statistically similar to water treated seeds at all the months of storage. In case of variety Jwalasakhi chemically treated seeds recorded higher root shoot ratio up to 7 month of storage compared to water treated seeds and thereafter both the treatments had similar root shoot ratio. But in case of Ujwala water treated seeds and chemical treated seeds produced a statistically similar root shoot ratio except in case of fresh seeds and fourth month of storage.

The main effects of variety, chemical, concentration, duration of treatment and period of storage on root shoot ratio are presented in Table 2

Variety Jwalasakhi recorded significantly higher root - shoot ratio (0.341) compared to Ujwala (0.332) which was 58.7 per cent and 6.86 per cent more when compared to absolute control at tenth month of storage. Among chemicals sodium chloride favoured significantly for higher root - shoot ratio (0.341) compared to PEG (0.331). The concentrations tried showed significant effect on root - shoot ratio with

Table 7. Correlation coefficients of different characters of chilli var. Jwalaskahi and Ujwala

	Root shoot ratio		Electric conductivity		Dehdrogenase activity		Vigour index		Protein		Mitotic index	
	Jwalasakhi	Ujwala	Jwalasakhi	Ujwala	Jwalasakhi	Ujwala	Jwalasakhi	Ujwala	Jwalasakhi	Ujwala	Jwalasakhi	Ujwala
Electric conductivity	-0.238 *	-0.318 **										
Dehdrogenase activity	0.363 **	0.263 **	-0.798 **	-0.705 **								
Vigour index	0.347 **	0.291 **	-0.793 **	-0.731 **	0.872 **	0.927 **						
Protein	0.281 **	0.228 *	-0.521 **	-0.634 **	0.652 **	0.736 **	0.683 **	0.773 **				
Mitotic index	0.388 **	0.268 **	-0.799 **	-0.789 **	0.834 **	0.874 **	0.853 **	0.983 **	0.708 **	0.762 **		
Germination	0.397 **	0.239 *	-0.715 **	-0.680 **	0.808 **	0.892 **	0.936 **	0.966 **	0.662 **	0.760 **	0.822 **	0.880 **

* Significant at 5 % level
** Significant at 1 % level

Table 8a. Effect of osmopriming on dehydrogenase enzyme activity in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	1.378	1.245	0.733	0.667	0.550	0.468	0.351	0.299	0.260	0.297	0.257
$V_1H_1C_1D_2$	1.319	1.190	0.997	0.860	0.795	0.747	0.681	0.531	0.420	0.372	0.245
$V_1H_1C_1D_3$	1.200	1.027	0.838	0.783	0.696	0.592	0.476	0.442	0.420	0.392	0.344
$V_1H_1C_1D_4$	1.352	1.176	0.899	0.853	0.799	0.749	0.687	0.645	0.568	0.519	0.425
$V_1H_1C_2D_1$	1.782	1.560	1.276	0.926	0.831	0.765	0.715	0.626	0.568	0.522	0.442
$V_1H_1C_2D_2$	1.302	1.134	0.665	0.632	0.580	0.574	0.564	0.451	0.397	0.357	0.239
$V_1H_1C_2D_3$	1.271	1.074	0.906	0.841	0.771	0.680	0.574	0.474	0.450	0.433	0.339
$V_1H_1C_2D_4$	1.418	1.172	0.870	0.745	0.689	0.560	0.462	0.377	0.353	0.344	0.233
$V_1H_1C_3D_1$	1.598	1.548	1.090	0.662	0.954	0.820	0.761	0.624	0.557	0.527	0.431
$V_1H_1C_3D_2$	1.628	1.454	0.926	0.856	0.755	0.610	0.575	0.516	0.446	0.394	0.307
$V_1H_1C_3D_3$	1.728	1.610	0.973	0.865	0.770	0.647	0.586	0.521	0.520	0.502	0.477
$V_1H_1C_3D_4$	1.421	1.202	0.968	0.859	0.774	0.650	0.565	0.520	0.468	0.435	0.365
$V_1H_1C_4D_1$	1.402	1.295	0.886	0.727	0.658	0.587	0.546	0.450	0.414	0.344	0.276
$V_1H_1C_4D_2$	1.149	1.055	0.821	0.749	0.645	0.577	0.477	0.435	0.412	0.312	0.311
$V_1H_1C_4D_3$	1.656	1.517	0.926	0.899	0.646	0.611	0.613	0.531	0.437	0.407	0.349
$V_1H_1C_4D_4$	1.715	1.650	1.211	0.763	0.678	0.610	0.588	0.529	0.459	0.415	0.335
$V_1H_2C_1D_1$	1.722	1.672	1.396	0.962	0.885	0.766	0.715	0.613	0.529	0.414	0.278
$V_1H_2C_1D_2$	1.416	1.319	1.247	0.839	0.711	0.672	0.618	0.522	0.435	0.317	0.221
$V_1H_2C_1D_3$	1.203	1.002	0.981	0.751	0.714	0.624	0.556	0.520	0.454	0.322	0.106
$V_1H_2C_1D_4$	1.116	0.978	0.874	0.759	0.740	0.647	0.601	0.530	0.463	0.324	0.103
$V_1H_2C_2D_1$	1.191	0.976	0.823	0.660	0.615	0.554	0.523	0.473	0.440	0.390	0.130
$V_1H_2C_2D_2$	1.438	1.381	0.937	0.825	0.681	0.533	0.516	0.472	0.453	0.331	0.301
$V_1H_2C_2D_3$	1.500	1.366	0.837	0.798	0.718	0.600	0.664	0.514	0.467	0.422	0.216
$V_1H_2C_2D_4$	1.823	1.727	1.517	0.974	0.856	0.779	0.729	0.664	0.631	0.542	0.416
$V_1H_2C_3D_1$	1.725	1.617	0.940	0.804	0.726	0.656	0.572	0.534	0.478	0.353	0.195
$V_1H_2C_3D_2$	1.532	1.481	0.976	0.749	0.719	0.674	0.547	0.477	0.357	0.319	0.204
$V_1H_2C_3D_3$	1.419	1.256	0.667	0.924	0.821	0.667	0.572	0.474	0.433	0.362	0.275
$V_1H_2C_3D_4$	1.606	1.414	0.857	0.705	0.626	0.583	0.503	0.394	0.317	0.298	0.254
$V_1H_2C_4D_1$	1.716	1.569	0.684	0.955	0.883	0.741	0.642	0.578	0.433	0.375	0.302
$V_1H_2C_4D_2$	1.456	1.216	0.930	0.876	0.733	0.648	0.528	0.423	0.382	0.326	0.172
$V_1H_2C_4D_3$	1.436	1.214	0.885	0.725	0.673	0.537	0.510	0.478	0.432	0.335	0.286
$V_1H_2C_4D_4$	1.554	1.321	0.966	0.893	0.644	0.528	0.484	0.464	0.375	0.323	0.250
V_1O	1.661	1.550	0.731	0.584	0.459	0.355	0.307	0.295	0.216	0.177	0.094
V_1WD_1	1.730	1.626	0.939	0.859	0.563	0.382	0.372	0.314	0.291	0.362	0.155
V_1WD_2	1.603	1.411	0.869	0.765	0.626	0.482	0.415	0.364	0.311	0.309	0.083
V_1WD_3	1.396	1.232	0.933	0.723	0.565	0.428	0.448	0.364	0.311	0.252	0.101
V_1WD_4	1.676	1.521	0.826	0.742	0.528	0.461	0.384	0.344	0.306	0.276	0.151
CD	0.051	0.072	0.177	0.114	0.005	0.005	0.005	0.005	0.005	0.051	0.005

Table 8b. Effect of osmopriming on dehydrogenase enzyme activity in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	1.655	1.558	1.256	0.953	0.828	0.762	0.637	0.552	0.443	0.427	0 304
$V_2H_1C_1D_2$	1.658	1.484	0.940	0.792	0.626	0.532	0.516	0.499	0.445	0 402	0 348
$V_2H_1C_1D_3$	1.723	1.593	1.305	0.880	0.762	0.644	0.585	0.517	0.493	0.444	0 384
$V_2H_1C_1D_4$	1.902	1.801	1.190	0.910	0.835	0.685	0.576	0.521	0.490	0.456	0.413
$V_2H_1C_2D_1$	1.596	1.436	0.989	0.922	0.836	0.733	0.655	0.633	0.546	0.588	0.462
$V_2H_1C_2D_2$	1.674	1.521	1.142	0.883	0.736	0.643	0.588	0.525	0.486	0.438	0.309
$V_2H_1C_2D_3$	1.867	1.746	1.202	0.834	0.759	0.627	0.617	0.555	0.443	0.454	0 429
$V_2H_1C_2D_4$	1.744	1.643	1.117	0.974	0.859	0.743	0.676	0.647	0.575	0.549	0.412
$V_2H_1C_3D_1$	1.582	1.505	1.005	0.869	0.768	0.639	0.620	0.536	0.514	0.471	0.464
$V_2H_1C_3D_2$	1.408	1.226	1.087	0.967	0.855	0.721	0.694	0.628	0.527	0.476	0.465
$V_2H_1C_3D_3$	1.413	1.273	1.004	0.830	0.751	0.631	0.589	0.519	0.495	0.482	0.445
$V_2H_1C_3D_4$	1.619	1.456	1.102	0.948	0.785	0.717	0.685	0.677	0.652	0.552	0.430
$V_2H_1C_4D_1$	1.424	1.240	0.943	0.855	0.733	0.658	0.563	0.534	0.475	0.447	0.383
$V_2H_1C_4D_2$	1.621	1.525	0.978	0.857	0.742	0.695	0.587	0.534	0.520	0.463	0 428
$V_2H_1C_4D_3$	1.499	1.255	0.939	0.817	0.761	0.644	0.575	0.521	0.485	0.467	0.450
$V_2H_1C_4D_4$	1.518	1.306	1.013	0.890	0.756	0.685	0.576	0.542	0.520	0.481	0.361
$V_2H_2C_1D_1$	1.700	1.438	0.940	0.852	0.732	0.594	0.545	0.516	0.458	0.434	0 355
$V_2H_2C_1D_2$	1.482	1.304	0.907	0.784	0.632	0.584	0.533	0.492	0.441	0.411	0.369
$V_2H_2C_1D_3$	1.635	1.420	0.904	0.843	0.683	0.583	0.533	0.483	0.424	0.405	0.345
$V_2H_2C_1D_4$	1.707	1.469	0.971	0.819	0.744	0.661	0.535	0.462	0.425	0.378	0.229
$V_2H_2C_2D_1$	1.608	1.429	1.271	0.916	0.726	0.648	0.538	0.479	0.431	0.374	0.298
$V_2H_2C_2D_2$	1.711	1.539	1.165	0.874	0.714	0.647	0.522	0.447	0.420	0.381	0.257
$V_2H_2C_2D_3$	1.638	1.465	0.940	0.865	0.756	0.654	0.574	0.523	0.445	0.308	0.243
$V_2H_2C_2D_4$	1.452	1.223	0.865	0.719	0.630	0.558	0.532	0.473	0.462	0.359	0.318
$V_2H_2C_3D_1$	1.400	1.215	1.010	0.863	0.676	0.646	0.594	0.437	0.375	0.361	0.217
$V_2H_2C_3D_2$	1.804	1.639	1.151	0.865	0.684	0.558	0.525	0.475	0.437	0.382	0.316
$V_2H_2C_3D_3$	1.321	1.190	0.884	0.630	0.552	0.498	0.428	0.421	0.355	0.289	0.103
$V_2H_2C_3D_4$	1.638	1.410	0.937	0.758	0.631	0.592	0.488	0.481	0.443	0.354	0.313
$V_2H_2C_4D_1$	1.416	1.229	1.089	0.864	0.737	0.646	0.571	0.486	0.466	0.432	0.348
$V_2H_2C_4D_2$	1.314	1.171	0.803	0.646	0.536	0.516	0.464	0.428	0.371	0.342	0.218
$V_2H_2C_4D_3$	1.381	1.160	0.739	0.571	0.540	0.522	0.473	0.417	0.356	0.199	0.043
$V_2H_2C_4D_4$	1.617	1.394	0.788	0.674	0.612	0.527	0.511	0.494	0.424	0.316	0.233
V_2O	1.529	1.329	0.731	0.681	0.454	0.315	0.255	0.104	0.016	0.014	0.006
V_2WD_1	1.710	1.525	0.828	0.645	0.555	0.437	0.420	0.376	0.363	0.243	0.203
V_2WD_2	1.786	1.599	0.783	0.549	0.497	0.456	0.411	0.379	0.320	0.263	0 215
V_2WD_3	1.864	1.635	0.859	0.564	0.526	0.445	0.417	0.366	0.263	0.233	0 105
V_2WD_4	2.067	1.910	0.829	0.578	0.465	0.422	0.364	0.358	0.298	0.243	0 225
CD	0.051	0.072	0.177	0.114	0.005	0.005	0.005	0.005	0.005	0.051	0.005

C_4 (-2.0 MPa) recording highest value of 0.350 and C_1 (-1.0 MPa) the least value of 0.326. The osmopriming treatment duration of 48 hour registered the highest value (0.341). A progressive reduction in root - shoot ratio was observed as the time of storage elapsed from one to ten months.

