SEED INVIGORATION STUDIES IN RICE (*Oryza sativa* L.)

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SEED INVIGORATION STUDIES IN RICE (*Oryza sativa* L.)

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C E R T I F I C A T E

This is to certify that the thesis entitled "**SEED INVIGORATION STUDIES IN RICE (*Oryza sativa* L.)**" submitted by **Mr. G.L. NATARAJA** for the award of degree of **MASTER OF SCIENCE (Agriculture) IN SEED TECHNOLOGY** to the university of Agricultural Sciences, Bangalore is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma associateship, fellowship or other similar titles.

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INTRODUCTION

I INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food crop of two thirds the population of the world. It occupies an area of 147.17 million ha. with a production of 525.48 million tonnes and a productivity of 3571 kg/ha.. In India rice is the major food crop occupying 42 million ha. with a production of 109.5 million tonnes and with a productivity of 2607 kg/ha. (Anon, 1992). In Karnataka it accounts for 13.16 million ha. with a production of 30.69 million tonnes and productivity is 2300 kg/ha (Anon, 1992-93). The increasing population rate grimly dictates the world's food requirements, expecially for rice, so the extra required to feed the accelarating population ought to be met only by improving the present productivity level.

Seed being a basic and crucial input, plays an important role in increasing the productivity under marginal and intensive farming systems. Fortunately the farmers have become more discriminating with regard to the use of high quality seed and are now becoming aware of the benefits of using high vigour seeds as a source of planting material.

Seed vigour can be considered as the summation of all seed attributes which contribute to seed performance in the field. Seed deterioration is an irreversible degenerative changes in the quality of seed leading to loss

in vigour and viability of seeds which inturn results in low field emergence and field stand. There are cause and factor(s) effect on seed deterioration, Lipid peroxidation and free radical production are believed to be the basic causes for seed deterioration. Scavenging free radicals by hydration-dehydration treatment of stored seeds has shown beneficial effects on the maintenance of vigour and viability of a number of crop seeds (Dharmalingam and Basu, 1978).

Seed invigoration implies on improvement in seed performance by any post harvest treatment resulting in improved germinaibility, greater storability and better field performance than the corresponding untreated seed (Basu, 1990). In these treatments membrane integrity is improved, it counteracts lipid peroxidation and free radical chain reactions. A wide range of substances are used for soaking treatments like bio active ingredients, nutrients, antioxidants etc.

Seed invigoration or seed priming treatments have been successfully used in a range of species to improve germination performance and/or emergence even under less than ideal conditions and have also been shown to protect and/or to improve the performance of naturally aged seeds.

In Indian situation normally rice seeds have been stored under ambient conditions in gunny bags or cloth bags in godowns/seed stores where the temperature and relative

humidity are fluctuating. Hence the seed lots deteriorate faster resulting in reduced vigour and viability.

It was often observed that aged rice seed lots having germination of above minimum certification standards have failed to give satisfactory emergence in the field due to reduced seed vigour. Some of the researchers have tried hydration-dehydration treatments with or without chemicals to improve germination and storability in rice but most of these studies were only limited to the laboratory and there are no systematic studies pertaining to the effect of seed invigoration on different vigour level seed lots and its impact on crop performance. Hence the present study entitled "Seed invigoration studies in rice variety Mangala" was taken up on five different vigour level lots (viability levels) with the following objectives.

1. To standardize the period of soaking for hydration-dehydration treatment in rice.

2. To study the effect of seed invigoration on different vigour level seed on germination, vigour and storability, and

3. To study the influence of seed invigoration on growth and yield in rice var. Mangala.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Seed viability is controlled by several factors of which, seed moisture content, relative humidity and temperature of the storage environment play major role. It is often considered that seeds are in store soon after they are harvested and then there starts the processed of deterioration (Harrington, 1973). Generally the loss of vigour and viability is invariably associated with loss in membrane integrity. This results in leakage of cell contents and changes in cell constituents are also concurrent with loss in viability. Any means to protect the seed from rapid deterioration should start from good production practices and appreciable storage conditions. In addition, seed treatment can also be used as a measure to prevent rate of deterioration land seed performance both in storage and also in field.

The review of literature, pertaining to the present investigation are presented in this chapter.

2.1 Seed vigour concept and definition

Generally seed attains maximum viability and vigour at physiological maturity. Then onwards seed starts deteriorating in all crops. Loss in vigour and germination is a reflection of seed deterioration and has

considerable economic impact. Seed vigour is a multiple concept and an important seed quality component (Perry, 1987). The concepts of seed vigour has been extensively reviewed by many scientists.

Isley (1957) defined the "vigour as the sum total of all seed attributes which favour stand establishment under unfavourable field conditions", Seed vigour is the sum total of all seed attributes which favour rapid and uniform stand establishment in the field (Delouche and Caldwell, 1960). Heydecker (1972) defined the seed vigour as the ability of seed to germinate and produce a stand in a sub-optimal environment. Seed vigour is the potential performance of seed both in the field and in storage (perry, 1981).

Association of Official Seed Analysts defined seed vigour as "the sum total of all those properties in seed which upon planting results in rapid and uniform production of healthy seedlings under a wide range of environment including both favourable and stress conditions". ISTA (International Seed Testing Association) defined seed vigour as "the sum of those properties which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence.

2.1.1 Seed deterioration and loss of viability

Delouche (1973) defined seed deterioration as "summation of physical, physiological, biochemical changes occurring in a seed which ultimately leads to its death". He also characterised seed deterioration as inexorable, irreversible, minimal at the time of physiological maturity and variable among seed kinds, varieties, seed lots of same variety and among individual seeds.

In the deterioration model proposed by Delonche and Baskin (1973), it is suggested that deterioration of several aspects of seed vigour preceeds loss of germinability.

Several bio-chemical changes are known to occur in seeds during their deterioration, they are;

1. **Enzymatic changes** : Which could be either an increase in metabolic activity of certain enzymes such as phytase, protease and phosphatases or a decrease in the activity of other enzymes such as catalase, peroxidase, dehydrogenase, cytochrome oxidase, glutamic acid decarboxylase and

2. **Metabolic changes** : such as changes in (a) respiration (b) Carbohydrate metabolism and (c) Organic acid metabolism.

Major cause for the loss of viability is supposed to be predominently associated with membrane break down which is shown by increased leaching of electrolytes and non-electrolytes from seeds following storage.

2.1.2 Physiological and Biochemical manifestation of seed deterioration

The consequence of deteriorative changes of seed like membrane degradation, accumulation of toxic metabolites, decreased enzymatic activity, lipid autoxidation, reduced yield and finally loss of germination of seeds have been highlighted by Delonche (1973).

2.1.2.1 Effect of Ageing

Mitochandria are the most studied cellular organelle with regard to seed vigour. Abu-Shakra and Ching (1967) indicated a decrease in mitochondrial phosphorilative efficiency in old seeds as major reasons for loss of vigour. Seed ageing and vigour are related to the biochemical changes, decreased sugar and protein contents and decreased dehydrogenase activity (Ovcharov *et al.*, 1978).

Chauhan *et al.* (1984) has reviewed the major changes in sub cellular system (membranes, Mitochandria, protein synthesis, ribosomes and DNA) and enzyme machinery which leads to loss of viability and vigour in aged seeds. The ageing mechanism in seeds resulting from lipid peroxidation which include bio-membrane degradation, protein denaturation, interference with DNA and protein synthesis, accumulation of toxic meterials and the destruction of the electron transport system of oxidative phosphorylation has been proposed by Wilson and McDonald (1986). It is more probable that several important cellular systems become significantly degraded with age, so that inefficiencies in any one function amplify imperfections in others. All the processes occurring during deterioration are not necessarily irrepairable or irreversible.

2.1.2.2 Membrane degradation

It was reported that the old deteriorated seeds are physiologically and biochemically inactive and support the concept that seed ageing may be associated with loss of membrane integrity (Ghosh *et al.*, 1981).

Ching and School Craft (1968) who studied the aged seeds of clover and age considered the increase in

conductance, sugars, amino acids and phosphate concentration of the leachate of deteriorating and dead seeds as resulting from degradation of cellular membrane and subsequent loss of permeability followed by loss of viability.

Broadnok and Mathews (1970) reported that weaker the membrane system, the larger would be quantity of electrolytes leached from the seeds and greater the conductivity of the steep water. Agarwal (1980) and Ghosh *et al.* (1981) observed increased seed leachate and electrical conductivity due to membrane degradation during seed deterioration in rice.

2.1.2.3 Free radical damage

Das Gupta *et al.* (1976) reported that the free radical damage as an important factor in seed senescence having a close relationship between the loss of vigour and viability of seeds and radio sensitivity. Basu *et al.* (1975) also supported a relation between free radical damage and seed deterioration.

A free radical is an atom or group of atoms with an unpaired electron, which possesses the ability of donating or receiving an electron. The hydroxyl (-oH) and superoxide (O_2^-) are the most important radicals believed to cause most

damaging biological action in free radical formation of lipid peroxidation which act on the membrane leading to its rupture and loss of viability. The free radical damage to cellular components leading to deterioration in aged seeds was reported by many workers in maize (Pammenter *et al.*, 1974), sunflower, wheat, rice, mung, gram, pea, onion and tomato (Busu *et al.*, 1975) and wheat and jute (Das Gupta *et al.*, 1977).

2.1.2.4 Impaired enzymatic activity

The decreased activity of dehydrogenase with decline in seed vigour in rice seeds was reported by Ghosh *et al.* (1981). They suggested that complete loss of activity of this enzyme prevented germination. The loss of viability in association with enzymatic activity was reported in sorghum (Perl *et al.*, 1978), sunflower (Dey and Basu, 1982) and wheat (Bhattacharya and Mandi, 1985).

2.1.2.5 Respiration changes

Several aspects of respiratory metabolism are correlated with seed deterioration, i.e., decline in oxygen uptake and increase in respiratory quotients. Loss of ability to produce ATP were found to be highly correlated with loss of viability in cauliflower, rape & soybean seeds (Lunn and Madsen, 1981).

2.1.2.6 Toxic metabolites accumulation

Toxic metabolites are the cause of many secondary events in the deterioration of seeds. Ethanol, aldehydes, short chain fatty acid and phenols are found in aged seeds. Phenolics and ABA were known to cause metabolic blocks to enzyme function there-by causing loss in viability of seed.

2.2 Seed invigoration

The term invigoration broadly denotes any treatment (physical, chemical and physiological) which is applied to improve germination. Seedling vigour or field stand or to protect seed quality. Recently, infusion of bio-ingredients, agro-chemicals etc., into the seed is reported to invigorate seeds. Even mid storage seed invigoration was reported to improve seed viability and vigour during subsequent storage.

2.2.1 Physiological basis of seed invigoration

The key basis of all pre-sowing seed treatment is to hydrate the seed under controlled conditions, so that they become physiologically active. Thus, they are able to initiate repair and detoxification systems and also become physiologically advanced by carrying out certain initial steps of germination without radicle emergence. The subsequent

improvement in germinability of the stored seed could be due to the fact that such "advanced" seed would retain the ability to carry on from where they left off upon re-imbibition (Heydecker, 1974).

Heydecker *et al.* (1975) described priming as a technique accomplished by imbibing the seed in an osmotic/salt solutions that allows the seed to imbibe water to a level that permits some of the initial steps of germination to proceed but prevents radicle emergence. Limited uptake of water appears to be the key to seeds in all treatments. Priming allows "slow" or "fast" seeds in a population to attain the same stage of readiness, a property of considerable significance in obtaining a rapid and uniform population seedlings. Pre-sowing treatments aimed at enhancement of germination performance of seeds. Per cent emergence and uniformity havea major impact on stand establishment, yield and quality.

2.2.2 Role of cellular repair systems

Whether the cellular repair system, which can restore much of the age-induced damage plays a major role during short term hydration of seeds before drying back is yet to be critically elucidated (Berjak and Villers, 1972). Basu

and Pal (1979) opined that much of the effect of hydration would not involve any major biochemical repair system in the cell and the effect may be rather biophysical than biochemical. While, Osborne (1982) gave physiological and biochemical evidence of repair of DNA lesions and restoration and maintenance of DNA integrity upon seed germination.

2.2.3 Leaching of inhibitors

Basu *et al.* (1974) reported the beneficial affects of water soaking and chemical treatments on leaching of auto toxic metabolites from the rice and jute seeds. Similar effects were observed by Basu and Das Gupta (1974) in wheat and Rudrapal and Basu (1982) in mustard.

2.2.4 Enzymatic activity and lipid peroxidation

The enzymatic activity has been related to the process of seed invigoration by hydration dehydration or chemical seed treatment.

Rudrapal and Basu (1979 a) in wheat, Dey and Basu (1982) in sunflower and Basu *et al.* (1985) in mustard reported the beneficial effects of physico-chemical treatment in controlling the loss of vigour and viability due to increased

activity of amylolytic and dehydrogenase enzyme and reduced lipid peroxidation. Significant improvement in the vigour and storage life was found to be related to an enhanced activity of dehydrogenase and peroxidase with a simultaneous reduction in free fatty acid formation, Lipase activity and lipid peroxidation in stored seeds of wheat and mustard (Rudrapal and Basu, 1982), maize and mustard (Dey and Mukherjee, 1986) and soybean (Saha *et al.*, 1990). Malavika Dadlani *et al.* (1994) observed that increased peroxy value and decrease in phospho-lipid and tocopheral content and they were concurrent with lose in viability and vigour.

2.2.5 Cell membrane function and free radical damage

First and fore most important consequence of seed deterioration is cellular membrane degradation and then loss of permeability. Simon (1974) reported that the membrane functional properties can be reconstituted by imbibition. The electrical conductivity of the leachates of treated seeds was found to be significantly lower than the control. Many workers have therefore, suggested a beneficial effect of the chemicals on the cell membrane functions. Some sort of protective action of the treatments would presumably extend seed viability. Several workers have concluded beneficial effect of seed treatment as reflected in better germination

and early seedling growth to be associated with greater cellular membrane integrity as indicated by low electrical conductance of seed leachate and reduced leakage of sugars and amino acid from the seed, often found to be correlated with seed vigour (Das Gupta *et al.*, 1977; Rudrapal and Basu, 1979 a; Dey and Mukherjee, 1984; Nilanjana and Basu, 1988; Rudrapal and Nakamura, 1988 and Saha *et al.*, 1990).

The basic reason for ageing and senescence of the cell was the reaction of oxygen and the lipid constituents of the cellular membrane, to form free radical intermediates (Tappel, 1973). This hypothesis of free radical damage as a major cause for deterioration was supported by extending the seed viability by radio-protective chemical (i.e., ,free radical controlling agents) from the work of Basu *et al.* (1975) and Basu (1976). The free radical damage can be significantly reduced by providing a electron source. Many workers have ascribed seed invigoration to phenomenon of repair, endogenously formed free radical quenching and reorganisation of bio-organells for the counteraction of physiological deterioration by hydration-dehydration and chemical treatments (Das Gupta *et al.*, 1977; Basu and Pal, 1979; Dey and Basu, 1982; Dolly pan and Basu, 1985 and Rudrapal and Nakamura, 1988).

2.2.6 Repair and protection of seed in storage

Basu (1976); Savino *et al.* (1979) and Basu and Rudrapal (1980) described the relative better performance of storage by pre-sowing or mid storage seed treatments. Brocklehurt and Dearman (1984) reported the better germination performance of pre-soaked stored seeds. Relatively short duration hydration and dehydration treatments (2-24 hrs imbibition) have reported to increase the vigour of stored seed and/or extend the longevity both under natural and adverse storage conditions in rice, jute, sunflower, pulses and vegetable seeds (Basu, 1976) and wheat (Rudrapal and Basu, 1982).

Dey and Mukherjee (1984) and Rudrapal and Basu (1982) attributed the beneficial effects of treatments to reduced lipase activity, lowered fatty acids, lowered lipid peroxidation in treated seeds. The free radical quenching or scavenging treatments has been suggested to terminate the free radical chain reaction in aged seeds (Basu, 1976; Mitra and Basu, 1979 and Dey and Mukherjee, 1986). The improved vigour and increase in the longevity associated with priming hydration-dehydration treatments have been interpreted as indications that repair of accumulated damage occurs during treatment (Tilden and West, 1985.

2.2.7 Effect of hydration-dehydration treatment in controlling seed deterioration

Several reports on the beneficial effects of seed soaking in water alone are available. Zubenko (1959) reported the response of seed hardening was much greater in plants when they experience water stress either due to shortage of soft water or high rates of potential transpiration. . Maize seeds soaked for 24 hrs recorded 40 per cent increase in plant growth and 33 per cent increase in grain yield.

Austin *et al.* (1969) stated that increase in embryolength of those seeds subjected to hydration-dehydration was due to cell division rather than cell elongation. Basu *et al.* (1974), Basu and Pal (1979) observed that soaking of rice seeds in water for six hours followed by drying to an initial moisture content significantly checked the loss of seed vigour and viability during subsequent storage.

The wheat seeds pre soaked in water for two or three hours followed by drying greatly slowed down the loss of vigour and viability during subsequent storage with improved seed germination and seedling vigour (Basu and Das Gupta, 1974 and Rudrapal and Basu, 1979 b, 1982).

Basu and Pal (1980) reported Hydration of 12 month old rice seeds by moisture equilibration for 24 to 72 hours or by soaking in water for 6 hours followed by drying back greatly minimised the deterioration under accelerated and natural ageing conditions. Pre-soaking of barley seeds in water for two hours followed by drying back significantly increased germination percentage, root and short length and grain yield (Punjabi *et al.*, 1982). Low vigour seeds showed increased rate of germination, per cent emergence and seedling establishment by subjecting them to hydration-dehydration treatments for two hours and also concluded repair of previously sustained deterioration by invigoration treatments (Burgass and Alison, 1984).

Mohammed *et al.* (1982) and Nagappa (1983) reported that increased germination percentage root and shoot length by soaking the sunflower seeds in water for 2 hours followed by drying.

Saha and Basu (1984) studied the soaking drying and moisture equilibration drying treatments for 12 month old soybean seeds. They found MED (at 100% RH, 28^0C) treatment was effective in counteracting soaking injury and physiological deterioration of seeds. Hydration- dehydration

treatment showed significant improvements in storage life and vigour of maize seeds (Dey and Mukherjee, 1986).

Mandal and Basu (1987) observed the improved seedling emergence, grain yield, 1000 grain weight and storage life of stored wheat seeds by mid way hydration-dehydration treatments. Saha *et al.* (1990) suggested the beneficial effects of hydration-dehydration treatments. Moisture equilibrated sand drying and moist sand conditioning soaking drying improved seed vigour and viability of soybean by counteracting the lipid peroxidation reactions.

Basu (1990) reported the extended storability of hydrated-dehydrated seed in addition to improved vigour and viability. Soaking of maize seeds in distilled water for six hours gave better germination, seedling vigour and increased field performance (Eshanna and Kulkarni, 1990). The loss of viability of seeds of paddy cultivars under ambient conditions could be significantly slowed down by giving soaking drying treatments at the thresh hold of declining viability with water or dilute salt solutions (Geetha and Vadivelu, 1994).

Chemicals

Sodium phosphate

Basu and Das Gupta (1974) observed that soaking of wheat seed in sodium phosphate (10^{-4}m) for three hours followed by drying back to original moisture content appreciably slowed down the loss of vigour and viability during storage with improved germination, seedling vigour and grain yield. Similar results were reported by Das Gupta *et al.* 1976, 1977 and Rudrapal and Basu (1979 a).

The vigour and viability of stored seeds of winter crops (winter wheat, rice, sunflower, pulses, which deteriorate faster) can be maintained by soaking in sodium dihydrogen phosphate at 20 to 50 mg/l water and 2 to 4 l/kg seed for two to six hours (Basu, 1977).

Mitra and Basu (1979) observed the better field performance and productivity of tomato seeds by soaking in 10^{-4} m solution of disodium phosphate. Increased seed germination (35 per cent), viability and vigour was reported by Basu and Pal (1979) in six month old rice seeds by treating with 10^{-4} m sodium phosphate solution.

Kundu and Basu (1981) found that soaking of stored carrot seed in disodium phosphate (10^{-4}m) for two hours followed by drying greatly reduced deterioration during subsequent storage and also performed well in the field.

Punjabi *et al.* (1982) reported that pre-soaking of barley seed in sodium phosphate (10^{-4}m) for two hours followed by drying back significantly increased germination percentage, seedling length and grain yield. Bhattacharya *et al.* (1984) observed the vigorous seedlings and higher yield of black gram seeds pre-soaked in sodium dihydrogen phosphate (5×10^{-4}m). Jayaraj *et al.* (1986) noticed that mid storage correction of sorghum seeds with sodium phosphate resulted in higher viability and vigour. The increased seed yield was obtained by Chatterjee *et al.* (1987) in groundnut seeds treated with sodium dihydrogen phosphate (5×10^{-4}m). Better germination percentage of rice seeds was obtained in coastal saline soils by presoaking the seeds in 1-1.5 % NaH_2PO_4 or 2-2.5 % Nacl for 24 hours prior to sowing (Patil, 1989).

Manmohan Kaur (1992) reported the significant improvement in field emergence, field establishment and speed of emergence in sunflower seeds treated with sodium dihydrogen phosphate (0.5%) for 6 hours. Similar improvement in seed quality and storability was observed in parental lines of BSH-

l sunflower hybrid (Basu, 1994). Geetha *et al.* (1994) concluded that sodium phosphate (10^{-4}m) was effective in prolonging the shelf life of the rice seeds.

Sodium thio sulphate

Basu *et al.* (1974) and Basu and Pal (1979) reported that rice seeds of low viability treated with sodium thio sulphate (10^{-5}) for six hours increased the rate of germination and early seedling growth markedly. Similar findings were reported in wheat (Basu and Das Gupta, 1974 and Das Gupta *et al.*, 1976).

Das Gupta *et al.* (1977) reported that seed treatment of wheat and jute seed with dilute solution of sodium thio sulphate (10^{-5} to 10^{-3} m) for three hours minimised the loss of vigour and viability. Sunflower seed priming with 1.0 per cent sodium thio sulphate showed significant improvement in field emergence, field establishment and speed of emergence (Manmohan Kaur, 1992).

Sodium Chloride

Basu and Das Gupta (1974) noticed that soaking of wheat seeds in sodium chloride (10^{-3} m) for three hours

appreciably slowed down the loss of viability with improved speed of germination and seedling vigour. Basu (1977) reported that the vigour and viability of stored seeds of winter crops (winter wheat, rice, sunflower, pulses ,which deteriorate faster) can be maintained by soaking in sodium chloride at 20 to 50 mg/l water at 2 to 4 l/kg seed for two to six hours.

Basu and Pal (1979) studied beneficial effects of sodium chloride ($(10^{-5}$ to 10^{-4}m), in slowing down the loss of viability and vigour during subsequent storage. Similarly the maximum germination was obtained in rice var. Jaya by soaking seeds in 2.5 per cent solution of sodium chloride (Patil, 1989).

Rice variety IR-8 seeds of 6 months old were soaked for 4 hours with various solutions and then dried in the shade. 0.5 per cent sodium chloride soaked seeds recorded highest germination (76 %) after six months storage (Mathew and Alexander, 1991).

Santha Celine Mary *et al.* (1994) reported the influence of seed invigoration treatments on differentially aged seeds of bhendi and lab-lab under different soil media. Invigoration with one per cent sodium chloride recorded improved field emergence in loamy soils.

Potassium nitrate

Basu *et al.* (1974) reported the beneficial effects of pre-soaking the rice seeds with potassium nitrate. Dimov *et al.* (1978) observed the improvement in germination of capsicum and tomato seeds soaked for three hours in one per cent potassium nitrate.

Beneficial effects of potassium nitrate was observed in rice (Tomar *et al.*, 1987; Karivaratharaju and Ramakrishna, 1985 and Geetha and Vadivelu, 1994).

Potassium phosphate

Mehrotra *et al.* (1967) found that soaking of rice seeds in 15 and 20 per cent solution of KH_2PO_4 for 18 hours before sowing increased grain yield over control.

Dimov *et al.* (1978) noticed that pre-soaking treatment of potassium phosphate to tomato and capsicum (1.5 %) seeds for three hours improved the field emergence, uniformity of emergence and seedling growth. Similar reports were observed by Kathiresan *et al.* (1984 a) in sunflower (0.1 %) for 12 hours and Solanki and Joshi (1985 a) in cucumber and capsicum (3 %) for 12 hours. Contrarily potassium phosphate

reduced percentage of germination and emergence in leek and celery (Brocklehurt and Dearman, 1984).

Seed invigoration with potassium phosphate increased seed germination, vigour index and seedling growth rate in maize (Kurdikeri *et al.*, 1993).

Jagadish and Mahadevappa (1994) observed significant improvement in field establishment and fruit yield in capsicum and tomato seeds pre-soaked in 150mM solution of potassium phosphate.

Poly ethylene Glycol (PEG-6000)

Yaklich and Orzolek (1977) observed early emergence of sweet pepper seeds when pre-soaked in-8 bars solution of PEG-6000 (240 g/litre) and pre-treatment of onion, carrot and tomato seeds with -12 bars of PEG-6000 shortened the germination period by about 25 per cent (Wiebe, 1982).

Starmonth and Doling (1982) reported the detrimental effect of PEG in winter wheat. The germination of treated seed ranged from 56 to 98 per cent where-as in control it is 85 to 100 per cent. Priming the seeds of hot pepper in -4 bar PEG (6000) for 120 h retarded the seedling development (Rivas *et al.*, 1984).

Karansingh and Kakralya (1990) reported effective improvement in seed germination, storability, seedling vigour, seedling emergence and field performance of chickpea seed treated with PEG-6000 for 48 hours. Osmo conditioning with PEG at -12.7 bars for 7 days at 18°C improved significantly rate of germination and seed performance and field emergence in rice (Vieira and De, 1992).

Gibberellic acid

Omran *et al.* (1980) observed the increased germination, plant height, plant dry weight and yield in Okra seeds treated with GA_3. Germination percentage of sunflower seed was markedly increased by soaking in 25 ppm GA_3 for 24 hours followed by drying (Mohammed *et al.*, 1982).

Solanki and Joshi (1985 b) observed that pre-soaking of tomato and cauliflower seeds in GA_3 for 12 hours at 10 and 5 ppm respectively followed by drying markedly increased the germination percentage.

Cow dung

The cow dung extract treatment exhibited a significant superiority in germination root and shoot

development and vigour index over soaking in urine and hydration-dehydration treatment (Kamalan Joseph and Rajapan Nair, 1989).

The mode of action of the seed invigoration treatments is still unclear but prevention of damaging oxidative reactions especially free radical-induced lipid peroxidation reactions involving unsaturated lipid moieties of lip-protein biomembrane and repair of age induced damage to vital bio-organelles by the cellular repair system, appear to be the primary reason of invigoration (Basu, 1990).

MATERIALS AND METHODS

III MATERIAL AND METHODS

In the present study the effect of various seed invigoration treatments on germination, vigour, storability and field performance of five vigour level lots of rice variety Mangala with different germination percentage were assessed in the laboratory at the Department of Seed Technology, Gandhi Krishi Vignana Kendra, and the field experiment was carried out at Wet Land, Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore during Kharif season, 1995.

The material and methods adopted in the present study are described below.