4.1.5 Seedling abnormalities

Observations on seedling abnormalities revealed that in osmoprimed seeds of both the varieties did not show any notable abnormality (Table 6a and 6b). But in case of hydroprimed and untreated seeds abnormalities were evident from eighth month of storage onwards, with ninth and tenth month depicting 100 per cent. The abnormalities included seedlings with stubby radicle and first leaf trapped in the seed coat blocking further development .

The seed and seedling characters like germination per cent, vigour index and root – shoot ratio were found positively correlated (Table 7) for both the varieties.

4.1 Biochemical Observations

4.2.1 Dehydrogenase enzyme activity

The overall mean data of dehydrogenase enzyme activity of chilli varieties Jwalasakhi and Ujwala are presented in Table 8a and 8b.

Seeds treated with water recorded comparatively higher values for enzyme activity than absolute control. After tenth month of storage, the water treated seeds of Ujwala and Jwalasakhi recorded a mean value of 0.187 and 0.122 respectively where as for absolute control it was 0.006 and 0.094. Seeds treated with chemicals found to maintain dehydrogenase enzyme activity better than controls.

The main effects of variety, chemical, concentration and duration of treatment and period of storage on dehdrogenase activity are given in Table 9.

The variety Ujwala registered the highest mean value of 0.772 compared to Jwalasakhi (0.738). Among the chemicals, sodium chloride recorded the highest value of 0.78 where as for PEG it was 0.730. The concentrations showed significant difference with C_2 (-1.5 MPa) recording highest enzyme activity (0.776) and C_4 (-0.2 MPa) the least

Table 9. Main effects of Variety, Chemical, Concentration, Duration and Period of storage on dehydrogenase activity, protein, electrical conductivity and mitotic index

a. Variety

Variety	Dehydrogenase activity	Protein	Electrical conductivity	Mitotic index
V_1	0.738	13.19	0.033	62.84
V_2	0.772	13.69	0.032	62.38
CD	0.004	0.027	0.0003	0.217

b. Chemical

Chemical	Dehydrogenase activity	Protein	Electrical conductivity	Mitotic index
H_1	0.781	13.45	0.035	62.62
H_2	0.730	13.42	0.029	62.61
CD	0.004	0.0271	0.0003	0.217

c. Concentration

Concentration	Dehydrogenase activity	Protein	Electrical conductivity	Mitotic index
C_1	0.756	13.30	0.031	63.40
C_2	0.776	13.60	0.032	61.20
C_3	0.767	13.50	0.034	63.70
C_4	0.723	13.40	0.033	62.10
CD	0.006	0.038	0.001	0.310

d. Duration

Duration	Dehydrogenase activity	Protein	Electrical conductivity	Mitotic index
D_1	0.780	13.60	0.031	63.50
D_2	0.738	13.30	0.034	62.00
D_3	0.733	13.20	0.032	62.80
D_4	0.772	13.60	0.032	62.00
CD	0.006	0.038	0.001	0.310

e. Period of storage

Month	Dehydrogenase activity	Protein	Electrical conductivity	Mitotic index
M_0	1.530	14.77	0.011	84.00
M_1	1.370	14.60	0.016	80.03
M_2	0.986	14.32	0.020	75.20
M_3	0.822	14.00	0.024	70.89
M_4	0.724	13.70	0.028	65.86
M_5	0.635	13.44	0.031	61.48
M_6	0.572	13.44	0.035	58.13
M_7	0.509	12.89	0.040	54.57
M_8	0.454	12.62	0.043	50.99
M_9	0.401	12.42	0.049	47.28
M_{10}	0.309	11.93	0.057	40.33
CD	0.009	0.064	0.0006	0.434

Table 10a. Effect of osmopriming on protein (mg g^{-1}) in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	13.03	13.33	13.33	13.27	13.07	12.90	12.60	12.53	12.37	12.23	12.10
$V_1H_1C_1D_2$	12.80	12.70	12.73	12.60	12.70	12.70	12.57	12.43	12.23	12.27	12.13
$V_1H_1C_1D_3$	12.67	12.73	12.67	12.60	12.60	12.63	12.53	12.47	12.53	12.50	12.33
$V_1H_1C_1D_4$	12.80	12.73	12.63	12.57	12.47	12.47	12.57	12.40	12.40	12.50	12.37
$V_1H_1C_2D_1$	12.37	12.40	12.37	12.33	12.33	12.33	12.40	12.30	12.20	12.33	12.27
$V_1H_1C_2D_2$	12.50	12.73	12.74	12.67	12.53	12.40	12.50	12.43	12.23	12.13	11.97
$V_1H_1C_2D_3$	12.60	12.73	12.60	12.57	12.40	12.40	12.30	12.40	12.37	12.07	12.00
$V_1H_1C_2D_4$	14.63	14.73	14.50	14.23	13.67	13.63	13.60	13.30	13.13	12.93	12.40
$V_1H_1C_3D_1$	16.20	15.53	15.10	14.47	14.30	14.17	13.93	13.63	13.30	13.20	12.73
$V_1H_1C_3D_2$	16.03	15.60	15.53	15.40	14.90	14.50	14.17	13.67	13.40	12.93	12.30
$V_1H_1C_3D_3$	16.13	15.63	15.30	15.10	14.70	14.00	13.67	13.27	12.90	12.53	12.53
$V_1H_1C_3D_4$	14.53	14.83	14.77	14.73	14.50	14.03	13.63	13.23	12.97	12.63	12.30
$V_1H_1C_4D_1$	16.17	15.73	15.50	15.47	14.53	14.13	13.60	13.17	12.67	12.60	12.57
$V_1H_1C_4D_2$	12.70	12.73	12.63	12.70	12.60	12.40	12.40	12.57	12.43	12.43	12.03
$V_1H_1C_4D_3$	13.57	13.23	13.13	12.90	13.23	12.73	12.83	12.73	12.67	12.53	12.43
$V_1H_1C_4D_4$	14.53	14.37	14.13	13.77	13.57	13.60	13.17	12.90	12.70	12.63	12.27
$V_1H_2C_1D_1$	15.37	15.00	14.27	13.83	13.60	13.37	13.13	12.90	12.70	12.50	12.20
$V_1H_2C_1D_2$	15.37	14.67	14.33	14.47	13.93	13.77	13.50	13.63	13.07	12.37	11.67
$V_1H_2C_1D_3$	14.10	13.93	13.77	13.57	13.30	12.93	12.73	12.50	12.50	12.53	12.23
$V_1H_2C_1D_4$	15.47	14.93	14.37	13.80	13.70	12.90	12.30	12.20	12.30	12.13	9.30
$V_1H_2C_2D_1$	14.87	14.00	13.53	13.30	12.77	12.57	12.30	11.90	11.73	10.73	8.60
$V_1H_2C_2D_2$	14.97	14.60	14.33	13.80	13.73	13.37	12.87	12.53	12.57	12.40	11.90
$V_1H_2C_2D_3$	15.17	14.60	14.30	14.00	13.67	13.50	13.00	12.70	12.43	12.33	11.83
$V_1H_2C_2D_4$	16.40	15.80	15.00	14.57	13.80	13.50	13.33	13.17	13.03	12.77	12.60
$V_1H_2C_3D_1$	15.67	15.20	14.67	14.13	13.73	13.60	13.37	13.20	12.83	12.40	11.93
$V_1H_2C_3D_2$	13.10	13.37	13.37	13.07	12.73	12.77	12.50	12.37	12.37	12.23	12.03
$V_1H_2C_3D_3$	13.13	13.17	12.97	12.53	12.40	12.40	12.40	12.40	12.40	12.33	12.20
$V_1H_2C_3D_4$	13.47	13.53	13.60	13.40	13.33	13.27	13.17	12.97	12.63	12.43	11.90
$V_1H_2C_4D_1$	14.80	14.83	14.70	14.20	14.07	13.60	13.40	13.37	13.17	12.53	12.37
$V_1H_2C_4D_2$	14.33	14.20	14.00	13.40	13.30	13.10	12.67	12.50	12.23	11.60	8.00
$V_1H_2C_4D_3$	13.87	14.13	13.87	13.50	13.13	12.70	12.53	12.47	11.77	11.53	11.00
$V_1H_2C_4D_4$	13.90	14.03	14.07	13.87	13.50	13.40	12.87	12.67	12.50	12.20	12.13
V_1O	11.83	11.93	11.43	11.13	10.83	11.03	10.63	10.40	9.27	6.27	5.47
V_1WD_1	11.73	11.60	11.67	11.40	11.47	11.33	11.00	10.57	10.23	10.17	9.60
V_1WD_2	11.93	12.13	12.07	11.87	11.70	11.57	11.30	11.00	10.53	10.10	5.47
V_1WD_3	11.47	12.00	11.80	11.57	11.50	11.20	11.13	10.50	10.37	10.13	9.03
V_1WD_4	11.83	11.83	11.77	11.60	11.40	11.33	11.10	10.67	10.57	10.33	9.23
CD	1.18	0.50	0.38	0.32	0.29	0.55	0.27	0.27	0.29	0.32	0.51