3.1 Seed material

Mangala being popularly grown short duration rice variety in Karnataka was cho-sen for the study. Five commercial seed lots which differ in vigour/per cent germination were procured from different sources as indicated below:

Source	Season and year of production	Germination(%)	Vigour level
Seed Farm, Shala Bangalore Dist.	Kharif 1994	94	V1-High vigour R.K.
Karnataka State Seeds Corpn., Chikaballapur Kolar Dist.	Kharif 1994	92	V2-High vigour
Tekahally Sidlaghatta Tq., Kolar Dist.	Summer 1994	85	V3-Medium vigour
Doddatekahally Siddlaghatta Tq., Kolar Dist.	Kharif 1993	74	V4-Low vigour
Processing plant GKVK,Bangalore	Kharif 1993	71	V5-Low vigour

The seeds were classified as high, medium and low vigour seed lots based on per cent germination and season of production.

The seed to water volume, 1:2 was employed for all the soaking treatments suggested by Basu and Pal (1979) in rice seeds.

3.2 Standardization of soaking period for hydration-dehydration

A preliminary study was undertaken to standardize optimum soaking period for hydration- dehydration treatment by using the seed lot with 71% germination. Seed samples were drawn and soaked with 1:2 seed to water volume in the beakers for various periods of time as mentioned below and then soaked seeds were dried in shade for 2 days followed by sun drying to bring back to the original moisture content.

Treatment Notations	Soaking period
T_1	Control (no soaking)
T_2	4 hours soaking
T_3	6 hours soaking
T_4	12 hours soaking
T_5	24 hours soaking
T_6	48 hours soaking

3.2.1 Laboratory observations

The details of observations recorded in the laboratory on seed quality attributes are presented below:

3.2.1.1 Germination

The standard germination test using between paper method was followed. Two hundred seeds of four replications were tested for germination. The germination counts were recorded on 5th day and 14th day and per cent germination was expressed on normal seedling basis (Anon, 1985).

3.2.1.2 Seedling length

Ten seedlings in each replication were randomly selected for measurement of root and shoot length on the day of first count and the mean of root and shoot length was expressed in centimeters.

3.2.1.3 Vigour index

Vigour index was calculated by adopting the following formula suggested by Abdul Baki and Anderson (1973).

Vigour index = Total length of seedling(cm) X Germination(%)

3.3 Effect of seed invigoration treatment on storability

Five vigour level seeds of rice var. Mangala of fresh and aged which differ in their germination have been

subjected for ten invigoration treatments including hydration-dehydration. Seeds were soaked in aqueous solutions of the chemicals. In case of biogas slurry cloth bag containing seeds were dipped inside the slurry container. The treated seeds were dried in shade for 2 days and sun dried to 10 ± 0.5 per cent moisture content. 100 g seeds were stored in cloth bag under ambient conditions for six months. The seeds were tested after the invigoration treatments and bimonthly for germination and other seed quality parameters.

The treatment details

A. Seed vigour levels

Treatment Notation	Vigour level	Germination (%)
V_1	High vigour seed lot	94
V_2	High vigour seed lot	91
V_3	Medium vigour seed lot	85
V_4	Low vigour seed lot	74
V_5	Low vigour seed lot	71

B. Seed invigoration treatments

T_1	Untreated control	
T_2	Hydration-dehydration	
T_3	Potassium dihydrogen phosphate KH_2PO_4	0.5%
T_4	Sodium dihydrogen phosphate NaH_2PO_4	1.0%
T_5	Gibberalic acid GA_3	50 ppm

T_6	Sodium thio sulphate $NaS_2O_3.5H_2O$	1.0%
T_7	Potassium nitrate, KNO_3	1.0%
T_8	Mercuric chloride $Hgcl_2$	0.1%
T_9	Sodium chloride Nacl	300m.molar
T_{10}	PEG - 6000 (240 g/Lt of water)	-8 bars
T_{11}	Bio gas slurry	

Total treatment combinations - 55

Replications - 4

Experimental design : Factorial complete Randomised design (CRD)

The following observations were recorded.

1. Germination percent
2. Seedling length (cm)
3. Vigour index
4. Electrical conductivity (μ mhos/cm)
5. Field emergence

3.3.4 Electrical conductivity (E.C) test

Three replications of five grams of seeds of each treatment were weighed and soaked in 25 ml distilled water. Beakers were placed in an incubator at constant temperature of $25^0 \pm 1^0C$ for 17 hours. The Electrical Conductivity of seed leachates was measured in the Digital Conductivity meter model

(Sensitive conductivity cell - CGS-811) and expressed in μ mhos/cm at $25^0 \pm 1^0C$.

3.3.5 Field emergence

The seeds were sown in 15 cm raised beds. 50 seeds of three replications were used. The seeds were placed at 2-3 cm depth with 4cm row spacing. The seedlings which emerged more than one cm above the ground were counted as emerged. The total seedlings emerged as on 20th day after sowing were considered.

3.4 Field experiment

Six seed invigoration treatments including hydration-dehydration treatments which performed well in laboratory studies with respect to germination and vigour and untreated control were taken to the main field to assess the effect of seed invigoration on crop performance of different vigour level seeds. The experiment was laid out in a factorial randomised block design with three replications. The treatment details were:

A. Vigour levels

Treatment Notation	Germination	Vigour level
V_1	94%	High vigour seed lot
V_2	91%	High vigour seed lot
V_3	85%	Medium vigour seed lot
V_4	74%	Low vigour seed lot
V_5	71%	Low vigour seed lot

B. Invigoration treatments

T_1 Untreated control

T_2 Hydration-dehydration

T_3 Potassium dihydrogen phosphate KH_2PO_4 0.5%

T_4 Sodium dihydrogen phosphate NaH_2PO_4 1.0%

T_5 Gibberalic acid GA_3 50 ppm

T_6 Sodium thio sulphate $NaS_2O_3.5H_2O$ 1.0%

T_7 Potassium nitrate, KNO_3 1.0%

Replications - 3

Total treatment combinations - 35

Design : Factorial Randomised complete Block Desdign (RCBD)

3.6.1 General Description

The field experiment was conducted during Kharif 1995 at Main Research Station, University of agricultural Sciences, Hebbal, Bangalore-65. The soil type was clay loam with high fertility.

3.5.2 Cultural operations

The land was deep ploughed and brought to well puddled condition. Wet nursery beds of 15 cm height was prepared. The seeds were sown in lines with a row spacing of 10 cm and covered with well decomposed farm yard manure on 29th July 1995. Light irrigation was given as and when required. Nursery beds were sprayed on 18th and 26th day after sowing with Monocrotophos (0.1 %) and Zineb (0.02%) to protect against pests and diseases. Fertilizers were not applied to the nursery due to high soil fertility.

3.5.3 Transplanting

Twenty six days aged fifty seedlings of the each treatment were transplanted in the main field with a row spacing of 20 cm and 15 cm between plants. The field was fed with a high fertility sewage water. The standing water is maintained for the entire period of crop growth fertilizers

were not applied since the soil having high fertility due to continuous use of sewage contaminated water for the last 8 years. Weeding was done at two stages of crop growth on 30 days and 50 days after transplanting. The crop was sprayed with Monocrotophos (0.01%) and Endosulfan (0.02%) at 35 days and 60 days respectively along with Zineb (0.02 %) after transplanting to control pests and diseases. The crop was harvested at 95 days after transplanting.

3.5.4 Harvesting

Five randomly selected plants from each of the treatment and replication were harvested and threshed. Grains were sun dried for four days to a safe moisture content of 12 per cent. The grains were hand cleaned thoroughly.

3.5.5 Field observations

1. Plant height (cm)
2. Number of tillers
3. Panicle length (cm)
4. Grain yield per plant (gm)
5. Test weight of seeds (gm)

3.5.5.1 Plant height

Height of randomly selected five plants was measured in centimeters from the base of the plant to the tip of the top leaf on 30th day after transplanting and measured to the tip of the main panicle at the time of harvesting.

3.5.5.2 Number of tillers

Total number of tillers per plant at maturity were counted from randomly selected 5 plants and recorded as whole number.

3.5.5.3 Panicle length

The length of five panicles per plant selected at random were measured from the base of the panicle to the tip of the panicle in centimeters and mean length was recorded.

3.5.5.4 Grain yield per plant

The grains from each of the randomly selected five plants were weighed in grams and the mean yield per plant was determined.

3.5.5.5 1000 grain weight

One thousand grains from each treatments were counted in four replication and weighed in grams and mean weight was determined.

3.6 Statistical analysis

The data were statistically analysed as per the methods outlined by Sundararaj *et al*. (1972). The results have been discussed at the probability level of 5 per cent.

EXPERIMENTAL RESULTS

IV EXPERIMENT RESULTS

The results obtained from the laboratory and field studies on invigoration of different vigour level seeds on germination, vigour, storability and field performance in rice var. Mangala are presented here under.

4.1 Standardization of period of soaking required for hydration-dehydration treatments

The results on different seed quality parameters such as germination, root length, shoot length and vigour index of low germinable seed lot of paddy var. Mangala as affected by different periods of soaking for hydration-dehydration are presented in Table 4.1.

4.1.1 Germination

The germination percentage differed significantly among the soaking periods. The highest germination of 75.75 per cent was recorded with 6 hours soaking period which was on par with 4 hours soaking (75.25 %) and 12 hours soaking (74.50 %). The lowest germination percentage was recorded in 48 hours soaking (65.0 %) which was less than the untreated control (71.5 %).

Table 4.1 Seed germination, Root length, Shoot length and Vigour index as affected by period of soaking

Soaking Period (hr)		Germination	Root length (cm)	Shoot length (cm)	Vigour Index
T_1	0	71.5	4.92	3.23	582
T_2	4	75.25	5.36	3.32	654
T_3	6	75.75	5.94	3.34	704
T_4	12	74.50	7.28	3.89	835
T_5	24	66.25	5.11	3.35	559
T_6	48	65.00	5.57	2.70	525
SEM ±		1.472	0.40	0.09	40.49
CD at 5%		3.141	0.85	0.19	86
CV %		2.92	9.97	3.77	8.9

4.1.2 Root length

The root length differed significantly among the treatments. The maximum root length of 7.28 cm was recorded in 12 hours soaking and drying followed by 6 hours soaking (5.94 cm), 48 hours soaking (5.57 cm), four hours soaking (5.36 cm), 24 hours soaking (5.11 cm)were on par while and minimum root length was recorded in control treatment (4.92 cm).

4.1.3 Shoot length

The shoot length differed significantly among the soaking treatments. The highest shoot length was recorded in 12 hours soaking (3.89 cm). The lowest was 2.70 cm recorded in 48 hours soaking. Soaking of 4 hours (3.32 cm), 6 hours (3.34 cm) and 24 hours (3.35 cm)were on par with control (3.23 cm).

4.1.4 Vigour index

The vigour index differed significantly among the soaking treatments. The highest vigour index was observed in 12 hours soaking (835). The lowest (525) was observed in 48 hours soaking which was on par with 24 hours soaking (559) and control seed (582).

Results obtained from the preliminary study on the effect of period of soaking for Hydration- dehydration indicated that soaking the rice seeds for 12 hours was found to be effective in improving the germination and vigour. Hence it was selected as the standardized treatment for seed invigoration with or without chemicals for further studies.

4.2 Effect of invigoration on storability of different vigour level seeds

Seeds of five vigour level lots of Rice Var. Mangala were subjected to invigoration treatments representing inorganic chemicals, growth regulator and Biogas slurry including hydration-dehydration and untreated control have been stored in cloth bags under ambient conditions and the date on storability was recorded with respect to germination and other seed quality attributes by drawing samples before storage and after storage at bimonthly intervals and the results are presented below in Table 4.2.1 to 4.2.6.

4.2.1 Germination

The data on germination percentage as influenced by seed vigour levels, seed invigoration treatments and their interactions at different storage periods are presented in Table 4.2.1 and depicted in Fig. 4.1.

Initially the mean germination percentage differed significantly among seed vigour levels. The highest vigour level lot recorded highest germination percentage (96.04 %) followed by V_2 (93.54 %), V_3 (89.84 %), V_4 (79.09 %) and lowest germination was recorded in low vigour seed lot (76.02 %).

All the seed invigoration treatments had significant influence on germination percent and were superior over untreated control. The highest germination 89.20 per cent was obtained with 1.0 per cent KNO_3 which was on par with 1.0 per cent NaH_2PO_4 (88.9 %), 1.0 per cent $Na_2S_2O_3.5H_2O$ (88.4 %), 0.5 per cent KH_2PO_4 (87.9 %) and Nacl 300m molar (87.55 %), while the germination due to Biogas slurry (87.10 %), 0.1 per cent $HgCl_2$ (87.4 %) and 50 ppm GA_3 (87.0 %) and hydration-dehydration were on par with each other. The lowest germination (82.4 %) was recorded in untreated control. Germination did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At two months of storage the mean germination percentage differed significantly among vigour levels. The germination of V_1 was highest (94.84 %) followed by V_2 (92.20 %), V_3 (87.41 %), V_4 (77.34 %) and lowest germination was observed in V_5 (74 %).

Table 4.2.1 Effect of seed invigoration treatments on per cent germination of different vigour level seeds during storage in rice Var Mangala

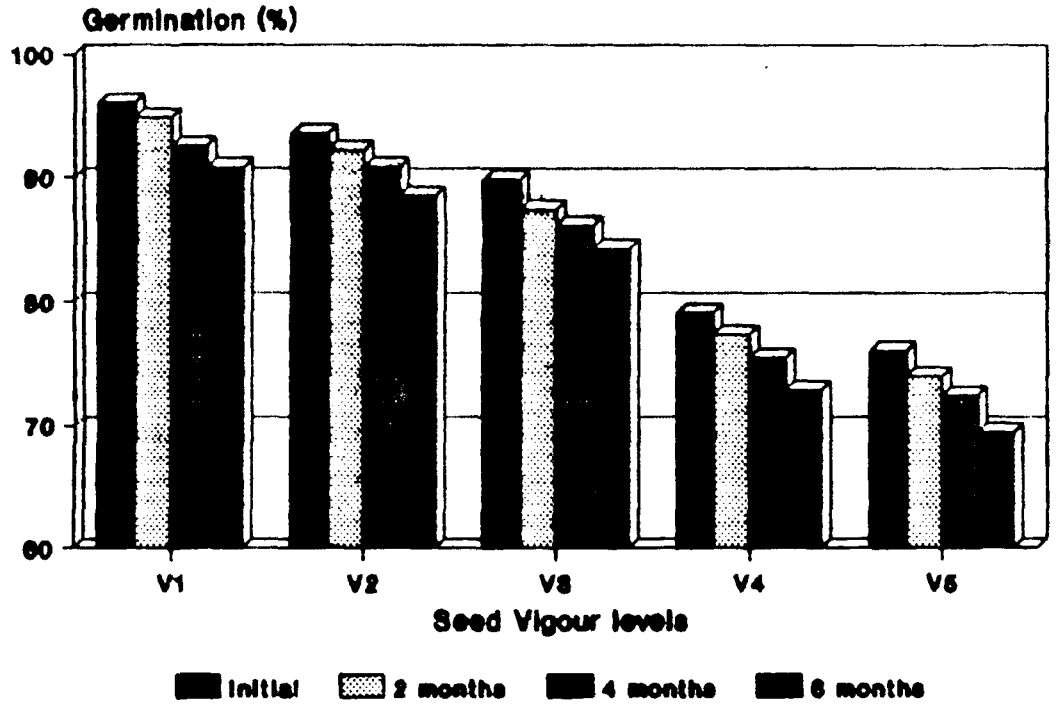
Invigoration treatments	Months after storage											
	0 months						2 months					
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	V_5	Mean
T_1 untreated control	93.50	90.50	84.00	74.00	70.00	82.40	92.00	89.25	82.00	72.50	68.50	80.85
T_2 hydration dehydration	94.50	92.50	87.00	78.00	76.50	85.50	95.50	91.00	85.50	76.50	74.00	84.50
T_3 0.5 per cent KH_2PO_4	97.50	94.00	89.00	81.00	78.00	87.90	96.00	93.50	87.50	79.50	75.00	86.30
T_4 1.0 per cent NaH_2PO_4	97.50	95.00	93.00	81.00	78.00	88.90	96.00	94.25	92.75	80.00	76.50	87.90
T_5 50 ppm GA_3	97.00	93.00	90.00	78.50	76.50	87.00	95.50	94.00	89.00	77.00	75.00	86.10
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	97.00	96.00	92.00	79.50	77.00	88.40	95.75	94.50	91.00	78.00	75.00	86.85
T_7 1.0 per cent KNO_3	97.50	94.50	94.00	81.50	78.50	89.20	96.25	93.25	88.00	79.75	76.50	86.75
T_8 1.0 per cent $Hgcl_2$	95.00	94.00	92.50	79.00	76.50	87.40	93.25	91.50	86.75	77.00	75.00	84.70
T_9 300m molar Nacl	96.00	94.00	90.00	81.00	76.75	87.55	95.00	90.00	87.25	78.00	75.00	85.05
T_{10} -8Burs PEG-6000	94.50	91.50	88.25	76.50	71.50	84.45	93.50	90.25	85.50	75.00	69.00	82.65
T_{11} Biogas Slurry	96.50	94.00	88.00	80.00	77.00	87.10	84.50	92.75	86.25	77.50	74.50	85.10
Mean	96.04	93.54	89.84	79.09	76.02	86.91	94.84	92.20	87.41	77.34	74.00	85.20

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.43	1.19		0.39	1.07	
Treatments (T)	0.64	1.80	CV % 20.71	0.57	1.60	CV % 3.48
Interaction (V x T)	1.43	NS		1.28	NS	

Contd.... Table 4.2.1

Invigoration treatments	Months after storage											
	4 months						6 months					
	V_1	V_2	V_3	V_4	V_5	Mean	V_1	V_2	V_3	V_4	V_5	Mean
T_1 untreated control	91.00	88.67	80.33	70.33	65.33	79.13	88.00	87.33	77.67	68.33	62.33	76.73
T_2 hydration dehydration	91.33	90.00	83.00	75.33	72.67	82.47	90.00	88.33	81.00	73.33	70.00	80.53
T_3 0.5 per cent KH_2PO_4	94.00	91.00	86.00	76.67	73.00	84.13	92.67	89.33	85.00	74.33	70.33	82.33
T_4 1.0 per cent NaH_2PO_4	94.67	92.67	92.00	77.67	74.67	86.33	92.67	90.33	89.67	76.67	73.00	84.47
T_5 50 ppm GA_3	93.67	92.00	86.67	74.67	79.67	85.33	90.33	90.00	85.33	72.00	71.00	81.73
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	93.00	91.33	88.00	76.00	71.33	83.93	91.33	90.00	85.33	72.67	70.00	81.87
T_7 1.0 per cent KNO_3	95.00	91.67	90.67	78.00	75.00	86.06	93.00	91.00	88.67	75.33	73.33	84.27
T_8 1.0 per cent $Hgcl_2$	93.33	92.33	86.00	77.33	74.33	84.06	89.33	87.33	83.67	72.67	69.67	80.53
T_9 300m molar Nacl	91.67	90.00	87.00	75.33	72.00	83.20	90.67	88.00	85.00	72.33	70.67	81.33
T_{10} -8Burs PEG-6000	91.33	88.67	83.33	73.67	66.33	80.67	91.33	87.67	83.00	72.00	64.67	79.73
T_{11} Biogas Slurry	92.00	90.67	84.67	74.67	72.33	82.87	89.33	84.67	83.00	71.67	69.00	79.53
Mean	92.55	90.82	86.15	75.42	72.42	83.47	90.79	88.55	84.30	72.85	69.45	81.19

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.36	1.00		0.34	0.95	
Treatments (T)	0.54	1.48	CV % 2.48	0.51	1.41	CV % 2.43
Interaction (V x T)	1.20	3.31		1.11	3.15	



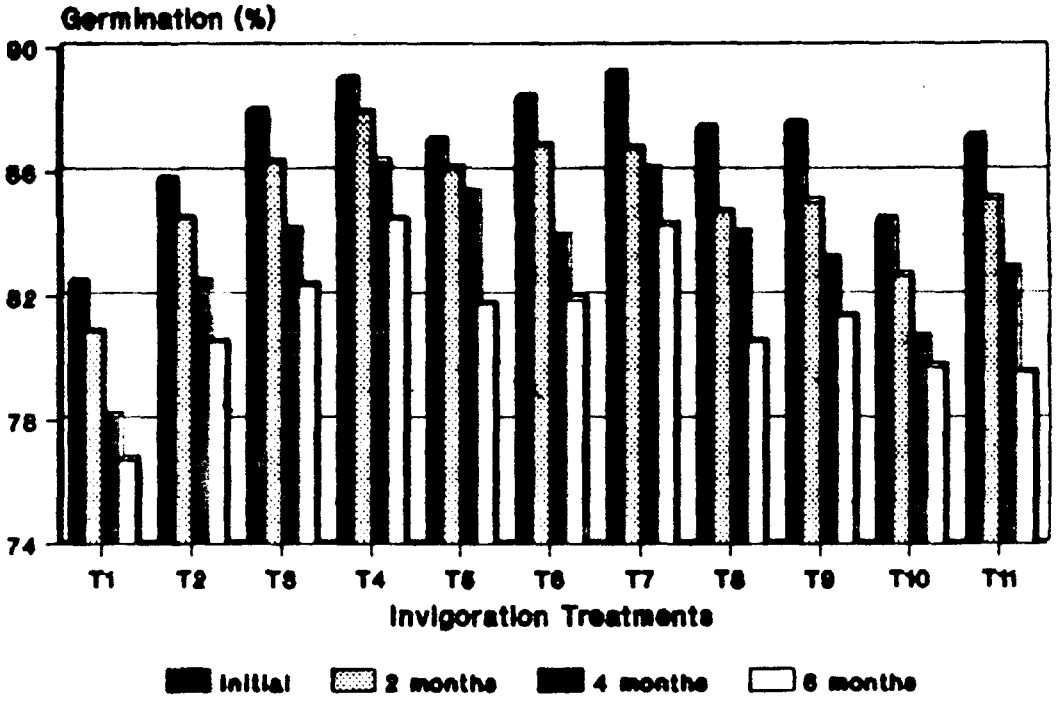


FIG 4.1 GERMINATION (%) AS INFLUENCED BY SEED VIGOUR LEVELS AND INVIGORATION TREATMENTS IN RICE.

The germination percentage due to seed invigoration treatment were significant. All the seed treatment showed significant difference over untreated control. NaH_2PO_4 recorded highest germination (87.90%), which was on par with $Na_2S_2O_3.5H_2O$ (86.85%), KNO_3 (86.75 %). Invigoration with KH_2PO_4 (86.30%) and GA_3 (86.10 %) was on par with $Na_2S_2O_3.5H_2O$ and KNO_3 while biogas slurry (85.10 %), Nacl (85.05 %), $Hgcl_2$ (84.70 %) and Hydration-dehydration (84.50 %)were on par. The lowest germination percentage was recorded in untreated control (80.85 %). Germination percentage did not differ significantly ,due to interaction effect of seed vigour levels and seed invigoration treatments.

At Fourth month of storage the mean germination percentage differed significantly among the vigour levels. The germination reduced with decrease in vigour level recording the highest germination in V_1 (92.55%) and lowest germination V_5 (72.42 %). Vigour level V_2, V_3 and V_4 recorded 90.82, 86.15 and 75.42 per cent germination respectively.

The germination due to seed invigoration treatments were significant NaH_2PO_4 recorded highest germination (86.33 %) followed by KNO_3 (86.06 %) and 50 ppm GA_3 (85.33 %) which were on par. While $HgCl_2$ recorded 84.06 per cent germination which was on par with NaCl (83.20 %) and Biogas slurry (82.87 %). The lowest germination percentage was observed in untreated control (79.13 %).

Germination percentage differed significantly due to interaction effect of seed vigour levels and invigoration treatments. The highest germination was noticed in vigour level V_1 with KNO_3 (95.0 %) followed by NaH_2PO_4 (94.67 %), KH_2PO_4 (94.0 %), 50 ppm GA_3 (93.67 %) and $Na_2S_2O_3.5H_2O$ (93.0 %). The lowest Germination percentage was recorded in untreated control (91.0 %). The KNO_3 recorded 4.0 per cent enhanced germination over untreated control.

High vigour level V_2 with NaH_2PO_4 recorded highest per cent germination (92.67 %) followed by $Hgcl_2$ (92.33 %) and 50 ppm GA_3 (92.0 %). Control and PEG-6000 treated seeds recorded lowest germination (88.67 %). NaH_2PO_4 recorded 4.0 per cent enhancement of germination over untreated control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 recorded significantly highest per cent Germination (92.0 %) which is on par with KNO_3 (90.67 %). NaH_2PO_4 recorded 11.67 per cent enhancement of germination over untreated control (80.33 %).

Invigorating low ,vigour seed V_4 with NaH_2PO_4 obtained highest germination percentage (77.67 %) followed by $Hgcl_2$ (77.33 %) and KH_2PO_4 (74.67 %). NaH_2PO_4 recorded 7.34 per cent enhancement of germination over untreated control which recorded (70.33 %) lowest germination.

Invigorating low vigour seed V_5 with 50 ppm GA_3 recorded highest germination percentage (79.67 %) followed by KNO_3 (75.00 %) and NaH_2PO_4 (74.67 %). untreated control recorded lowest per cent Germination (65.33 %). In vigorating with GA_3 enhanced 14.34 per cent germination over untreated control.

At sixth month of storage the germination percentage significantly decreased with decrease in vigour levels. V_1 recorded highest Germination (90.79 %), followed by V_2 (88.55 %) V_3 (84.3 %), V_4 (72.85 %) and the lowest germination was in V_5 (69.45 %).

The germination due to invigoration treatments differed significantly. NaH_2PO_4 recorded highest Germination (84.47 %) which was on par with KNO_3 (84.27 %). While KH_2PO_4 (82.33 %), $Na_2S_2O_3.5H_2O$ (81.87 %, GA_3 (81.73 %) Nacl (81.33 %) have recorded higher germination and are on par with each other.

The interaction effect due to seed vigour levels land seed invigoration treatments was significant. High vigour seed V_1 with KNO_3 obtained highest per cent Germination (93.0 %) followed by KH_2PO_4 and NaH_2PO_4 (92.67 %) which are on par. Untreated control recorded lowest germination (88,0 %). The enhancement due to invigoration with KNO_3 was 5.0 per cent over control.

Invigoration of high vigour seed V_2 with KNO_3 obtained highest per cent germination (91 %) followed by NaH_2PO_4 (90.33 %), GA_3 and $Na_2S_2O_3.5H_2O$ (90 %). Biogas slurry recorded lowest germination percentage (84.67 %). While control recorded 87.33 per cent germination with V_2 seed KNO_3 obtained 3.67 per cent germination enhancement over untreated control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 recorded highest germination (89.67 %) followed by $Na_2S_2O_3.5H_2O$ (88.67 %). The NaH_2PO_4 recorded 12 per cent enhancement over untreated control (77.67 %).

Invigorating low vigour seed V_4 with NaH_2PO_4 recorded highest Germination (76.67 %) followed by KNO_3 (75.33 %) and KH_2PO_4 (74.33 %) which are on par. Untreated control recorded the lowest (68.33 %). The enhancement due to seed invigoration with NaH_2PO_4 was 8.34 per cent.

Invigorating low vigour seed V_5 with KNO_3 gave higher germination per cent (73.33 %) which was on par with NaH_2PO_4 (73.0 %), GA_3 (71 %), Nacl (70.67 %), and KH_2PO_4 (70.33 %). The KNO_3 recorded 11 per cent enhancement over untreated control (62.33 %).

Irrespective of seed invigoration treatments the germination percentage declined in each of the vigour level V_{12} V_1 (96.04 to 90.79 %), V_2 (93.54 to 88.55 %), V_3 (89.84

to 84.3 %), V_4 (79.09 to 72.85 %) and V_5 (76.02 to 69.45 %) at the end of 6th month of storage.