Table 10b. Effect of osmopriming on protein (mg g^{-1}) in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	16.60	16.00	14.93	14.40	13.83	13.73	13.10	12.67	12.50	12.20	11.90
$V_2H_1C_1D_2$	15.77	15.47	14.60	14.47	14.27	13.97	13.40	13.20	12.83	12.73	12.40
$V_2H_1C_1D_3$	15.37	15.47	15.00	14.33	13.97	13.67	13.40	12.63	12.53	12.33	11.60
$V_2H_1C_1D_4$	14.17	14.53	14.40	14.20	13.73	13.60	13.17	12.83	12.40	12.47	12.40
$V_2H_1C_2D_1$	15.07	14.87	14.33	14.27	14.17	13.63	13.27	13.07	12.73	12.50	12.53
$V_2H_1C_2D_2$	14.17	14.23	14.17	13.83	13.37	12.90	12.63	12.53	12.50	12.27	12.37
$V_2H_1C_2D_3$	13.97	14.20	14.20	13.87	13.80	13.63	13.33	13.03	12.60	12.50	12.20
$V_2H_1C_2D_4$	18.40	17.43	17.23	16 00	15.67	14.57	14 10	13.60	13.03	12 67	12.43
$V_2H_1C_3D_1$	18.47	16.63	15.63	15.10	14.90	14.17	13.67	13.40	13.13	12.63	12.23
$V_2H_1C_3D_2$	14.93	14.97	14.50	14.03	13.67	13.47	13 23	12.63	12.27	12.50	12 00
$V_2H_1C_3D_3$	14.03	15.03	14.53	14.33	14.30	13.97	13.60	13.30	12.83	12.40	12.10
$V_2H_1C_3D_4$	14.77	14.83	14.33	14.30	13.80	13.53	13.20	12.83	12.50	12.43	12.13
$V_2H_1C_4D_1$	14.47	14.57	14.37	14.00	13.70	14.90	13.33	12.97	12.60	12.40	12.27
$V_2H_1C_4D_2$	14.20	14.20	13.90	13.43	13.27	13.03	12.60	12.43	12.30	12.23	12.00
$V_2H_1C_4D_3$	16.17	15.83	15.23	14.70	14.20	13.83	12.97	13.23	12.93	12.47	12.23
$V_2H_1C_4D_4$	14.67	14.97	14.77	14.50	13.83	13.33	12.90	12.80	12.43	12.37	12.17
$V_2H_2C_1D_1$	15.53	15.60	15.43	15.10	14.67	14.43	13.63	13.47	12.83	12.60	12.33
$V_2H_2C_1D_2$	12.93	12.83	12.50	12.43	12.47	12.47	12.40	12.37	11.60	12.23	12.00
$V_2H_2C_1D_3$	14.80	14.77	14.60	14.40	13.83	13.50	13.17	12.87	12.60	12.60	12.37
$V_2H_2C_1D_4$	16.27	16.13	15.70	15.00	14.60	14.40	13.90	13.60	13.30	12.83	12.10
$V_2H_2C_2D_1$	18.10	17.23	16.43	15.53	15.07	14.50	14.00	13.87	13.60	13.50	12.00
$V_2H_2C_2D_2$	17.97	17.33	16.77	16.17	15.60	14.67	14.17	13.60	12.73	12.50	11.87
$V_2H_2C_2D_3$	17.70	17.03	16.50	15.83	15.23	14.57	13.80	13.57	12.80	12.67	12.20
$V_2H_2C_2D_4$	14.87	14.60	14.33	13.87	13.50	13.13	12.80	12.60	12.60	12.47	12.20
$V_2H_2C_3D_1$	14.13	14.20	13.83	13.60	13.37	13.27	12.63	12.53	12.40	12.20	11.87
$V_2H_2C_3D_2$	15.10	14.93	14.47	13.97	13.60	13.43	13.23	12.70	12.40	12.40	11.80
$V_2H_2C_3D_3$	12.70	12.53	12.63	12.47	12.30	12.27	12.23	12.23	12.10	11.63	8.67
$V_2H_2C_3D_4$	14.63	14.63	14.67	14.33	13.80	13.50	13.37	13.17	12.77	12.43	11.83
$V_2H_2C_4D_1$	14.07	14.03	14.00	13.77	13.57	13.17	12.97	12.80	12.60	12.37	12.20
$V_2H_2C_4D_2$	15.73	15.47	15.30	15.20	14.47	14.03	13.70	13.53	13.17	12.77	12.40
$V_2H_2C_4D_3$	13.03	12.97	12.97	12.70	12.67	12.53	12.40	12.17	12.37	12.20	11.77
$V_2H_2C_4D_4$	14.93	15.33	15.33	14.97	14.90	14.77	13.93	13.83	13.20	12.67	12.13
V_2O	12.03	12.03	12.00	11.80	11.63	11.63	10.77	10.43	10.37	10.20	9.63
V_2WD_1	12.07	12.03	12.03	11.70	11.50	11.30	11.23	11.17	10.33	10.27	9.60
V_2WD_2	11.90	12.10	12.10	11.63	11.50	11.30	11.00	10.53	10.17	10.10	9.50
V_2WD_3	12.07	12.00	11.80	11.60	11.47	11.13	11.03	10.53	10.30	10.17	9.63
V_2WD_4	11.97	11.83	11.83	11.53	11.37	11.20	11.10	10.67	10.57	10.30	9.67
CD	1.18	0.50	0.38	0.32	0.29	0.55	0.27	0.27	0.29	0.32	0.51

(0.723). Among the duration of osmopriming treatments carried out D_1 (12 hours) registered maximum value (0.780). D_2 and D_3 did not show any significant difference. Dehygrogenase enzyme activity significantly decreased from first month to tenth month of storage. The fresh seeds recorded a value of 1.530 which declined sharply to 0.309 after ten months of storage.

4.2.2 Soluble protein content

The mean data on soluble protein content of chilli varieties Jwalasakhi and Ujwala are given in Table 10a and 10b.

Remarkable variation could not be observed in soluble protein content between water treated and absolute control. After tenth month was storage soluble protein content was 9.66 mg g^{-1} for water treated seeds of Ujwala and 9.63 mg g^{-1} for absolute control. But for Jwalasakhi the water treated seeds recorded 8.33 mg g^{-1}, where as absolute control recorded the lowest value of 5.46 mg g^{-1}. The soluble protein content improved considerably with seed osmopriming.

The main effects of variety, chemical, concentration and duration of treatment and period of storage on soluble protein content are given in Table 9.

Variety Ujwala differed significantly in soluble protein content (13.69 mg g^{-1}) compared to Jwalasakhi (13.19 mg g^{-1}). In both the varieties soluble protein content reduced under storage. Chemicals PEG and Na Cl maintained statistically similar values for soluble protein 13.42 mg g^{-1} and 13.45 mg g^{-1} respectively. The concentrations showed significant effect on protein content with C_2 (-1.5 MPa) recording the maximum (13.6 mg g^{-1}) and C_1 (-1.0 MPa) the minimum (13.3 mg g^{-1}). Duration of treatments D_1 and D_4 differed significantly from D_2 and D_3. The highest protein content recorded was 13.6 mg g^{-1} by D_1 and D_4 (12 hour and 48 hour). As storage period increased there was a general decline in soluble protein content. The highest value shown by fresh seeds was 14.77 mg g^{-1} where as it was 11.93 mg g^{-1} after ten months of storage.

4.2.3 Electrical Conductivity (EC)

The mean data on electrical conductivity of chilli varieties Jwalasakhi and Ujwala are given in Table 11a and 11b.

Table 11a. Effect of osmopriming on electrical conductivity (mmhos cm^{-1}) in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	0.010	0.018	0.018	0.018	0.025	0.027	0.030	0.031	0.034	0.036	0 038
$V_1H_1C_1D_2$	0.011	0.016	0.025	0.027	0.033	0.035	0.031	0.040	0.036	0.040	0.044
$V_1H_1C_1D_3$	0.013	0.019	0.019	0.023	0.026	0.026	0.029	0.037	0.045	0.047	0.047
$V_1H_1C_1D_4$	0.009	0.020	0.020	0.024	0.032	0.029	0.034	0.039	0.040	0.044	0.055
$V_1H_1C_2D_1$	0.011	0.020	0.024	0.029	0.031	0.031	0.033	0.036	0.038	0.036	0 046
$V_1H_1C_2D_2$	0.014	0.020	0.022	0.029	0.030	0.040	0.041	0.043	0.042	0.049	0 051
$V_1H_1C_2D_3$	0.012	0.017	0.019	0.023	0.032	0.034	0.037	0.041	0.044	0.047	0 047
$V_1H_1C_2D_4$	0.012	0.021	0.023	0.032	0.033	0.037	0.039	0.040	0.038	0.049	0.048
$V_1H_1C_3D_1$	0.014	0.025	0.031	0.032	0.035	0.038	0.041	0.039	0.051	0.055	0.056
$V_1H_1C_3D_2$	0.018	0.027	0.039	0.043	0.044	0.045	0.047	0.050	0.056	0.061	0.065
$V_1H_1C_3D_3$	0.015	0.019	0.023	0.024	0.033	0.037	0.042	0.047	0.051	0.053	0.056
$V_1H_1C_3D_4$	0.018	0.023	0.026	0.029	0.036	0.038	0.046	0.044	0.049	0.051	0.056
$V_1H_1C_4D_1$	0.018	0.023	0.029	0.030	0.031	0.035	0.037	0.043	0.046	0.055	0.058
$V_1H_1C_4D_2$	0.016	0.021	0.026	0.032	0.037	0.037	0.029	0.043	0.047	0.054	0.063
$V_1H_1C_4D_3$	0.011	0.016	0.017	0.023	0.025	0.031	0.035	0.040	0.045	0.046	0.048
$V_1H_1C_4D_4$	0.014	0.018	0.028	0.036	0.039	0.045	0.048	0.048	0.050	0.058	0.062
$V_1H_2C_1D_1$	0.012	0.019	0.023	0.024	0.030	0.034	0.037	0.038	0.041	0.046	0.048
$V_1H_2C_1D_2$	0.016	0.024	0.026	0.029	0.030	0.032	0.037	0.041	0.045	0.043	0.049
$V_1H_2C_1D_3$	0.010	0.012	0.014	0.017	0.018	0.023	0.026	0.031	0.040	0.055	0.069
$V_1H_2C_1D_4$	0.010	0.014	0.016	0.022	0.027	0.030	0.033	0.036	0.037	0.040	0.045
$V_1H_2C_2D_1$	0.014	0.018	0.021	0.025	0.027	0.029	0.033	0.040	0.044	0.047	0.049
$V_1H_2C_2D_2$	0.015	0.018	0.020	0.021	0.024	0.028	0.033	0.037	0.039	0.041	0.043
$V_1H_2C_2D_3$	0.012	0.017	0.017	0.024	0.027	0.033	0.035	0.043	0.047	0.051	0.065
$V_1H_2C_2D_4$	0.006	0.010	0.013	0.016	0.019	0.020	0.023	0.028	0.029	0.033	0.036
$V_1H_2C_3D_1$	0.011	0.021	0.020	0.022	0.019	0.023	0.031	0.036	0.039	0.049	0.051
$V_1H_2C_3D_2$	0.013	0.019	0.024	0.025	0.025	0.030	0.032	0.037	0.040	0.040	0.044
$V_1H_2C_3D_3$	0.012	0.017	0.020	0.022	0.025	0.030	0.034	0.038	0.045	0.047	0.050
$V_1H_2C_3D_4$	0.012	0.019	0.022	0.025	0.030	0.033	0.037	0.040	0.039	0.040	0 046
$V_1H_2C_4D_1$	0.011	0.012	0.016	0.020	0.025	0.033	0.037	0.042	0.040	0.047	0.053
$V_1H_2C_4D_2$	0.012	0.018	0.020	0.025	0.026	0.027	0.033	0.039	0.045	0.050	0.057
$V_1H_2C_4D_3$	0.012	0.015	0.018	0.022	0.024	0.028	0.033	0.036	0.040	0.042	0.045
$V_1H_2C_4D_4$	0.013	0.016	0.019	0.025	0.031	0.032	0.034	0.040	0.047	0.050	0.055
V_1O	0.001	0.003	0.017	0.023	0.035	0.046	0.058	0.064	0.070	0.079	0.198
V_1WD_1	0.010	0.016	0.024	0.029	0.033	0.038	0.041	0.042	0.058	0.083	0.119
V_1WD_2	0.013	0.018	0.023	0.027	0.035	0.039	0.045	0.043	0.049	0.059	0 060
V_1WD_3	0.011	0.018	0.021	0.025	0.029	0.030	0.038	0.051	0.064	0.084	0.182
V_1WD_4	0.008	0.018	0.022	0.029	0.028	0.035	0.042	0.044	0.047	0.058	0 098
CD	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051