Irrespective of the vigour levels all the invigoration treatments except PEG exceeded the mean germination percentage at 4 months storage over the initial germination of untreated seed. Invigoration with NaH_2PO_4, KNO_3 and KH_2PO_4 maintained mean germination at 6 months of storage to that of initial seed germination of untreated control seed.

4.2.2 Field emergence

The data on field emergence percentage as influenced by seed vigour levels, seed invigoration treatments and their interaction at different storage periods are presented in the Table 4.2.2.

Initially the field emergence per cent differed significantly due to vigour levels. V_1 recorded highest per cent field emergence (85.73 %) which was on par with V_2 l(84.55 %) while V_3 and V_4 recorded 80.7 and 70.09 per cent respectively. V_5 recorded lowest field emergence percentage (65.85 %).

The field emergence percentage differed significantly among the invigoration treatments. NaH_2PO_4 (80.33 %) recorded highest per cent field emergence which

Table 4.2.2 Effect of seed invigoration treatments on per cent field energence of different vigour level seeds during storage

Treatments		Months after storage			
		Initial (0 months)	2 months	4 months	6 months
		Percent field emergence			
Vigour levels					
V_1	High	85.73	83.97	82.61	80.33
V_2	High	84.55	82.76	81.15	79.61
V_3	Medium	80.70	79.03	77.03	75.15
V_4	Low	70.09	67.30	65.58	63.00
V_5	Low	65.85	63.30	61.94	59.76
SEM ±		0.55	0.51	0.47	0.55
CD at 5%		1.52	1.42	1.31	1.52
Invigoration					
T_1	Control	74.40	71.13	68.33	66.00
T_2	Hyd delyd	76.87	74.80	72.27	69.50
T_3	KH_2PO_4	78.73	75.93	73.60	72.53
T_4	NaH_2PO_4	80.33	77.53	76.93	74.47
T_5	GA_3	78.40	77.47	77.53	75.20
T_6	$Na_2S_2O_3.5H_2O$	78.53	76.87	75.40	73.40
T_7	KNO_3	79.20	77.53	76.33	75.07
T_8	$Hgcl_2$	78.53	75.73	74.40	71.53
T_9	Nacl	76.47	74.80	72.93	71.47
T_{10}	PEG-6000	74.33	71.33	69.47	67.67
T_{11}	Biogas slurry	75.40	74.87	73.07	70.40
SEM ±		0.82	0.76	0.70	0.81
CD at 5%		2.26	2.11	1.94	2.26
CV %		4.08	3.92	3.69	3.73

was on par with KNO_3 (79.20 %), KH_2PO_4 (78.73 %), $Na_2S_2O_3.5H_2O$ and $HgCl_2$ (78.53 %) and GA_3 (78.4 %) were on par. Hydration-dehydration (76.87 %) was on par with all other treatments except NaH_2PO_4, control (74.4 %) and PEG (74.33 %). Untreated control and PEG were on par with each other. NaH_2PO_4 recorded 5.93 % enhancement over untreated control. Field emergence did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At Second month of storage the means field emergence differed significantly among vigour levels. The highest vigour level V_1 recorded 83.97 per cent field emergence followed by V_2 (82.76 %), V_3 (79.03%), V_4 (67.30%) and lowest was recorded in low vigour level V_5 (63.30 %).

Field emergence percentage significantly differed due to invigoration treatments. NaH_2PO_4 and KNO_3 were recorded highest (77.53 %) field emergence which was on par with GA_3 (77.47 %), $Na_2S_2O_3.5H_2O$ (76.87 %), KH_2PO_4 (75.93 %) and $HgCl_2$ (75.73%). Bio-gas slurry (74.87 %), Hydration-dehydration and Nacl (74.80 %) were found to be on par. Control recorded (71.13 %) lowest field emergence which was on par with PEG (71.33 %). The interaction effect did not differ significantly due to interaction effect of seed vigour levels and seed invigoration treatments.

At fourth month of storage field emergence percentage differed significantly due to seed vigour levels. The field emergence percentage decreased with decrease in vigour levels. High vigour level V_1 recorded (82.61 %) highest per cent field emergence followed by V_2 (81.15 %), V_3 (77.03 %), V_4 (65.58 %) and lowest was obtained in low vigour level V_5 (61.94 %).

The field emergence percentage differed significantly due to invigoration treatments. GA_3 recorded highest (77.53 %) field emergence which was on par with NaH_2PO_4 (76.93 %) and KNO_3 (76.33 %), while $Na_2S_2O_3.5H_2O$ (75.40%), $HgCl_2$ (74.40 %) and KH_2PO_4 (73.60 %) on par. Bio-gas slurry (73.07 %), Nacl (72.93 %) and Hydration-dehydration (72.27 %) were on par. Control recorded lowest (68.33 %) per cent field emergence which was on par with PEG (69.47 %). GA_3 obtained 9.20 % enhancement of field emergence over untreated control. Field emergence did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At Sixth month of storage per cent field emergence differed significantly due to seed vigour levels. The field emergence reduced with decrease in vigour level recording the highest field emergence in V_1 (80.33 %) which was on par with V_2 (79.61 %), followed by V_3 (75.15 %), V_4 (63.0 %) which is on par with V_5 (59.76 %).

The field emergence due to seed invigoration treatments were significant GA_3 recorded (75.20 %) recorded highest per cent field emergence which was on par with KNO_3 (75.07 %), NaH_2PO_4 (74.47 %) and $Na_2S_2O_3.5H_2O$ (73.40 %). KH_2PO_4 (71.53 %), Hgcl (71.53 %), Nacl (71.47 %) and Bio-gas slurry (70.4 %) were found to be on par, while Hydration-dehydration (69.53 %), PEG (67.67 %) and control were found on par (66.0 %), GA_3 obtained 9.20 per cent enhancement in field emergence over untreated control. The field emergence did not differ significantly due to interaction effect of seed vigour levels and seed invigoration treatments.

Irrespective of seed invigoration treatments, the field emergence percentage declined in each of the vigour level viz. V_1 (85.73 to 80.33 %), V_2 (84.55 to 79.61 %) after 6 month of storage.

Irrespective of the vigour levels all the invigoration treatments except PEG exceeded the mean field emergence percentage at 2 months of storage over the initial germination of untreated seed. Invigoration with NaH_2PO_4, KNO_3 and GA_3 maintained per cent field emergence at 6 months of storage to that of initial field emergence of untreated seed.

4.2.3 Root length

The results on root length as influenced by seed vigour levels, seed invigoration treatments and their interactions at different storage periods are presented in Table 4.2.3 and depicted Fig. 4.2.

Initially the root length decreased with decrease in seed vigour levels. The V_1 recorded significantly highest root length (8.55 cm) while V_2 recorded 7.86 cm which was on par with V_3 (7.70 cm). The lowest mean root length was found in V_5 (6.45 cm).

All the seed invigoration treatments had significant influence on root length and were superior over untreated control. The highest root length 9.39 cm was obtained with NaH_2PO_4. Nacl (7.78 cm), KH_2PO_4 (7.77 cm), Biogas slurry (7.65 cm), $Na_2S_2O_3.5H_2O$ (7.56 cm) GA_3 (7.512 cm), KNO_3 (7.46 cm) and $Hgcl_2$ (7.39 cm) found to be on par with each other. Control recorded the lowest (6.38 cm) which was on par with PEG (6.66 cm).

Root length differed significantly due to interaction effect of seed vigour levels and invigoration treatments. The highest root length was noticed in vigour level V_1 with NaH_2PO_4 (11.54 cm) followed (9.28 cm), by KH_2PO_4 (9.65 cm) which was on par with $Na_2S_2O_3.5H_2O$ (9.28 cm), GA_3 (8.63 cm) and Nacl (8.38 cm). Untreated control

Table 4.2.3 Effect of seed invigoration treatments on root length (cm) of different vigour level seeds during storage

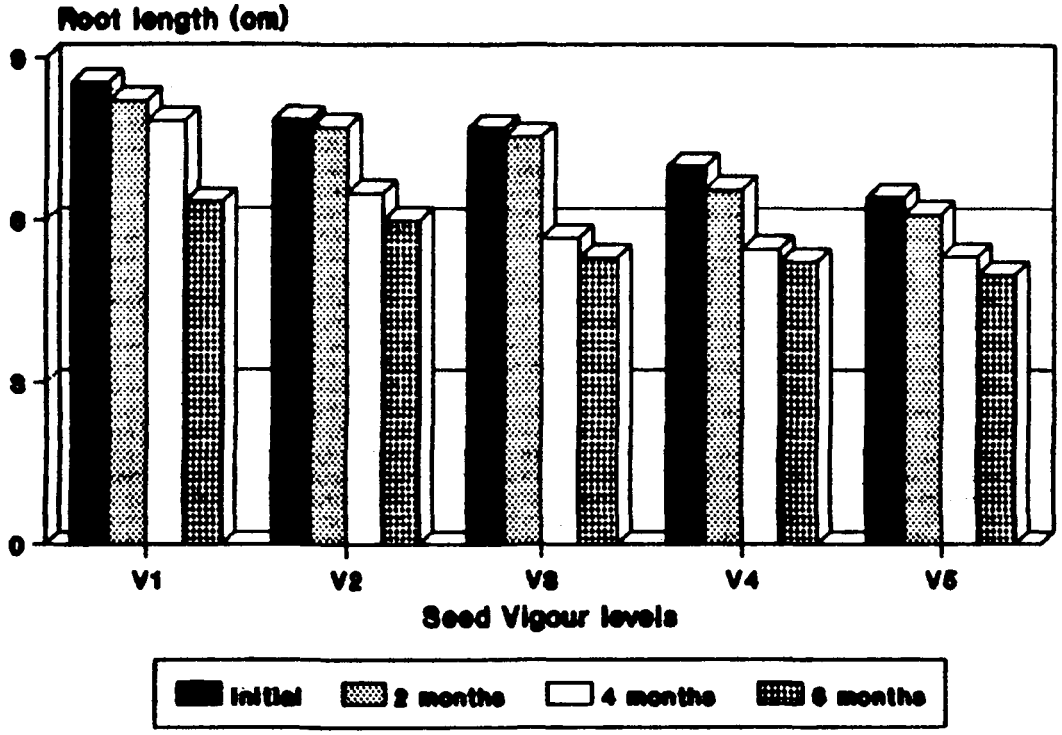
Seed invigoration treatments	Months after storage											
	Initial (0 months)						2 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	7.13	6.59	6.50	6.12	5.58	6.38	7.02	6.33	6.08	5.38	4.86	5.93
T_2 hydration dehydration	8.07	7.42	7.18	6.93	6.05	7.13	7.50	7.28	6.84	6.55	5.76	6.78
T_3 0.5 per cent KH_2PO_4	9.65	8.05	7.65	6.79	6.71	7.77	9.50	7.99	7.69	6.83	5.86	7.57
T_4 1.0 per cent NaH_2PO_4	11.54	10.30	9.93	7.79	7.38	9.39	10.61	10.27	9.91	7.54	7.28	9.12
T_5 50 ppm GA_3	8.63	7.35	7.68	7.43	6.45	7.51	7.84	7.31	7.81	6.75	6.20	7.18
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	9.28	8.25	7.85	6.61	5.81	7.56	9.26	8.13	7.59	5.98	5.59	7.31
T_7 1.0 per cent KNO_3	8.17	7.51	7.88	7.71	6.04	7.46	8.08	8.09	7.78	7.53	7.69	7.83
T_8 1.0 per cent $Hgcl_2$	7.80	7.85	7.39	7.03	6.89	7.39	7.31	6.64	7.30	6.87	6.01	6.83
T_9 300m molar Nacl	8.38	8.25	7.92	7.38	6.98	7.78	8.24	8.08	7.99	6.05	5.81	7.23
T_{10} -8Burs PEG-6000	7.33	6.70	7.05	6.15	6.05	6.66	7.05	6.78	6.38	5.98	5.35	6.31
T_{11} Biogas Slurry	8.13	8.20	7.69	7.20	7.05	7.65	7.93	8.14	7.68	6.95	6.95	7.53
Vigour level Mean	8.55	7.86	7.70	7.01	6.45	7.52	8.21	7.73	7.55	6.58	6.12	7.23

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.14	0.40		0.12	0.34	
Treatments (T)	0.21	0.59	CV % 16.27	0.18	0.51	CV % 13.31
Interaction (V x T)	0.47	1.31		0.40	1.13	

Contd..... Table 4.2.3

Seed invigoration treatments	Months after storage											
	4 months						6 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	5.80	4.73	4.22	3.88	3.90	4.51	5.03	4.62	4.03	4.00	3.77	4.29
T_2 hydration dehydration	6.83	5.75	4.75	4.23	4.45	5.20	5.80	5.50	4.28	4.88	4.60	5.01
T_3 0.5 per cent KH_2PO_4	8.90	6.17	6.10	6.72	5.42	6.66	6.60	5.77	7.00	5.55	4.60	5.50
T_4 1.0 per cent NaH_2PO_4	7.57	7.17	6.23	6.67	6.90	7.31	7.60	6.93	6.17	5.42	6.20	6.46
T_5 50 ppm GA_3	7.02	6.35	5.37	6.05	5.75	6.11	6.47	6.07	5.20	6.55	5.10	5.88
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	9.23	7.02	7.33	6.15	6.37	7.22	7.07	6.87	6.60	5.08	5.57	6.24
T_7 1.0 per cent KNO_3	9.70	7.38	6.10	7.00	6.62	7.36	7.03	6.73	5.70	6.42	6.40	6.46
T_8 1.0 per cent $Hgcl_2$	7.53	7.27	5.78	6.13	5.63	6.47	6.73	6.98	5.55	5.77	5.60	6.13
T_9 300m molar Nacl	7.65	7.25	5.90	4.83	5.27	6.18	6.23	5.85	5.60	4.75	4.80	5.45
T_{10} -8Burs PEG-6000	6.27	5.63	4.97	4.27	3.63	4.95	5.27	4.87	4.76	4.02	3.55	4.49
T_{11} Biogas Slurry	7.85	6.90	5.88	4.47	4.80	5.98	5.97	5.77	5.65	5.30	4.83	5.50
Vigour level Mean	7.84	6.51	5.69	5.49	5.34		6.35	6.01	5.32	5.25	5.00	