Table 11b. Effect of osmopriming on electrical conductivity (mmhos cm^{-1}) in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	0.007	0.013	0.019	0.026	0.029	0.033	0.038	0.041	0.050	0.050	0.065
$V_2H_1C_1D_2$	0.011	0.014	0.020	0.030	0.038	0.041	0.048	0.048	0.058	0.087	0.071
$V_2H_1C_1D_3$	0.010	0.014	0.023	0.028	0.029	0.033	0.037	0.043	0.051	0.064	0.074
$V_2H_1C_1D_4$	0.012	0.018	0.021	0.024	0.030	0.033	0.037	0.038	0.042	0.048	0.065
$V_2H_1C_2D_1$	0.008	0.012	0.016	0.022	0.026	0.030	0.035	0.037	0.041	0.041	0.049
$V_2H_1C_2D_2$	0.013	0.017	0.019	0.023	0.028	0.032	0.038	0.041	0.043	0.051	0.057
$V_2H_1C_2D_3$	0.011	0.012	0.017	0.023	0.027	0.030	0.039	0.045	0.051	0.063	0.112
$V_2H_1C_2D_4$	0.010	0.017	0.020	0.025	0.029	0.035	0.045	0.055	0.068	0.076	0.080
$V_2H_1C_3D_1$	0.011	0.018	0.021	0.028	0.028	0.032	0.039	0.042	0.045	0.051	0.058
$V_2H_1C_3D_2$	0.009	0.017	0.021	0.022	0.029	0.031	0.039	0.045	0.049	0.055	0.063
$V_2H_1C_3D_3$	0.010	0.012	0.015	0.025	0.032	0.037	0.041	0.046	0.053	0.061	0.102
$V_2H_1C_3D_4$	0.009	0.014	0.024	0.030	0.032	0.037	0.040	0.042	0.046	0.052	0.058
$V_2H_1C_4D_1$	0.011	0.016	0.023	0.026	0.034	0.044	0.045	0.050	0.053	0.060	0.063
$V_2H_1C_4D_2$	0.009	0.014	0.023	0.026	0.030	0.032	0.039	0.053	0.058	0.073	0.145
$V_2H_1C_4D_3$	0.007	0.013	0.015	0.021	0.027	0.031	0.034	0.042	0.031	0.050	0.055
$V_2H_1C_4D_4$	0.011	0.014	0.022	0.027	0.031	0.034	0.040	0.043	0.044	0.053	0.060
$V_2H_2C_1D_1$	0.012	0.017	0.017	0.020	0.023	0.025	0.030	0.033	0.038	0.039	0.049
$V_2H_2C_1D_2$	0.009	0.014	0.018	0.021	0.025	0.026	0.031	0.035	0.037	0.042	0.049
$V_2H_2C_1D_3$	0.010	0.010	0.013	0.015	0.019	0.023	0.027	0.031	0.035	0.041	0.046
$V_2H_2C_1D_4$	0.007	0.013	0.013	0.018	0.023	0.024	0.027	0.028	0.029	0.031	0.036
$V_2H_2C_2D_1$	0.010	0.011	0.016	0.018	0.024	0.026	0.034	0.040	0.043	0.044	0.048
$V_2H_2C_2D_2$	0.011	0.013	0.014	0.019	0.023	0.028	0.029	0.030	0.035	0.040	0.049
$V_2H_2C_2D_3$	0.009	0.012	0.016	0.019	0.022	0.026	0.032	0.036	0.038	0.049	0.063
$V_2H_2C_2D_4$	0.008	0.010	0.013	0.017	0.022	0.022	0.031	0.039	0.049	0.055	0.064
$V_2H_2C_3D_1$	0.012	0.015	0.016	0.021	0.024	0.027	0.033	0.036	0.040	0.046	0.050
$V_2H_2C_3D_2$	0.009	0.013	0.016	0.023	0.026	0.029	0.034	0.040	0.039	0.041	0.045
$V_2H_2C_3D_3$	0.011	0.014	0.021	0.023	0.027	0.028	0.032	0.035	0.037	0.041	0.044
$V_2H_2C_3D_4$	0.010	0.012	0.015	0.019	0.024	0.030	0.032	0.037	0.042	0.048	0.062
$V_2H_2C_4D_1$	0.010	0.014	0.018	0.021	0.024	0.027	0.030	0.033	0.034	0.039	0.048
$V_2H_2C_4D_2$	0.004	0.010	0.014	0.019	0.026	0.028	0.031	0.035	0.040	0.042	0.048
$V_2H_2C_4D_3$	0.009	0.012	0.015	0.018	0.022	0.024	0.030	0.032	0.034	0.039	0.048
$V_2H_2C_4D_4$	0.006	0.010	0.016	0.021	0.027	0.031	0.038	0.045	0.049	0.059	0.068
V_2O	0.007	0.011	0.024	0.035	0.041	0.049	0.059	0.077	0.108	0.149	0.228
V_2WD_1	0.011	0.015	0.018	0.023	0.025	0.032	0.038	0.044	0.053	0.062	0.104
V_2WD_2	0.009	0.011	0.016	0.020	0.028	0.034	0.040	0.043	0.048	0.062	0.072
V_2WD_3	0.007	0.010	0.016	0.023	0.027	0.029	0.037	0.044	0.051	0.055	0.110
V_2WD_4	0.008	0.013	0.017	0.025	0.031	0.034	0.041	0.047	0.053	0.062	0.102
CD	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051	0.0051

The absolute control recorded a mean value for electrical conductivity of leachate as 0.228 mmhos cm^{-1} for Ujwala and 0.198 mmhos cm^{-1} for Jwalasakhi ten months after storage. In hydroprimed seeds EC values increased in Jwalasakhi and Ujwala to 0.112 mmhos cm^{-1} and 0.097 mmhos cm^{-1} respectively ten months after storage.

The main effects of variety, chemical, concentration and duration of treatment and period of storage on electrical conductivity of seed leachate are given in Table 9.

The variety Ujwala was found superior recording 0.032 mmhos cm^{-1} compared to Jwalasakhi (0.033 mmhos cm^{-1}). Due to ageing or prolonged storage the EC values were progressively increased for both the varieties. Though both the chemicals i.e., sodium chloride and PEG responded well PEG recorded lowest value (0.029 mmhos cm^{-1}) compared to Na Cl (0.035 mmhos cm^{-1}). The concentration C_1 was found superior by producing the least value of electrical conductivity (0.031 mmhos cm^{-1}). In the case of duration of treatment D_1, D_3 and D_4 were found to be superior to D_2. The lowest recorded by D_1 (12 hour) was 0.031 mmhos cm^{-1}. The EC value of 0.011 mmhos cm^{-1} recorded by the fresh seeds was found significantly increasing up to 0.057 mmhos cm^{-1} at tenth month after storage.

The biochemical characters like dehydrogenase activity and soluble protein content expressed a positive correlation with germination and vigour index where as, EC of seed leachate showed negative correlation with all other characters studied (Table 7).

Cytological studies

4.2.4 Mitotic index (MI)

The mean data on mitotic index of chilli varieties Jwalasakhi and Ujwala are given in Table 12a and 12b.

Water treated seeds maintained comparatively higher MI values to absolute control. For both varieties there was uniform reduction in MI values up to 8 month after storage. The chemical treated seeds recorded a reduction of 35 to 45 per cent in MI values where as it was more than 60 per cent in absolute control.

The main effects of variety, chemical, concentration and duration of treatment and period of storage on mitotic index are given in Table 9.

Table 12a. Effect of osmopriming on mitotic index of germinated seeds in chilli variety Jwalasakhi

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_1H_1C_1D_1$	87.10	84.00	84.17	80.37	77.26	66.53	67.57	64.00	56.90	55.37	52.03
$V_1H_1C_1D_2$	86.67	84.00	83.27	77.77	71.87	67.33	63.77	64.77	57.33	54.70	48.93
$V_1H_1C_1D_3$	82.47	74.67	72.23	71.87	63.77	62.57	57.33	54.70	50.93	53.37	51.60
$V_1H_1C_1D_4$	84.00	80.83	72.30	66.43	62.57	56.67	56.70	56.33	50.67	50.33	48.00
$V_1H_1C_2D_1$	78.00	76.67	68.53	60.33	55.43	48.33	50.00	49.33	48.93	41.33	37.33
$V_1H_1C_2D_2$	80.23	76.67	66.90	57.33	50.67	46.67	48.77	47.33	42.67	40.93	32.67
$V_1H_1C_2D_3$	86.00	81.77	71.10	70.43	63.00	60.67	52.27	48.33	46.00	42.00	44.67
$V_1H_1C_2D_4$	84.90	80.90	71.10	63.10	58.00	51.33	45.33	45.60	44.67	43.33	43.33
$V_1H_1C_3D_1$	87.33	82.50	80.90	77.77	74.22	66.67	66.10	64.00	55.33	54.03	51.27
$V_1H_1C_3D_2$	85.77	83.90	80.67	72.20	65.43	60.90	58.00	50.93	52.00	42.67	34.67
$V_1H_1C_3D_3$	86.90	83.27	80.20	77.77	77.26	66.53	67.57	64.00	56.90	55.37	52.03
$V_1H_1C_3D_4$	84.23	80.20	75.00	65.33	65.77	60.67	59.10	55.33	53.77	48.00	48.33
$V_1H_1C_4D_1$	88.00	80.67	75.67	69.77	65.23	62.67	64.87	56.67	55.80	55.60	52.27
$V_1H_1C_4D_2$	74.67	70.67	64.67	64.00	58.23	54.00	54.67	53.83	49.67	50.00	32.67
$V_1H_1C_4D_3$	84.67	80.67	75.77	71.10	64.00	63.67	60.90	57.00	55.53	52.67	47.67
$V_1H_1C_4D_4$	84.67	78.67	75.67	70.00	63.43	62.67	53.67	52.33	53.20	52.67	42.67
$V_1H_2C_1D_1$	88.43	85.50	78.00	76.20	72.00	66.33	64.67	66.67	61.33	51.33	40.67
$V_1H_2C_1D_2$	84.23	80.00	76.00	69.77	64.67	62.90	57.33	52.10	49.77	50.67	36.00
$V_1H_2C_1D_3$	79.33	74.00	68.67	66.43	64.67	64.00	64.00	60.00	60.67	56.00	55.33
$V_1H_2C_1D_4$	78.00	72.67	67.67	64.67	63.33	53.33	52.67	50.67	42.00	36.00	28.00
$V_1H_2C_2D_1$	80.00	76.20	68.00	64.00	61.10	58.23	52.00	46.67	37.33	33.33	29.00
$V_1H_2C_2D_2$	86.67	80.00	76.67	75.33	68.43	66.77	65.33	59.33	52.33	42.00	39.33
$V_1H_2C_2D_3$	86.43	82.17	75.33	73.40	67.10	64.67	60.00	56.67	55.33	45.33	40.00
$V_1H_2C_2D_4$	86.90	83.93	78.67	75.07	72.00	68.43	66.67	62.00	58.00	57.33	56.67
$V_1H_2C_3D_1$	83.33	80.00	76.67	73.97	67.10	66.33	64.90	58.00	56.67	48.43	44.67
$V_1H_2C_3D_2$	83.57	78.00	74.87	67.33	64.33	61.77	58.57	56.00	54.67	49.33	34.67
$V_1H_2C_3D_3$	84.90	79.33	76.00	68.43	64.33	64.43	63.33	59.33	56.67	55.33	52.67
$V_1H_2C_3D_4$	83.57	79.33	76.00	66.67	65.33	62.43	59.10	58.00	56.00	48.67	33.33
$V_1H_2C_4D_1$	85.33	80.67	74.67	72.00	66.67	61.67	63.10	58.67	56.90	43.33	33.33
$V_1H_2C_4D_2$	83.33	76.67	70.43	68.00	63.00	63.33	56.00	55.33	49.33	47.33	36.00
$V_1H_2C_4D_3$	85.10	82.40	75.33	71.33	65.33	63.33	61.67	56.23	50.00	47.33	40.67
$V_1H_2C_4D_4$	83.33	74.67	67.33	65.00	62.00	63.33	57.33	56.00	50.00	47.33	37.33
V_1O	84.67	80.00	72.67	65.67	54.67	52.67	49.33	37.33	33.33	0.00	0.00
V_1WD_1	87.10	84.90	73.33	67.00	56.67	52.00	50.00	39.33	33.33	28.67	21.33
V_1WD_2	82.67	78.67	73.33	62.00	55.33	50.43	48.00	38.67	36.00	32.67	22.00
V_1WD_3	84.47	78.67	74.00	66.00	52.93	51.77	46.00	43.33	36.00	31.33	23.33
V_1WD_4	82.00	78.67	72.00	66.67	56.53	52.00	44.67	42.67	37.33	27.33	21.33
CD	3.44	3.64	3.43	4.00	3.87	3.81	4.26	4.50	5.02	4.28	4.47

Table 12b. Effect of osmopriming on mitotic index of germinated seeds in chilli variety Ujwala

Treatments	Months after storage										
	0	1	2	3	4	5	6	7	8	9	10
$V_2H_1C_1D_1$	84.67	81.33	75.33	74.00	67.57	58.00	57.33	55.63	48.00	47.00	41.33
$V_2H_1C_1D_2$	80.67	78.00	76.00	74.43	67.10	58.27	59.33	52.10	46.67	46.00	36.00
$V_2H_1C_1D_3$	84.23	79.33	74.90	68.67	66.23	63.33	56.23	54.67	48.00	45.33	36.00
$V_2H_1C_1D_4$	84.00	81.57	77.10	68.77	62.00	56.90	51.00	48.00	49.67	47.33	43.33
$V_2H_1C_2D_1$	82.00	81.97	77.33	70.00	64.67	56.90	51.10	46.00	46.00	47.33	44.00
$V_2H_1C_2D_2$	86.67	81.60	76.67	67.33	63.33	56.27	53.33	50.33	48.67	46.33	44.00
$V_2H_1C_2D_3$	87.33	82.17	75.33	68.00	64.67	56.70	55.77	53.10	49.67	46.00	44 00
$V_2H_1C_2D_4$	84.67	82.00	76.43	66.67	62.67	54.70	51.27	48.00	47.33	45.33	46.00
$V_2H_1C_3D_1$	86.00	82.00	78.67	75.33	70.00	64.00	60.67	56.67	50.67	46.67	48.00
$V_2H_1C_3D_2$	84.90	78.67	76.67	74.00	68.67	64.00	60.00	55.33	48.67	48.43	44.00
$V_2H_1C_3D_3$	82.00	77.10	73.33	72.67	66.67	61.33	57.33	54.67	50.67	48.00	46.00
$V_2H_1C_3D_4$	84.00	82.00	78.00	73.53	66.43	61.10	56.00	51.00	47.33	46.00	46.00
$V_2H_1C_4D_1$	82.23	80.67	76.00	72.20	66.23	60.00	54.93	51.77	51.33	44.67	42.67
$V_2H_1C_4D_2$	86.43	82.00	77.10	71.33	66.67	60.00	53.10	49.33	49.33	45.33	41.33
$V_2H_1C_4D_3$	85.57	79.33	75.33	71.10	64.67	58.50	53.33	50.43	48.00	45.33	43 33
$V_2H_1C_4D_4$	82.67	81.33	77.33	72.00	68.90	64.67	61.10	55.60	51.00	49.33	46.00
$V_2H_2C_1D_1$	82.33	80.00	76.00	74.67	67.33	63.77	60.67	56.00	51.77	49.33	44.67
$V_2H_2C_1D_2$	84.00	81.33	76.00	74.00	66.67	65.33	59.33	56.00	51.77	48.00	44.67
$V_2H_2C_1D_3$	84.00	79.33	78.00	74.67	69.33	64.00	58.67	54.00	52.27	48.00	44.00
$V_2H_2C_1D_4$	84.00	80.67	76.67	70.67	65.33	62.00	56.23	52.67	48.00	47.33	41.33
$V_2H_2C_2D_1$	86.00	82.00	76.67	76.00	64.67	63.33	55.77	50.67	48.67	49.33	46.00
$V_2H_2C_2D_2$	84.00	80.67	73.33	72.00	66.67	61.33	54.43	50.43	48.00	48.67	43.33
$V_2H_2C_2D_3$	85.33	82.67	78.00	74.67	70.67	66.87	62.00	58.00	52.67	48.00	45.33
$V_2H_2C_2D_4$	84.00	82.00	77.33	74.67	69.20	66.00	62.00	56.67	54.67	46.00	45.33
$V_2H_2C_3D_1$	82.67	80.67	76.67	74.67	71.33	66.67	62.00	58.00	52.67	46.00	36.00
$V_2H_2C_3D_2$	86.67	82.00	76.00	74.00	68.00	63.33	58.90	54.00	49.33	46.00	38.00
$V_2H_2C_3D_3$	78.67	76.67	72.00	66.67	62.00	54.67	52.00	46.00	43.33	32.67	30.00
$V_2H_2C_3D_4$	84.67	79.33	74.67	71.33	67.33	64.00	60.00	54.67	50.43	46.00	44.00
$V_2H_2C_4D_1$	84.00	81.33	74.00	71.33	65.57	60.67	57.33	53.33	49.33	46.67	43.33
$V_2H_2C_4D_2$	84.00	79.33	76.67	71.33	66.00	64.00	58.00	53.10	51.00	46.00	36.00
$V_2H_2C_4D_3$	79.33	77.33	74.67	72.00	66.67	62.67	58.67	55.33	50.00	36.00	32 00
$V_2H_2C_4D_4$	86.00	80.00	76.00	71.00	64.23	62.00	59.33	54.67	51.00	46.00	36.00
V_2O	84.00	82.00	72.67	65.00	54.67	54.00	46.00	36.00	26.67	0.00	0.00
V_2WD_1	85.33	82.00	77.33	64.00	56.00	51.10	43.33	42.00	36.67	32.67	24.67
V_2WD_2	82.00	80.67	74.00	64.00	57.33	51.00	44.00	42.00	37.33	30.67	32.00
V_2WD_3	86.67	77.33	70.67	64.00	55.33	51.77	43.33	38.67	33.33	31.33	34.67
V_2WD_4	86.67	78.00	73.33	66.00	54.67	50.00	44.67	38.67	31.33	30.00	30.67
CD	3.44	3.64	3.43	4.00	3.87	3.81	4.26	4.50	5.02	4.28	4.47

Varieties differed significantly in MI values. Jwalasakhi recorded significant higher value (62.84) compared to Ujwala (62.38). In the chemicals tried i.e. Na Cl and PEG recorded almost similar MI values (62.61 and 62.60). Concentrations C_1 and C_3 differed significantly from C_2 and C_4. The maximum value recorded was 63.7 by C_3 (-1.75 MPa). The duration of osmopriming treatments also showed significant difference. The highest value was 63.5 recorded by D_1 (12 hour). MI values were reduced to the tune of 51 per cent from one to ten months of storage. Fresh seeds showed the highest MI value of 84.00 which was reduced to 40.33 ten month after storage.

Mitotic index was positively correlated with seedling and biochemical characters studied except for electrical conductivity (Table 7).

4.2.5 Chromosomal aberrations

Any type of chromosomal aberration was not detected in the mitotic cells during the ten months of storage in both control as well as osmoprimed seeds.

Discussion

DISCUSSION

Much of the success of modern agriculture depends on the availability of good quality seeds with high genetic potential and proven performance in germination, emergence and growth. Farmers and horticulturists are interested in the factors related to seed germination as majority of conventional agriculturists are depend on seeds for plant propagation

Like any other form of life, seeds cannot retain their viability indefinitely and eventually they deteriorate and die. Seed storage and maintenance of quality requires special attention in a state like Kerala having a tropical humid climate. Rapid loss of quality during storage is a common problem in chilli seed production.

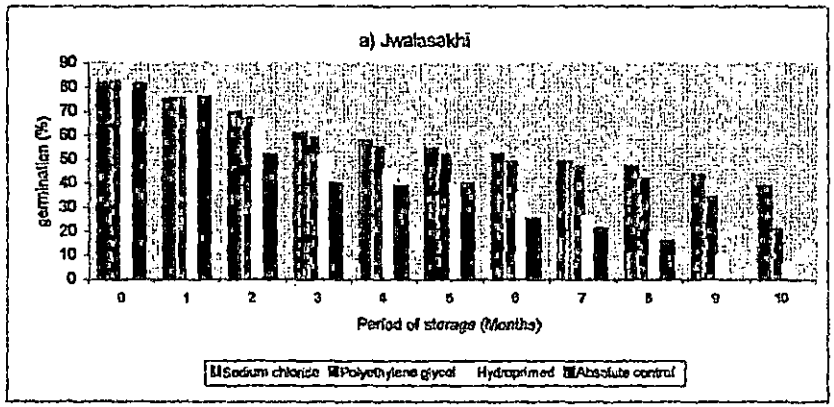
Osmopriming is one of the techniques used to ameleorate seed deterioration while storage. The mechanism behind this technique was explained by Heydecker *et al.* (1974) as osmotic potential can be adjusted to a level which permits the seeds to go through all the essential preparatory process of germination but prevents cell elongation and in consequence radicle emergence. Moreover during the pre germination period at the osmotic barrier the slower seeds catch up with the faster ones so that the subsequent germination is much more uniform. Favourable treatment conditions permits both the break down of food reserves and the synthesis of material required for germination to occur possibly to a greater extent than if seeds had germinated immediately. Thus it results in an instantaneous growth once the osmotic obstacle to further water intake has been removed.

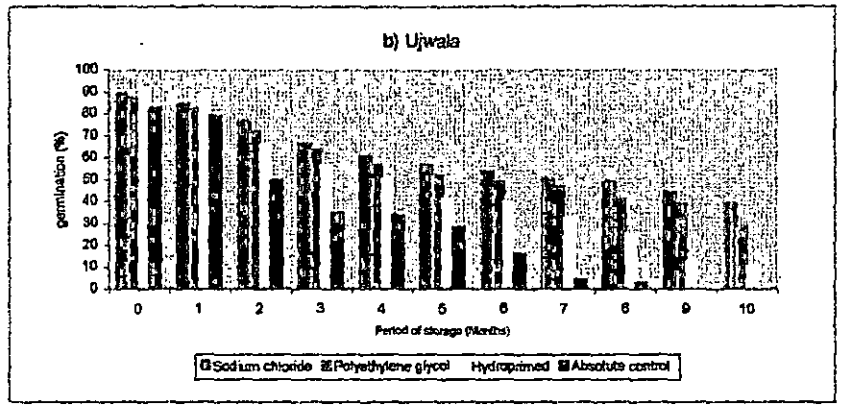
The present investigation was therefore undertaken to study the feasibility of osmopriming in overcoming physiological and genetic deterioration in stored chilli seeds.