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.13	0.37		0.09	0.24	
Treatments (T)	0.20	0.55	CV % 12.54	0.13	0.36	CV % 8.91
Interaction (V x T)	0.45	1.23		0.39	0.80	



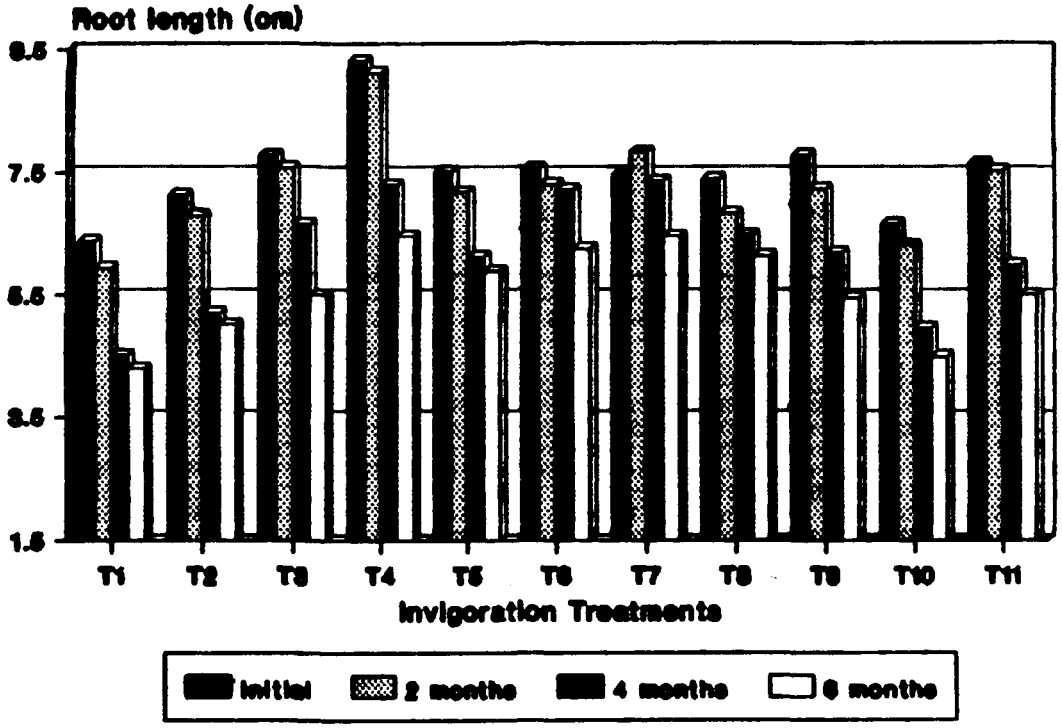


FIG 4.2 ROOT LENGTH (cm) AS INFLUENCED BY SEED VIGOUR LEVELS AND INVIGORATION TREATMENTS IN RICE.

recorded (7.13 cm), $Hgcl_2$ (7.80 cm). Hydration-dehydration (8.07 cm), lowest root length which was on par with PEG (7.33 cm), Biogas slurry (8.13 cm), KNO_3 (8.17 cm) and Nacl (8.38 cm). NaH_2PO_4 recorded 4.41 cm enhancement of root length over untreated control.

High vigour level V_2 with NaH_2PO_4 (10.3 cm) recorded highest root length. $Na_2S_2O_3.5H_2O$ (8.25 cm), Nacl (8.25 cm). Biogas slurry (8.2 cm), KH_2PO_4 (8,05 cm), $Hgcl_2$ (7.85 cm), KNO_3 (7.51 cm) Hydration-dehydration (7.42 cm) and GA_3 (7.35 cm) were found to be on par. Untreated control recorded lowest (6.59 cm) which was on par with PEG (6.70 cm). NaH_2PO_4 recorded 1.66 cm enhancement of root length over control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 recorded significantly (9.93 cm) highest root length. Nacl (7.92 cm), KNO_3 (7.88 cm), $Na_2S_2O_3.5H_2O$ (7.85 cm), Bio gas slurry (7.69 cm), GA_3 (7.68 cm), KH_2PO_4 (7.65 cm), $Hgcl_2$ (7.39 cm) Hydration-dehydration (7.18 cm) and PEG (7.05 cm) were found to be on par, control recorded (6.50 cm) lowest root length. Invigoration with NaH_2PO_4 recorded 3.43 cm root length enhancement over untreated control.

Invigorating low vigour seed V_4 with $Na_2H_2PO_4$ obtained highest root length (7.79 cm) which was on par with KNO_3 (7.71 cm) GA_3 (7.43 cm), Nacl (7.38 cm), Biogas slurry (7.2 cm), $Hgcl_2$ (7.03 cm), Hydration-dehydration

(6.93) KH_2PO_4 (6.79 cm) and $Na_2S_2O_3.5H_2O$ (6.61 cm). Control recorded lowest (6.12 cm) root length which was on par with PEG (6.15 cm). NaH_2PO_4 obtained 1.64 cm root length enhancement over untreated control.

Invigorating low vigour seed V_5 with NaH_2PO_4 (7.38 cm) recorded highest root length which was on par with Biogas slurry (7.05 cm). Nacl (6.98 cm), $Hgcl_2$ (6.89 cm), KH_2PO_4 (6.71 cm) and GA_3 (6.45 cm). Untreated control recorded the lowest 5.58 cm) which was on par with $Na_2S_2O_3.5H_2O$ (5.81 cm), KNO_3 (6.04 cm), Hydration-dehydration and PEG (6.05 cm) including GA_3, KH_2PO_4 and $Hgcl_2$. NaH_2PO_4 (6.05 cm) recorded 1.80 cm root length enhancement over untreated control.

At Second month of storage the mean root length differed significantly among the vigour levels. The root length of V_1 was highest (8.21 cm), V_2 (7.73 cm) and V_3 (7.55 cm) were found to be on par, V_4 (6.58 cm) and V_5 (6.12 cm) recorded the lowest root length.

The root length due to seed invigoration treatments were significant NaH_2PO_4 (9.12 cm) recorded highest root length. KNO_3 (7.83 cm), KH_2PO_4 (7.57 cm) and Biogas slurry (7.23 cm), GA_3 (7.18 cm) and $Hgcl_2$ (6.83 cm) were found to be on par. Hydration-dehydration (6.78 cm) and PEG (6.31 cm) were on par. NaH_2PO_4 recorded 3.19 cm enhancement over untreated control (5.93 cm).

The root length differed significantly due to interaction effect of seed vigour levels and invigoration treatments. The highest root length was noticed in high vigour seed V_1 with NaH_2PO_4 (10.61 cm) which was on par with KH_2PO_4 (9.50 cm). $Na_2S_2O_3.5H_2O$ (9.26 cm) and Nacl (8.24 cm) were on par with KH_2PO_4 (9.50 cm). $Na_2S_2O_3.5H_2O$ (9.26 cm) and Nacl (8.24 cm) were found to be on par with each other. Biogas slurry (7.93 cm), GA_3 (7.84 cm), Hydration-dehydration (7.5 cm), $Hgcl_2$ (7.31 cm), PEG (7.05 cm) and untreated control found to be on par. The NaH_2PO_4 recorded 13.59 cm root length enhancement over untreated control.

High vigour level V_2 with NaH_2PO_4 recorded highest (10.27 cm) root length. Biogas slurry (8.14 cm), $Na_2S_2O_3.5H_2O$ (8.13 cm), KNO_3 (8.09 cm), Nacl (8.08 cm), KH_2PO_4 (7.99 cm), GA_3 (7.32 cm) and Hydration-dehydration (7.28 cm) were on par. PEG (6.78 cm), $Hgcl_2$ (6.64 cm) and control (6.33 cm) found to be on par with each other. NaH_2PO_4 recorded 3.94 cm root length enhancement over untreated control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 (9.91 cm) recorded highest root length while V_3 with Nacl (7.99 cm), GA_3 (7.81 cm), KNO_3 (7.78 cm), KH_2PO_4 (7.69 cm), $Na_2S_2O_3.5H_2O$ (5.59 cm), $Hgcl_2$ (7.30 cm) and Hydration-dehydration (6.84 cm) found to be on par. NaH_2PO_4 recorded 3.93 cm enhancement over untreated control (6.08 cm).

Invigorating low vigour seed V_4 with NaH_2PO_4 obtained highest root length (9.91 cm), KH_2PO_4 (7.45 cm), KNO_3 (7.53 cm), Biogas slurry (6.95 cm), $Hgcl_2$ (6.87 cm), KH_2PO_4 (6.83 cm), GA_3 (6.75 cm) and Hydration-dehydration (6.55 cm) were found to be on par. Nacl (6.05 cm), $Na_2S_2O_3.5H_2O$ and PEG (5.98 cm) were found to be on par with control (5.38 cm). NaH_2PO_4 recorded 4.53 cm root length enhancement over control.

Invigoration of low vigour seed V_5 with KNO_3 (7.69 cm) recorded highest root length which was on par with KH_2PO_4 (7.28 cm) and Biogas slurry (6.95 cm), GA_3 (6.20 cm) $Hgcl_2$ (6.01 cm), KH_2PO_4 (5.86 cm), Nacl (5.81 cm), Hydration-dehydration (5.76 cm), $Na_2S_2O_3.5H_2O$ (5.59 cm) and PEG (5.35 cm) were found to be on par KNO_3 recorded 2.83 cm root length enhancement over untreated control (4.56 cm).

At Fourth month of storage the root length significantly decreased with decrease in vigour levels. V_1 recorded highest root length (7.84 cm), followed by V_2 (6.51 cm), V_3 (5.69 cm), V_4 (5.49 cm) and V_5 (5.34 cm) were found to be on par.

The root length due to invigoration treatments differed significantly. KNO_3 (7.36 cm) recorded highest root length which was on par with NaH_2PO_4 (7.31 cm) and $Na_2S_2O_3.5H_2O$ (7.22 cm). KH_2PO_4 (6.66 cm), $Hgcl_2$ (6.47 cm), Nacl (6.18 cm) and GA_3 (6.11 cm), found to be on par.

Hydration-dehydration (5.2 .cm), PEG (4.95 cm) and control (4.51 cm) were on par with other. The enhancement in root length due to invigoration with KNO_3 was 2.85 cm over untreated control.

The interaction effect due to seed vigour levels and seed invigoration treatments was significant.

High vigour seed with KNO_3 (9.7 cm) obtained highest root length which was on par with $Na_2S_2O_3.5H_2O$ (9.23 cm) and KH_2PO_4 (8.9 cm), Bio-gas slurry (7.85 cm), Nacl (7.65 cm), NaH_2PO_4 (7.57 cm), $Hgcl_2$ (7.53 cm), GA_3 and Hydration-dehydration (6.83 cm) were found to be on par with other. KNO_3 recorded 3.9 cm root length enhancement over untreated control (5.80 cm).

Invigorating high vigour seed V_2 with KNO_3 obtained highest root length (7.38 cm) which was on par with $Hgcl_2$ (7.27 cm), Nacl (7.25 cm), NaH_2PO_4 7.17 cm), $Na_2S_2O_3.5H_2O$ (7.02 cm), Biogas slurry (6.90 cm), GA_3 (6.35 cm) and KH_2PO_4 (6.17 cm). Hydration-dehydration (5.75 cm), PEG (5.63 cm) and control (4.73 cm) were found to be on par with each other. KNO_3 obtained 2.65 cm root length enhancement over untreated control.

Invigorating medium vigour seed V_3 with $Na_2S_2O_3.5H_2O$ recorded (7.33 cm) highest root length which was on par with NaH_2PO_4 (6.23 cm), KNO_3 and KH_2PO_4 (6.10 cm), PEG (4.97

cm) and Hydration-dehydration (4.75 cm) were to be on par. $Na_2S_2O_3.5H_2O$ recorded 3.11 cm root length enhancement over untreated control.

Invigorating low vigour seed V_4 with KNO_3 (7.0 cm) obtained highest root length which was on par with KH_2PO_4(6.73 cm), NaH_2PO_4 (6.67 cm), $Na_2S_2O_3.5H_2O$ (6.15 cm), $Hgcl_2$ (6.13 cm) and GA_3 (6.05 cm), Nacl (4.83 cm), Biogas slurry (4.47 cm), PEG (4.27 cm), Hydration-dehydration (4.23 cm) land control (3.88 cm) found to be on par. KNO_3 recorded 3.12 cm @ root length enhancement over untreated control.

Invigorating low vigour seed V_5 with NaH_2PO_4 (6.9 cm) recorded highest root length which was on par with KNO_3 (6.62 cm), $Na_2S_2O_3.5H_2O$ (6.37 cm), $Hgcl_2$ (5.63 cm) and GA_3 (5.75 cm). KH_2PO_4 (5.42 cm), Nacl (5.27 cm), Biogas slurry (84.8 cm) and Hydration-dehydration (4.45 cm) were found to be on par. NaH_2PO_4 obtained 3.27 cm enhancement in root length over untreated control (3.9 cm).

At Sixth month of storage the root length significantly decreased with decrease in vigour level. V_1 recorded highest root length (6.35 cm) followed by V_2 (6.01 cm), V_3 (5.32 cm) and V_4 (5.25 cm) found to be on par. Lowest was recorded in V_5 (5.0 cm).