5.1 Seedling characters as influenced by osmopriming, varieties and ageing

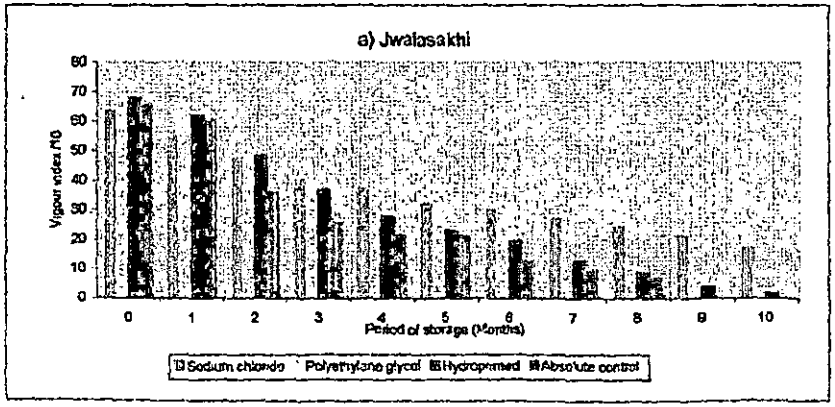
In this study fresh seeds of two chilli varieties Jwalasakhi and Ujwala were stored under ambient conditions for ten months. Random samples were drawn from the seed lots at monthly intervals and subjected to osmopriming. Two chemicals, namely PEG-6000 and Na Cl were used as osmoticum on the seed at different concentrations and durations for the reason reported by Heydeker *et al.* (1974) and Smith and Cobb (1992).

germination (%)





Vigour Index



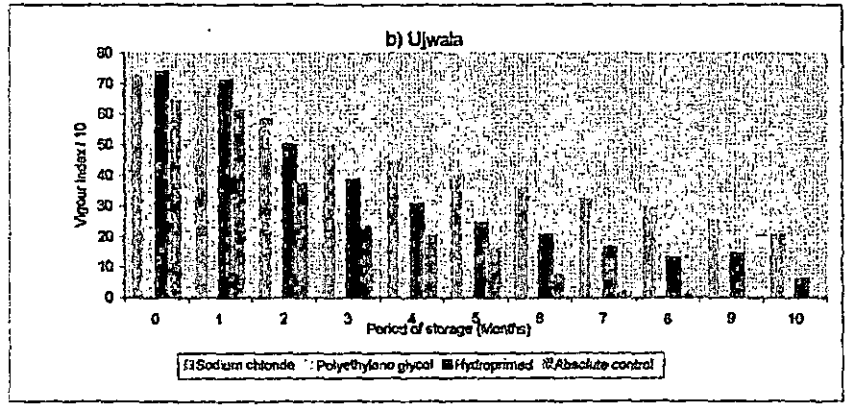


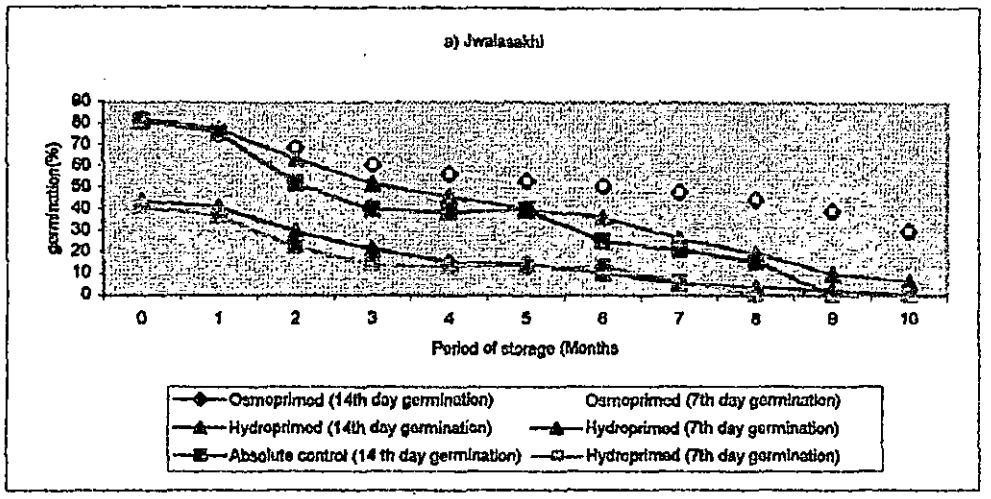
Fig. 1 Changes in seed quality parameters during storage of seeds in chilli var. Jwalasakhi and Ujwala

Results on germination percentage reveal that there is a progressive reduction in germination percentage with ageing (Fig 1). In control seeds, there was a significant reduction in germination after second month of storage. Osmopriming was found reduce this effect appreciably by the chemicals at different treatment combinations. A high degree of soundness resulted in a lower response to osmoconditioning as evidenced during the first two months where the untreated seeds also showed a high germination percentage.

Sodium chloride treatment resulted in higher germination percentage (39.00) even at 10th month after storage, followed by PEG (20.99) when compared to water treatment (6.50) and untreated control (0.00).

The effect of chemicals on improving germination as an osmoticum was established by many workers (Dey and Mukherjee, 1988; Rog *et al.*, 1995; Quing *et al.*, 1996). However, the information on precise conditions required for optimal priming is lacking as species, varieties and seed stocks of the same variety and also different osmotica yield different results. Previous studies also suggest that both the chemicals are effective in reducing water potential along with some repairing mechanism in aged seeds. Similar effect may be responsible in the present study also for improving germination in aged seeds of chilli when compared to control. Many workers reported promotive action of distilled water also (Saxena, 1979; Fujikura *et al.*, 1993a).

Presoaking seeds in water has been suggested as a means to speed up germination in egg plant and radish. The uniformity in germination is an important aspect which decides the vigour of crop. The most important observation from this study was a high uniformity and earlier germination as recorded on 7th day after sowing in osmoprimed seeds irrespective of total germination percentage. (Fig. 2a and 2b). In hydroprimed and untreated control the germination was found extended up to 14 days, thus recording a maximum of 50 per cent germination only after 7 days. In tomato and chilli it was established that osmopriming reduced the mean time of emergence and increased the uniformity and rate of germination. (Gray, 1994; Lanteri *et al.*, 1994; Dimer and Ellis, 1994). As a result of osmopriming higher rate and uniformity of germination have been reported in case of oil seeds (Fu *et al.*, 1988)



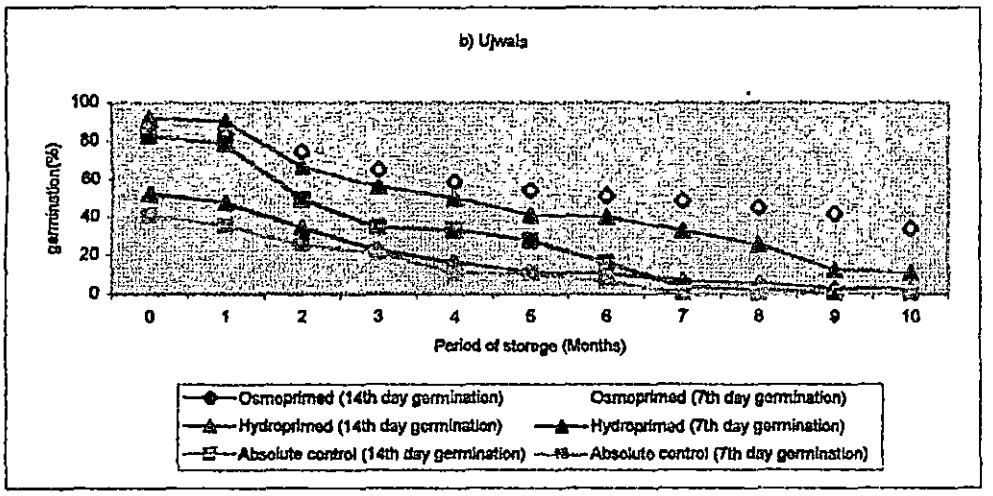


Fig. 2 Changes in uniformity in germination during storage of chilli seeds var, Jwalasakhi and Ujwala

3a Root abnormality (stubby roots) in chilli seedlings

3b Above ground abnormality (cotyledons trapped in seed coat) in chilli seedlings


NORMAL
ABNORMAL


NORMAL
ABNORMAL

In the present investigation a positive correlation was obtained between germination, vigour index and root shoot ratio of seedling (Table 7). Seeds of Ujwala proved more responsive than those of Jwalasakhi to beneficial action of critical levels of osmopriming treatments. The study revealed a rapid reduction in vigour index due to storage which was later improved by the chemical treatment (Fig. 1). Similar observations by Sathiyamoorthy and Vivekanandan (1989) suggested that specific osmoconditioning treatment reduced the seed leachate's conductivity, improved the seedling vigour index and emergence potential of seed lots. Production of ATP and activities of several enzymes like ATPase, acid phosphatase etc. were enhanced by priming (Fu, *et al.*, 1988) and rise in the activities of ATPase and acid phosphatase suggested that mobilisation of reserves may underlie the increase of germination and vigour index.

Among the different concentrations of the chemicals tried -1.5 MPa recorded maximum germination percentage and vigour index whereas duration of osmopriming treatments did not exhibit concordant results.

Seedling establishment is an important factor in any crop production programme during which the cell multiplication, elongation and enlargement initiate in an active manner. Root length and shoot length observed and root shoot ratio calculated from the present study throw a light in to the establishment of aged seeds of chilli by an osmoticum. Both the varieties manifested a high root shoot ratio which was evident from their vigour index. Osmopriming with Sodium chloride favoured root shoot ratio better than polyethylene glycol.

The commonest and most severe seedling abnormalities observed were to the root system in variety Ujwala and Jwalasakhi. With increasing duration of storage there was an increase in seedlings with stunted or stubby roots. These resulted from the death of the growing point which were very short and extremely swollen behind the tip (Plate 3a). Other type of abnormalities included trapping of cotyledons in the seed coat blocking further development and cause drying of seedlings (Plate 3b). These abnormalities were observed in the hypocotyl region of all the hydroprimed and absolute controlled seeds during advanced periods of storage. This is in agreement with the results published by

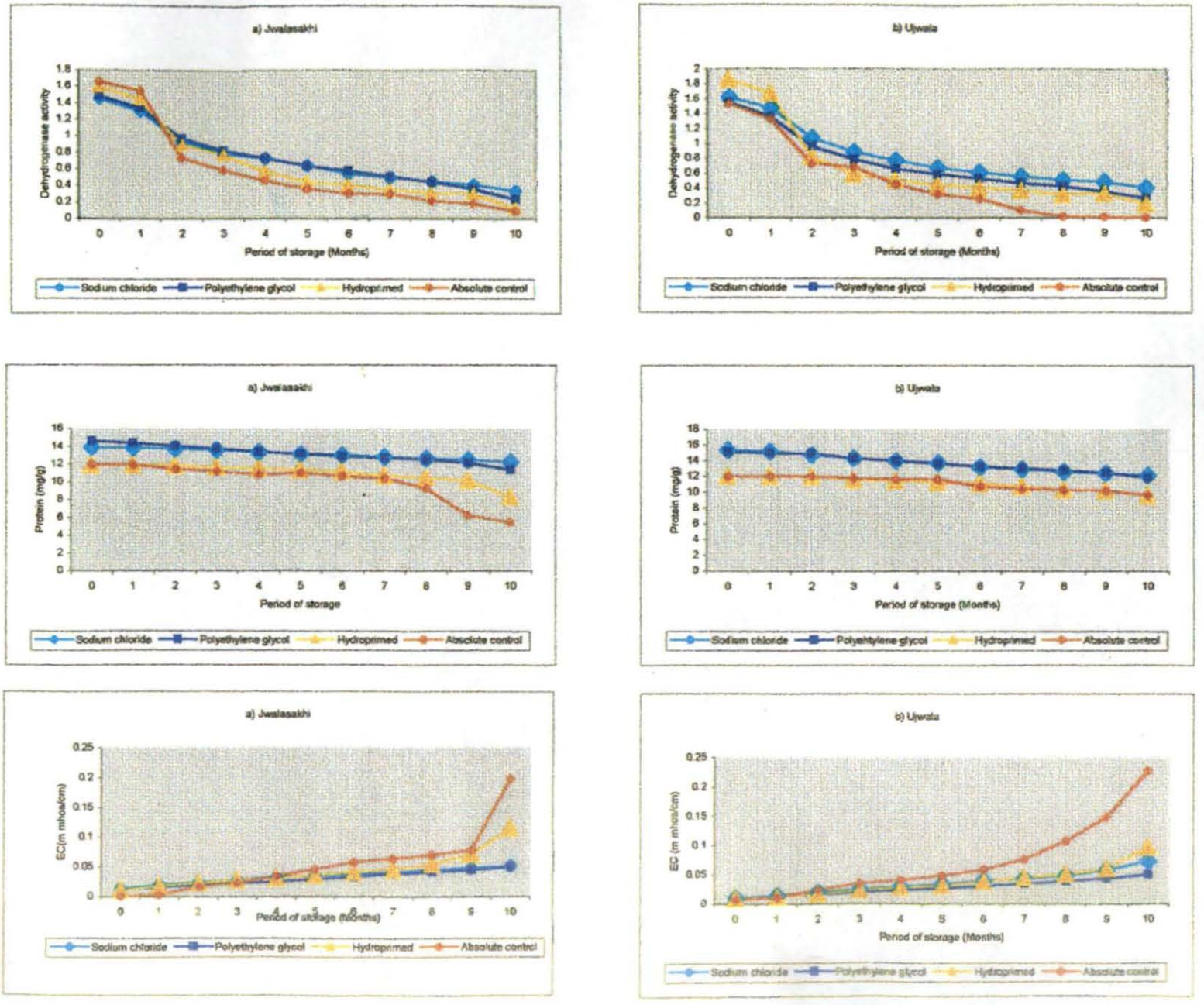


Fig. 3 Biochemical changes during storage of chilli seeds var. Jwalasakhi and Ujwala

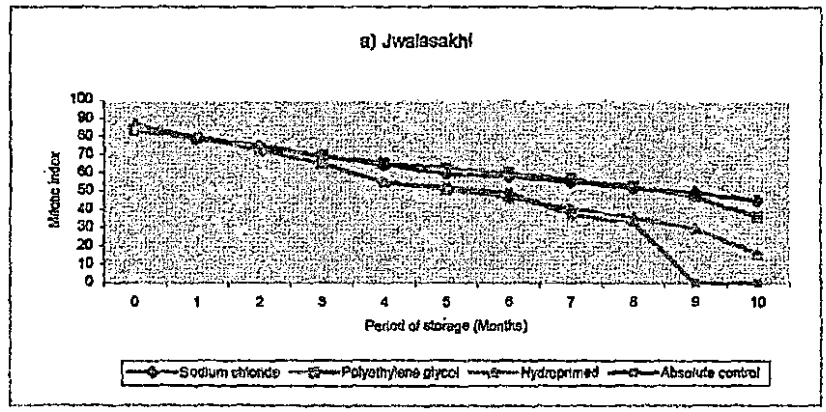
Maude *et al.*, (1994) in leek seeds where the seedling abnormalities included stunted roots with snake's head radicles.

The above observation on seedling characters clearly reflects the potentiality of osmoconditioning in enhancing germination per cent, earliness in germination, vigour index there by causing a better field establishment of seedlings raised from aged seeds. Pre sowing treatment may help to improve germination percentage by providing an opportunity for low vigour seeds to cope up with the more vigorous ones. Therefore it can be concluded that seed conditioning with PEG or Na Cl is a useful practice which will go a long way in producing quality seedlings by improving germinability and seedling vigour subsequently. It also confirms that retardation of ageing should be added to the already established beneficial results of osmoconditioning like i) faster and more uniform germination and vigour ii) higher emergence at suboptimal concentration and duration iii) ability of germination under adverse conditions.

5.2 Biochemical observations as influenced by osmopriming, varieties and ageing

Within the dry embryo, enzymes critical to repair of senescent lesions lose activity and cause progressive slowing and decline in percentage viability of seed stock as the period of dry storage is extended. A general event in the ageing seeds is the progressive loss of the activity of mitochondrial dehydrogenase with decline seed vigour culminating in the complete loss of activity at a stage at which embryo can no longer synthesise protein or germinate (Throneberry and Smith, 1955). The trend of dehydrogenase activity in aged seeds of Ujwala and Jwalasakhi from this investigation showed a steady decline from first month onwards, reaching the least in ten months after storage (Fig. 3). Sodium chloride recorded a better improvement in the enzyme activity followed by PEG (0.780 and 0.730). Treated seeds showed an increase in the enzyme activity which was evident from second month of storage onwards when compared to hydroprimed and untreated controls. Decreased activity of dehydrogenase enzyme in deteriorating seeds and its improvement by chemical treatment is well documented by Smith and Cobb (1992) and Copeland (1988).

At the biochemical level it has been observed that during osmopriming of chilli seeds there was an increase in the amount of total protein synthesis (Fig. 3). But it is not confirmed whether the protein is 'priming specific' or not. Earlier reports also showed



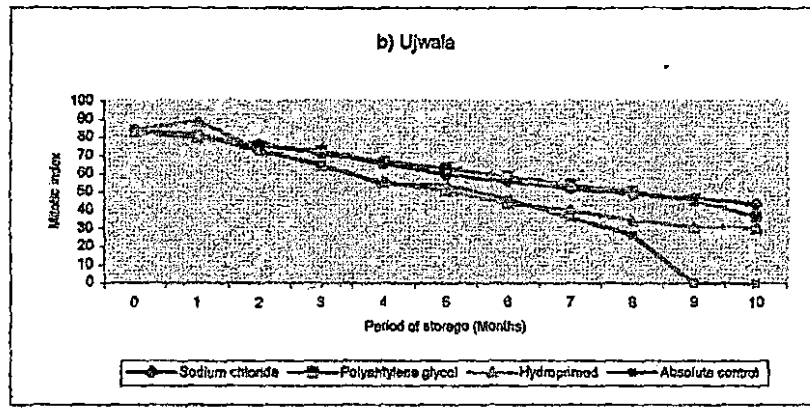


Fig. 4 Changes in mitotic index during storage of chilli seeds var. Jwalasakhi and Ujwala

that protein associated with germination are synthezised in presence of osmoticum which is a feature of particular system and priming conditions (Davison and Bray, 1991). The total reduction in protein content was only 19.22 per cent as storage period elapsed from one to ten months. The hydroprimed and untreated control produced statistically similar value for protein content. It is well documented that the osmotic stress generated by Na Cl or PEG can induce the expression of RNA and certain proteins in the embryonic axes of osmoprimed seeds (Fujikura and Karssen, 1992).

The -1.5 MPa (C_2) osmotic potential tried recorded highest dehydrogenase activity (0.776) and soluble protein (13.6 mg g^{-1}). Similarly 12 hours was found to register highest dehydrogenase activity (0.780) and soluble protein (13.6 mg g^{-1}).

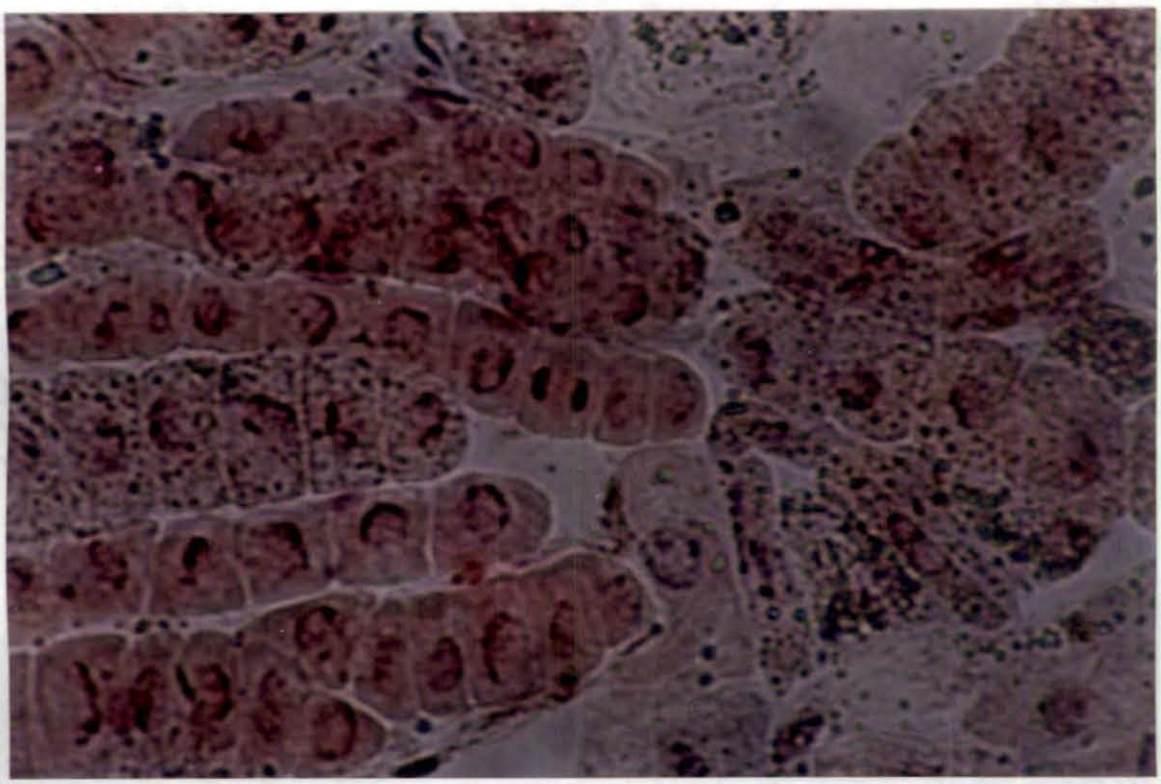
A frequently observed characteristic of deteriorated seeds is the increased leachate conductivity when soaked in water. The loss of germinability was positively correlated with extent of leakage in terms of conductivity (Vyas *et al.*, 1990). In the present study, there was a continuous increase in electrical conductivity of seed leachate as storage period advanced (Fig. 3). This indicates that a greater membrane damage had occurred in untreated control than in the seeds provided chemical treatment with Na Cl and PEG. Both the chemicals were effective in preventing the age induced leakage of solutes even after ten months of storage. A similar study was produced for leek seeds (Davison and Bray, 1991). Electric conductivity of seed leachate was negatively correlated with all other seedling and biochemical characters observed during the storage period for both varieties. The leakage was more for Ujwala when compared to Jwalasakhi. This investigation in the electrical conductivity of seed leachate evidenced that osmopriming treatment is operative through membrane integrity of cells of seed tissues.

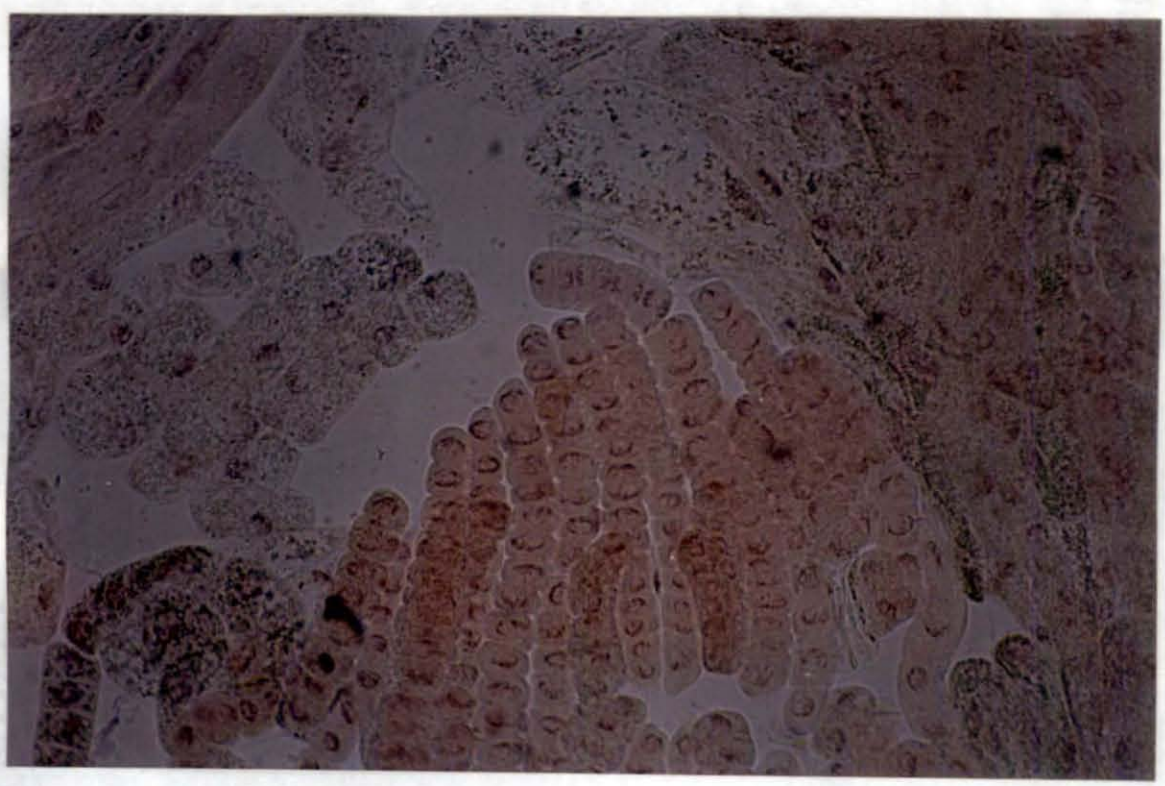
5.3 Cytological observations as influenced by osmopriming, varieties and ageing

The cytological examinations after priming showed that the mitotic index values reduced on an average to 51 per cent for both the varieties as the storage period advanced from one to ten months (Fig. 4a and 4b). The chemical Na Cl and PEG used in this study improved the appearance of early mitotic figures (Plate 4) which may be due to the partial alleviation of the restricted mechanisms for all cycle advancement and proliferation,

4a Normal mitotic cell division stage in chilli var. Jwalasakhi

4b Normal mitotic cell division stage in chilli var. Ujwala





imposed on dividing cells. This was in agreement with the findings of Mozaffari and Gahan (1978) in root apices of maize, pea and *vicia faba*.