The root length due to invigoration treatments differed significantly. NaH_2PO_4 and KNO_3 (6.46 cm) both recorded highest root length these were on par with $Na_2S_2O_3.5H_2O$ (6.24 cm) and $Hgcl_2$ (6.13 cm). KH_2PO_4 and Biogas slurry (5.50 cm) and Nacl (5.45 cm) were found to be on par. Hydration-dehydration obtained (5.01 cm) root length PEG (4.49 cm) and untreated control (4.29 cm) found to be on par with each other. The interaction effect due to seed vigour level and seed invigoration treatments was significant.

High vigour seed V_1 with NaH_2PO_4 (7.6 cm) recorded highest root length which was on par with $Na_2S_2O_3.5H_2O$ (7.07 cm) and KNO_3 (7.03 cm), $Hgcl_2$ (6.73 cm), KH_2PO_4 (6.6 cm), GA_3 (6.47 cm), Nacl (6.23 cm) and Biogas slurry (5.97 cm) found to be on par followed by Hydration-dehydration (5.80 cm), PEG (5.27 cm) and control (5.03 cm) which are on par. NaH_2PO_4 obtained 2.57 cm root length enhancement over untreated control.

Invigorating high vigour seed V_2 with $Hgcl_2$ (6.98 cm) recorded highest root length which was on par with NaH_2PO_4 (6.93 cm), $Na_2S_2O_3.5H_2O$ (6.87 cm) and KNO_3 (6.73 cm), GA_3 (6.07 cm), Nacl (5.85 cm), KH_2PO_4 and Biogas slurry (5.77 cm) and Hydration-dehydration (5.50 cm) were found to be on par. $Hgcl_2$ obtained 2.36 cm) enhancement of root length over untreated control (4.62 cm).

Invigorating medium vigour seed V_3 with $Na_2S_2O_3.5H_2O$ (6.60 cm) recorded higher root length which was on par with NaH_2PO_4 (6.17 cm), KNO_3 (5.7 cm), Biogas slurry (5.65 cm), Nacl (5.6 cm), $Hgcl_2$ (5.55 cm), GA_3 (5.20 cm) and KH_2PO_4 (5.0 cm) were found to be on par followed by PEG (4.76 cm), Hydration- dehydration (4.28 cm) and untreated control (4.03 cm) which are on par. $Na_2S_2O_3.5H_2O$ obtained 2.57 cm root length enhancement over untreated control.

Invigorating low vigour seed V_4 with GA_3 (6.55 cm) recorded highest root length which was on par with KNO_3 (6.42 cm) and $Hgcl_2$ (5.77 cm), KH_2PO_4 (5.55 cm), NaH_2PO_4 (5.42 cm), Biogas slurry (5.3 cm), $Na_2S_2O_3.5H_2O$ (5.08 cm), Hydration-dehydration (4.8 cm and Nacl (4.75 cm) were found to be on par. GA_3 obtained 2.55 cm root length enhancement over untreated control (4.0 cm).

Invigorating low vigour seed V_5 with KNO_3 (6.40 cm) recorded highest root length which was on par with NaH_2PO_4 (6.20 cm). $Hgcl_2$ (5.6 cm), $Na_2S_2O_3.5H_2O$ (5.77 cm). GA_3 (5.1 cm), Bio-gas slurry (4.83 cm) and Nacl (4.8 cm) were found to be on par. KH_2PO_4 and Hydration-dehydration (4.6 cm) were found to be on par with each other. KNO_3 obtained 2.93 cm enhancement of root length over untreated control (3.77 cm). PEG recorded lowest root length (3.55 cm).

Irrespective of seed invigoration treatments, the root length declined in each of the vigour level viz., V_1 (8.55 to 6.35 cm), V_2 (7.86 to 6.01 cm), V_3 (7.70 to 5.32 cm), V_4 (7.01 to 5.25 cm) and V_5 (6.45 cm to 5.0 cm) at the end of 6th month of storage.

Irrespective of the vigour levels all the invigoration treatments except PEG exceeded the mean root length at 2 month of storage over the initial root length of untreated seed. Invigoration with NaH_2PO_4 maintained mean root length in all vigour levels. $Na_2S_2O_3.5H_2O$ maintained in V_2, V_3 and V_5 vigour levels. Similarly KNO_3 and $Hgcl_2$ in V_2 and V_5 vigour levels at 6 months of storage to that of initial root length of untreated control seed.

4.2.4 Shoot length

The results on shoot length as influenced by seed vigour levels and invigoration treatments and their interactions at different storage periods are presented in Table 4.2.4 and depicted in Fig. 4.3.

Initially the mean shoot length decreased significantly with decease in vigour level, V_1 recorded highest root length (7.25 cm) which was on par with V_2 (7.15 cm) followed by V_3 (6.57 cm), V_4 (6.19 cm) and lowest was recorded in V_5 (5.78 cm).

The shoot length differed due to seed invigoration treatments. NaH_2PO_4 recorded highest shoot length (7.20 cm), which was on par with KNO_3 (7.0 cm) and GA_3 (6.96 cm). Bio-gas slurry (6.76 cm), Nacl and $Hgcl_2$ (6.62 cm), $Na_2S_2O_3.5H_2O$ (6.61 cm), KH_2PO_4 (6.47 cm) and Hydration-dehydration were found to be on par. PEG recorded the lowest shoot length which was on par with untreated control (5.90 cm), NaH_2PO_4 recorded 1.30 cm root length enhancement over untreated control.

Shoot length did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At second month of storage the mean shoot length significantly decreased with decrease in vigour levels. V_1 recorded highest root length (6.89 cm) which was on par with V_2 (6.75 cm), followed by V_3 (6.43 cm), V_4 (5.81 cm) and lowest was obtained in V_5 (5.34 cm).

The shoot length due to invigoration treatments differed significantly. NaH_2PO_4 (7.06 cm) obtained highest shoot length which was on par with KNO_3 (6.96 cm) and GA_3 (6.81cm). $Na_2S_2O_3.5H_2O$ (6.62 cm) and Bio-gas slurry (6.46 cm) were found to be on par with each other, Nacl (6.12 cm), KH_2PO_4 (6.02 cm), $Hgcl_2$ (5.99 cm) were found to be on par followed by Hydration-dehydration (5.92 cm). PEG recorded (5.34 cm) lowest shoot length which was on par

Table 4.2.4 Effect of seed invigoration treatments on shoot length (cm) of different vigour level seeds during storage

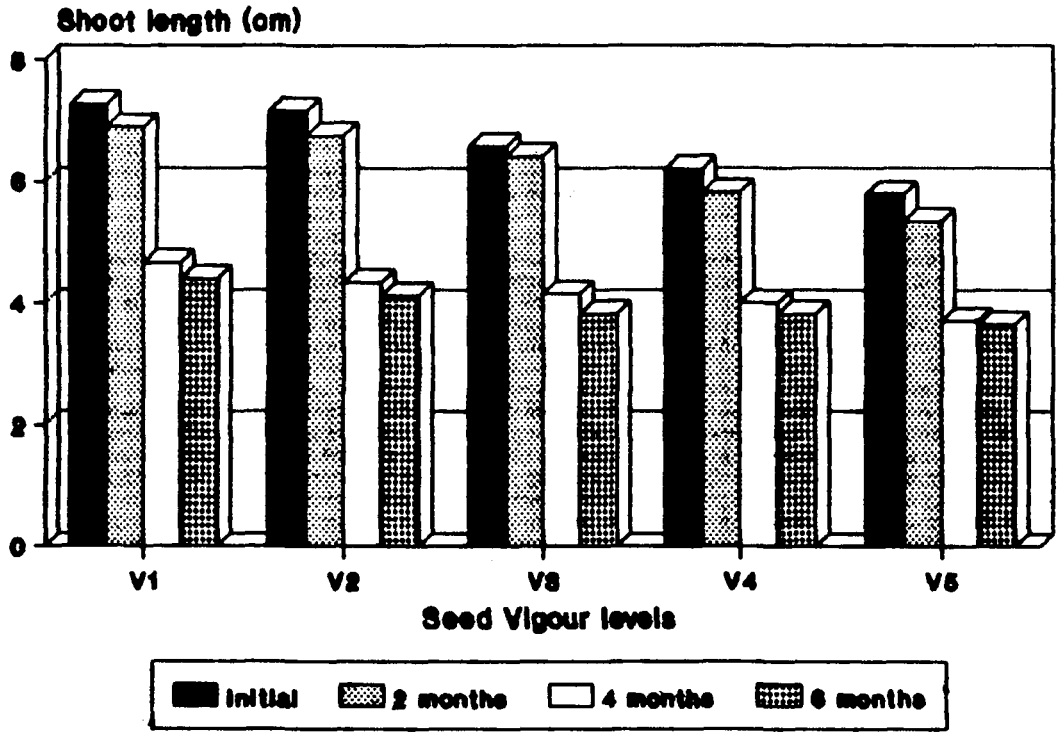
Seed invigoration treatments	Months after storage											
	Initial (0 months)						2 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	6.78	6.35	5.83	5.50	5.02	5.90	6.04	5.66	5.74	5.24	4.39	5.41
T_2 hydration dehydration	7.19	6.78	6.75	5.90	5.68	6.46	6.51	6.50	6.03	5.49	5.06	5.92
T_3 0.5 per cent KH_2PO_4	7.01	6.83	6.73	6.15	5.65	6.47	6.79	6.46	6.21	5.46	5,17	6.02
T_4 1.0 per cent NaH_2PO_4	8.02	7.80	7.08	6.90	6.21	7.20	7.93	7.74	7.13	6.85	5.65	7.06
T_5 50 ppm GA_3	7.81	7.74	6.58	6.45	6.25	6.96	7.73	7.51	6.41	6.35	6.05	6.81
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	7.40	7.40	6.48	6.10	5.65	6.61	7.09	7.07	7.21	6.16	5.55	6.62
T_7 1.0 per cent KNO_3	7.84	7.95	7.11	6.39	5.75	7.00	7.63	7.54	7.51	6.13	6.00	6.96
T_8 1.0 per cent $Hgcl_2$	6.89	6.95	6.65	6.40	6.20	6.62	6.31	6.29	6.53	5.53	5.30	5.99
T_9 300m molar Nacl	6.90	6.83	6.58	6.63	6.18	6.62	6.85	6.74	6.03	5.58	5.41	6.12
T_{10} -8Burs PEG-6000	6.83	6.15	5.70	5.43	5.28	5.88	6.06	5.69	5.45	5.12	4.68	5.34
T_{11} Biogas Slurry	7.05	7.91	6.83	6.28	5.75	6.76	6.84	7.05	6.48	6.00	5.91	6.46
Vigour level Mean	7.25	7.15	6.57	6.19	5.78	6.59	6.89	6.75	6.43	5.81	5.34	6.24

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.10	0.27		0.08	0.22	
Treatments (T)	0.14	0.40	CV % 9.72	0.12	0.33	CV % 9.58
Interaction (V x T)	0.32	NS		0.27	NS	

Contd..... Table 4.2.4

Seed invigoration treatments	Months after storage											
	4 months						6 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	3.48	3.43	3.41	3.30	2.87	3.30	3.30	3.18	3.07	2.80	2.70	3.01
T_2 hydration dehydration	3.97	3.87	3.73	3.67	3.63	3.77	3.90	3.78	3.58	3.43	3.32	3.60
T_3 0.5 per cent KH_2PO_4	4.98	4.82	4.48	4.38	3.85	4.50	4.83	4.82	4.22	4.05	3.70	4.32
T_4 1.0 per cent NaH_2PO_4	5.52	5.22	5.03	5.12	4.80	5.14	5.20	4.98	4.73	5.00	4.70	4.92
T_5 50 ppm GA_3	6.12	5.38	4.47	4.27	4.10	4.87	5.20	4.70	4.33	4.33	3.93	4.50
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	6.18	4.67	4.08	4.02	3.83	4.36	5.07	4.27	3.98	4.02	3.70	4.21
T_7 1.0 per cent KNO_3	4.77	4.32	4.40	4.25	4.20	4.39	4.50	4.22	4.32	4.08	3.90	4.20
T_8 1.0 per cent $Hgcl_2$	4.90	4.27	4.17	4.03	3.83	4.24	4.83	4.08	3.98	3.80	3.68	4.08
T_9 300m molar Nacl	4.32	4.13	3.83	4.17	3.77	4.04	4.00	4.07	3.75	3.87	3.53	3.84
T_{10} -8Burs PEG-6000	3.80	3.54	3.95	2.77	3.00	3.41	3.23	3.12	2.82	2.78	3.10	3.01
T_{11} Biogas Slurry	4.31	4.14	4.08	4.07	3.93	4.11	4.25	4.12	3.98	3.75	3.73	3.97
Vigour level Mean	4.67	4.34	4.15	4.00	3.70	4.19	4.39	4.12	3.89	3.81	3.64	3.97

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	0.07	0.19		0.07	0.19	
Treatments (T)	0.10	0.28	CV % 9.32	0.10	0.29	CV % 10.10
Interaction (V x T)	0.23	0.63		0.23	NS	



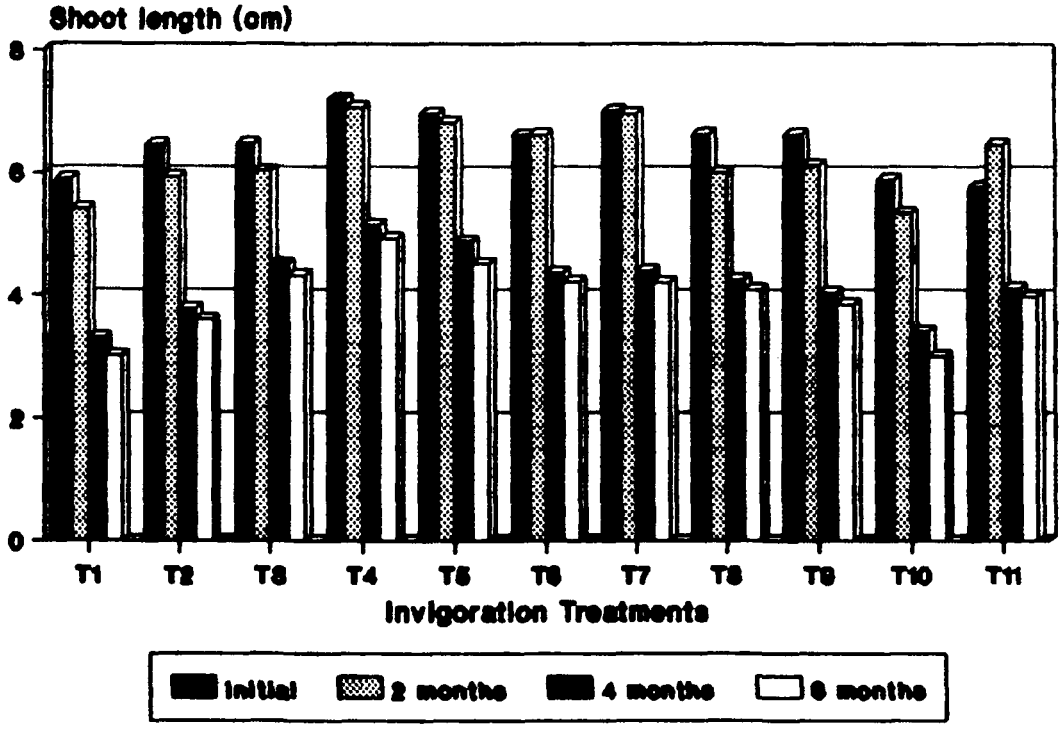


FIG 4.3 SHOOT LENGTH (cm) AS INFLUENCED BY SEED VIGOUR LEVELS AND INVIGORATION TREATMENTS IN RICE.

with control (5.41 cm), NaH_2PO_4 recorded 2.05 cm shoot length enhancement over untreated control. The interaction effect due to seed vigour levels and seed invigoration treatments did not differ significantly.