One of the changes associated with seed ageing is aberration of chromosomes, some times referred to as mutagenic effects. Chromosomal changes have been reported in old seeds of relatively large number of species of leak, maize, chilli, pea etc. In the present investigation any type of chromosomal aberration was not able to detect during the ten months of ageing period. Rota (1986) reported that *Capsicum annuum* L. seeds subjected to different accelerated ageing treatments showed chromosomal aberrations in different degrees, the severe treatment recording the highest. From the present study it can be suggested that genetic deterioration has little effect compared to biochemical deterioration in loss of viability of chilli under ambient conditions of storage. The senescent lesion due to genetic deterioration may occur only when seeds are subjected to accelerated ageing or when the storage period extends more than ten months.

Summary

SUMMARY

Investigations on "Cytological and biochemical changes in aged and osmoprimed seeds of chilli (*Capsicum annuum* L.)" were conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, during 1997 to 1998.

The objectives of the study were

1. To study the different types of cytological and biochemical changes in aged seeds of chilli
2. To investigate the effects of osmopriming in chilli seeds.
3. To study the feasibility of osmopriming as a technique in overcoming physiological and genetic deterioration of stored seeds.

In this study fresh seeds of two chilli var. namely Jwalasakhi and Ujwala were stored under ambient conditions for ten months. Random samples were drawn from the seed lots at monthly intervals and subjected to osmopriming. Chemicals namely PEG 6000 and Na Cl were used as osmoticum on the seed for different concentrations and durations. The osmoprimed seeds were tested for various seed quality parameters. The results obtained in the present investigation are summarized below:

During the ten months of storage in absolute control the germination per cent dropped from 81 to zero. In case of hydroprimed seeds the germination dropped from 82.67 per cent to 8.50 per cent. It was observed that osmopriming seeds could remarkably improve the germination per cent to 40 during the tenth month of storage.

Variety Ujwala (58.54) recorded higher germination per cent compared to Jwalasakhi (55.31). The chemical sodium chloride recorded highest germination per cent (59.10) compared to PEG (54.75). The chemical concentration C_2 (-1.5 MPa) recorded highest germination percentage (58.43). The 48 hour treatment duration registered best germination percentage (58.54).

Application of chemicals specifically sodium chloride was found to be better in improving germination of the seeds at various months over water treatment.

Interestingly germination could be retained near to 50 per cent during the ten months of storage. Another important finding of this experiment was that osmopriming produced early germination i.e. in the case of osmoprimed seeds germination was completed within seven days, whereas it was extended or spread up to fourteen days in the case of hydroprimed and absolute control. This is a very promising character.

Vigour index calculated also showed similar results as that of germination. Variety Ujwala showed highest germination. Among chemicals used as osmoticum sodium chloride at −1.5 MPa concentration for a duration of 48 hours gave better response for both varieties.

As period of storage advanced seedling abnormalities were visible in the absolute control and hydroprimed seeds. Two types of abnormalities were observed (1) short stubby roots (2) trapping of cotyledons in the seed coat. This may be due to the decreased vigour of seedlings. All osmopriming treatments could significantly overcome this by producing only normal seedlings.

The biochemical characteristics studied showed similar results i.e. as ageing proceeded there was a progressive reduction in the activity of mitochondrial dehydrogenase and soluble protein content, the tenth month recording the least. Osomopriming treatment could significantly improve the dehydrogenase activity and protein content over the control. Sodium chloride gave better results compared to PEG.

In the present study irrespective of the variety as period of storage advanced there was a continuous increase in electrical conductivity of seed leachate. This indicate that a greater membrane damage has occurred along with seed ageing. Osmopriming could restore this damaged membrane integrity to some extent showed by the decreased leachate conductivity.

Cytological examinations revealed a decreasing mitotic index as ageing advanced. But osmopriming was able to increase these mitotic index values compared to control, which may be due to partial alleviation of the restricted mechanisms for cell cycle advancement. Any type of chromosomal aberrations were not able to detect during the storage period studied.

The present study enlightens us that

1. Biochemical deterioration is the major reason for the loss of viability of chilli seeds in storage and genetic deterioration has little effect during the period of ten months under ambient conditions.

2. Technique of osmopriming can be suggested as post storage measurement for maintaining vigour and viability in chilli seeds.

3. Though PEG and Sodium chloride are effective as osmoticum for post storage priming technique, sodium chloride is most economical when compared to PEG.

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Appendix

APPENDIX I

General analysis of variance for effect of osmopriming on seed quality parameters in chilli

Variety	Degrees of Freedom	Mean sum of squares						
		Germination	Vigour index	Root shoot ratio	Dehydrogenase activity	Protein	Eiectrical conductivity	Mitotic index
Chemical (B)	1	10005.893 **	71788.654 **	0.036 **	1.372 **	0.501 **	0.021 **	0.027
Concentration(C)	3	1148.041 **	39353.81 **	0.057 **	0.279 **	7.482 **	0.001 **	712.639 **
BC	3	598.579 **	78438.627 **	0.033 **	0.145 **	61.603 **	0.000 **	1228.08 **
Duration (D)	3	823.862 **	20873.159 **	0.055 *	0.297 **	22.911 **	0.001 **	266.269 **
BD	3	364.906 **	33493.024 **	0.011 **	0.175 **	5.240 **	0.001 **	173.986 **
CD	9	804.943 **	43454.558 **	0.044 **	0.046 **	7.420 **	0.001 **	708.175 **
BCD	9	661.294 **	35178.274 **	0.066 **	0.287 **	16.425 **	0.000 **	318.448 **
Months(E)	10	51901.06 **	5286856.285 **	0.089 **	29.962 **	166.599 **	0.039 **	37461.78 **
BE	10	720.424 **	18766.486 **	0.014 **	0.040 **	2.492 **	0.000 **	414.017 **
CE	30	114.989 **	6213.186 **	0.006 **	0.014 **	0.665 **	0.000 **	50.233 **
BCE	30	95.869 **	3783.797 **	0.006 **	0.012 **	2.810 **	0.000 *	35.326 **
DE	30	109.868 **	4546.217 **	0.002	0.009 **	0.709 **	0.000 **	19.455 **
BDE	30	48.743 *	3043.756 *	0.003 **	0.017 **	0.255 **	0.000 **	29.506 **
CDE	90	111.948 **	5216.794 **	0.002 **	0.014 **	0.449 **	0.000 **	35.256 **
BCDE	90	133.331 **	4848.286 **	0.002 **	0.012 **	1.189 **	0.000 **	37.48 **
Variety (F)	1	5496.033 **	1164824.464 **	0.042 **	0.599 **	131.740 **	0.000	112.531 **
BF	1	42.897	376555.367 **	0.722 **	1.359 **	0.476 **	0.002 **	46.598 **
CF	3	341.52 **	2173.592 **	0.025 **	0.253 **	39.900 **	0.000 **	746.858 **
BCF	3	280.546 **	3365.181 *	0.039 **	0.077 **	9.088 **	0.001 **	527.451 **
DF	3	637.541 **	20342.951 **	0.002	0.045 **	0.129	0.000 **	677.325 **
BDF	3	390.386 **	30487.86 **	0.008 **	0.034 **	2.196 **	0.000 **	215.622 **
CDF	9	853.261 **	28695.751 **	0.008 **	0.186 **	12.439 **	0.000 **	546.866 **
BCDF	9	1660.181 **	82779.42 **	0.007 **	0.380 **	15.914 **	0.000 **	204.679 **
EF	10	341.732 **	44697.67 **	0.006 **	0.081 **	5.422 **	0.001 **	175.005 **
BEF	10	122.962 **	5345.714 **	0.027 **	0.015 **	2.440 **	0.001 **	6.348
CEF	30	87.234 **	5267.495 **	0.004 **	0.077 **	0.905 **	0.000 **	41.382 **
BCEF	30	92.634 **	5164.244 **	0.004 **	0.033 **	1.070 **	0.000 **	66.054 **
DEF	30	93.748 **	3637.057 **	0.002	0.028 **	0.336 **	0.000 **	97.591 **
BDEF	30	81.836 **	4216.408 **	0.002	0.008 **	0.236 **	0.000 **	72.113 **
CDEF	90	82.361 **	4977.051 **	0.002 *	0.025 **	0.415 **	0.000 **	32.645 **
BCDEF	90	75.125 **	4098.231 **	0.002	0.032 **	0.893 **	0.000 **	35.085 **
Error	1406	32.808	1999.134	0.002	0.002	0.101	0.000	6.464

** Significant at 1 % level

* Significant at 5 % level

CYTOLOGICAL AND BIOCHEMICAL CHANGES IN AGED AND OSMOPRIMED SEEDS OF CHILLI

(Capsicum annuum L.*)*

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
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1999

ABSTRACT

Studies on seed quality aspects in storage of chilli variety Jwalaşakhi and Ujwala were undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 1997 to 1998 to study the different types of cytological and biochemical changes in aged seeds of chilli, to investigate the effects of osmopriming in chilli seeds and to study the feasibility of osmopriming in overcoming physiological and genetic deterioration of stored seeds.

The germination studies conducted during the ten months of storage period revealed that chilli seeds lost viability completely from the nineth month of storage onwards in ambient conditions. Hydroprimed seeds germinated to the tune of 13 and 20 per cent in Jwalasakhi and Ujwala respectively. Under this conditions osmopriming with chemicals PEG and Na Cl significantly improved this germination per cent to 40 as observed during the tenth month of storage. The chemical Na Cl with concentration 1.5 MPa and 48 hours duration was found the best. Among the varieties Ujwala responded better compared to Jwalasakhi. Irrespective of the chemical all osmopriming treatments produced uniform seedlings compared to control and the germination was completed within seven days under ideal conditions. In general vigour index and root shoot ratio also expressed similar results to that of germination.

Studies on biochemical characteristics revealed a progressive loss of activity of mitochondrial dehydrogenase and soluble protein with ageing. The electrical conductivity of seed leachate also increased with period of storage revealing the loss of membrane integrity resulting in leakage of cell contents outside the cell membrane. Osmopriming treatments were able to repair this membrane damage to a good extent and increase the level of dehydrogenase activity and soluble protein content compared to control. In both varieties sodium chloride with −1.5 MPa was found the best treatment. Among varieties Ujwala responded better than Jwalasakhi.

Cytological studies revealed a reduction in mitotic index values during storage irrespective of the variety. Osmopriming was found to improve the mitotic index values over hydropriming and untreated control. Any type of chromosomal aberration was not

detected during the ten months of ageing period. Here also sodium chloride with 1.5 MPa was found to be superior.

It can be concluded that

1. The loss of viability in chilli seeds is mainly due to biochemical lesions
2. Osmopriming was found beneficial after two months of storage in chilli seeds, because chilli seeds could retain the innate capacity to germinate and produce quality seedlings up to two months of storage period.
3. PEG-6000 and Na Cl can be used as an osmoticum for post storage priming treatments in aged chilli seeds. Na Cl can be advocated more economically compared to PEG.