At Fourth month of storage the shoot length significantly decreased with decrease in vigour levels. V_1 recorded highest shoot length (4.67 cm) followed by V_2 (4.34 cm), V_3 (4.15 cm) and V_4 (4.0 cm) were on par with each other. The V_5 recorded lowest shoot length (3.70 cm).

The shoot length due to invigoration treatments differed significantly. NaH_2PO_4 recorded (5.14 cm) highest shoot length followed by GA_3 (4.87 cm), KH_2PO_4 (4.50 cm), KNO_3 (4.39 cm), $Na_2S_2O_3.5H_2O$ (4.36 cm) and $Hgcl_2$ (4.24 cm) were found to be on par. Bio-gas slurry (4.11 cm) and Nacl (4.04 cm) were on par with each other Hydration-dehydration recorded 2.77 cm shoot length control recorded lowest shoot length (3.30 cm) which was on par with PEG (3.41 cm). The interaction effect due to seed vigour levels and seed invigoration treatments was significant.

High vigour seed V_1 with GA_3 (6.12 cm) recorded highest shoot length. NaH_2PO_4 (5.52 cm), $Na_2S_2O_3.5H_2O$ (5.28 cm), KH_2PO_4 (4.98 cm) and $Hgcl_2$ (4.9 cm) were found to be on par. KNO_3 (4.77 cm), Nacl (4.32 cm) and Bio-gas slurry (4.31 cm) were found to be on par. Control (3.48 cm) recorded lowest shoot length which was on par with

Hydration dehydration (3.97 cm) and PEG (3.8 cm). GA_3 obtained 2.64 cm shoot length enhancement over control.

Invigorating high vigour seed V_2 with GA_3 (5.38 cm) obtained highest root length which was on par with NaH_2PO_4 (5.22 cm) and KH_2PO_4 (4.82 cm). $Na_2S_2O_3.5H_2O$ (4.67 cm), KNO_3 (4.32 cm), $Hgcl_2$ (4.27 cm), Bio-gas slurry (4.14 cm), Nacl (4.13 cm) were found to be on par. Untreated control recorded the lowest shoot length (3.43 cm) which was on par with PEG (3.54 cm) and Hydration-dehydration (3.87 cm). GA_3 obtained 1.95 cm shoot length enhancement over untreated control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 (5.03 cm) recorded highest shoot length which was on par with KH_2PO_4 (4.48 cm), GA_3 (4.47 cm) and KNO_3 (4.4 .cm). $Hgcl_2$ (4.17 cm), Bio-gas slurry and $Na_2S_2O_3.5H_2O$ (4.08 cm), PEG (3.95 cm), Nacl (3.83 cm) and Hydration-dehydration (3.73 cm) were found to be on par. NaH_2PO_4 obtained 1.62 cm shoot length enhancement over untreated control (3.41 cm).

Invigorating low vigour seed V_4 with NaH_2PO_4 recorded highest shoot length (5.12 cm). KH_2PO_4 (4.38 cm), GA_3 (4.27 cm) KNO_3 (4.25 cm), Nacl (4.17 cm), Bio-gas slurry (4.07 cm), $Hgcl_2$ (4.03 cm) and $Na_2S_2O_3.5H_2O$ (4.02 cm) were found to be on par. Hydration-dehydration (3.67 cm) and untreated control were on par with each other. PEG recorded lowest (2.77 cm) shoot length. NaH_2PO_4 obtained 1.82 cm shoot length enhancement over untreated control.

Invigorating low vigour seed V_5 with NaH_2PO_4 (4.80 cm) recorded highest shoot length which was on par with KNO_3 (4.20 cm). GA_3 (4.1 cm) Bio-gas slurry (3.93 cm) KH_2PO_4 (3.85 cm), $Na_2S_2O_3.5H_2O$ and $Hgcl_2$ (3.83 cm), Nacl (3.77 cm) and Hydration-dehydration were found to be on par. NaH_2PO_4 obtained 1.93 cm shoot length enhance over untreated control (2.87 cm) which was on par with PEG (3.0 cm).

At Sixth month of storage the shoot length significantly decreased with decrease in vigour level. V_1 recorded highest shoot length (4.39 cm), followed by V_2 (4.12 cm), V_3 (3.89 cm) and V_4 (3.81 cm) are on par with each other. V_5 recorded the lowest (3.64 cm) which was on par with V_4.

The shoot length due to invigoration treatments differed significantly. NaH_2PO_4 recorded highest (4.92 cm) shoot length. GA_3 (4.50 cm), KH_2PO_4 (4.32 cm) and $Na_2S_2O_3.5H_2O$ (4.21 cm) were found to be on par followed by KNO_3(4.20 cm), $Hgcl_2$ (4.08 cm) and Bio-gas slurry (3.97 cm) which were on par. Nacl (3.84 cm) and Hydration-dehydration (3.60 cm) found to be on par PEG and control recorded the lowest shoot length (3.05 cm).

The interaction effect due to seed vigour levels and seed invigoration treatments did not differ significantly.

Irrespective of the invigoration treatments, the shoot length declined in each of the vigour level VIZ, V_1 (7.25 to 4.39 cm), V_2 (7.15 to 4.12 cm), V_3 (6.57 to 3.89 cm), V_4 (6.19 to 3.81 cm) and V_5 (5.78 to 3.64 cm) at the end of 6th month of storage.

4.2.5 Vigour index (per cent germination x seedling length)

The data on vigour index as influenced by seed vigour levels. Seed invigoration treatments and their interactions at different storage periods are presented in Table 4.2.5 and depicted in Fig. 4.4.

Initially the vigour index decreased with decrease in seed vigour levels. The V_1 recorded significantly highest vigour index (1512) followed by V_2 (1407), V_3 (1283), V_4 (1044) and the V_5 (929) recorded lowest vigour index.

The vigour index due to seed invigoration treatments were significant. NaH_2PO_4 recorded highest (1496) vigour index KNO_3 (1302), Nacl (1270), GA_3 (1268), $Na_2S_2O_3.5H_2O$ (1266) and Bio-gas slurry (1263) were found to be on par. $Hgcl_2$ (1214) and Hydration- dehydration (1173) were on par with each other. Control (1016) recorded lowest vigour index which was on par with PEG (1054).

Table 4.2.5 Effect of seed invigoration treatments on vigour index of different vigour level seeds during storage

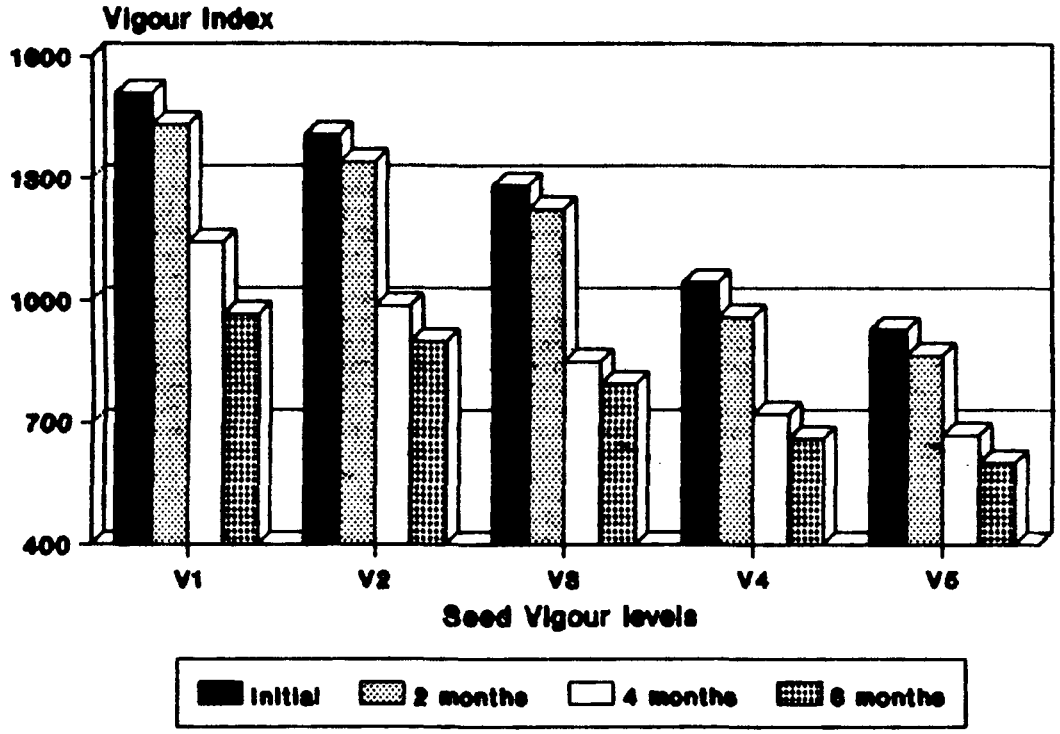
Invigoration treatments	Months after storage											
	0 months						2 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	1292	1170	1035	841	742	1016	1225	1070	969	770	635	934
T_2 hydration dehydration	1442	1316	1210	1001	896	1173	1342	1254	1100	920	800	1083
T_3 0.5 per cent KH_2PO_4	1629	1391	1283	1046	964	1263	1548	1352	1195	978	827	1180
T_4 1.0 per cent NaH_2PO_4	1906	1719	1581	1210	1061	1496	1787	1699	1155	1151	989	1435
T_5 50 ppm GA_3	1594	1404	1281	1091	972	1268	1487	1394	1267	1008	919	1215
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	1620	1514	1327	989	882	1266	1559	1435	1346	947	854	1228
T_7 1.0 per cent KNO_3	1560	1462	1413	1151	926	1302	1511	1445	1423	1089	1046	1303
T_8 1.0 per cent $Hgcl_2$	1372	1393	1300	1061	944	1214	1271	1229	1200	951	962	1123
T_9 300m molar Nacl	1467	1418	1305	1131	1028	1270	1433	1334	1201	907	847	1143
T_{10} -8Burs PEG-6000	1291	1174	1103	883	817	1054	1225	1126	1010	833	692	977
T_{11} Biogas Slurry	1461	1517	1270	1078	986	1263	1381	1407	1220	1004	959	1190
Vigour level Mean	1512	1407	1283	1044	929	1235	1432	1340	1225	960	866	1165

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	17	48		34	95	
Treatments (T)	26	72	CV % 9.36	51	141	CV % 19.32
Interaction (V x T)	58	160		114	315	

Contd.... Table 4.2.5

Invigoration treatments	Months after storage											
	4 months						6 months					
	V_1	V_2	V_3	V_4	V_5	Treatment Mean	V_1	V_2	V_3	V_4	V_5	Treatment Mean
T_1 untreated control	845	724	623	505	434	626	733	681	551	465	403	567
T_2 hydration dehydration	986	865	704	595	588	748	873	820	637	610	554	699
T_3 0.5 per cent KH_2PO_4	1306	1000	910	850	675	948	1060	974	840	714	608	839
T_4 1.0 per cent NaH_2PO_4	1239	1148	1036	915	873	1042	1186	1075	976	736	794	953
T_5 50 ppm GA_3	1232	1079	852	770	785	943	1053	968	813	784	637	851
T_6 1.0 per cent $Na_2S_2O_3.5H_2O$	1340	1066	984	772	728	978	1108	1002	905	686	647	870
T_7 1.0 per cent KNO_3	1375	1072	951	895	826	1024	1074	997	918	791	713	898
T_8 1.0 per cent $Hgcl_2$	1120	1067	857	786	702	907	1004	963	798	695	647	821
T_9 300m molar Nacl	1096	1024	847	678	650	859	861	872	795	648	587	753
T_{10} -8Burs PEG-6000	920	813	744	518	440	687	776	700	687	484	430	616
T_{11} Biogas Slurry	1116	1001	844	632	632	845	914	842	800	647	591	759
Vigour level Mean	1143	987	850	720	667	873	967	900	793	660	601	784

For comparing means of	SEM ±	CD at 5%		SEM ±	CD at 5%	
Seed vigour levels (V)	13	37		11	29	
Treatments (T)	20	55	CV % 8.82	16	43	CV % 7.71
Interaction (V x T)	44	123		35	97	



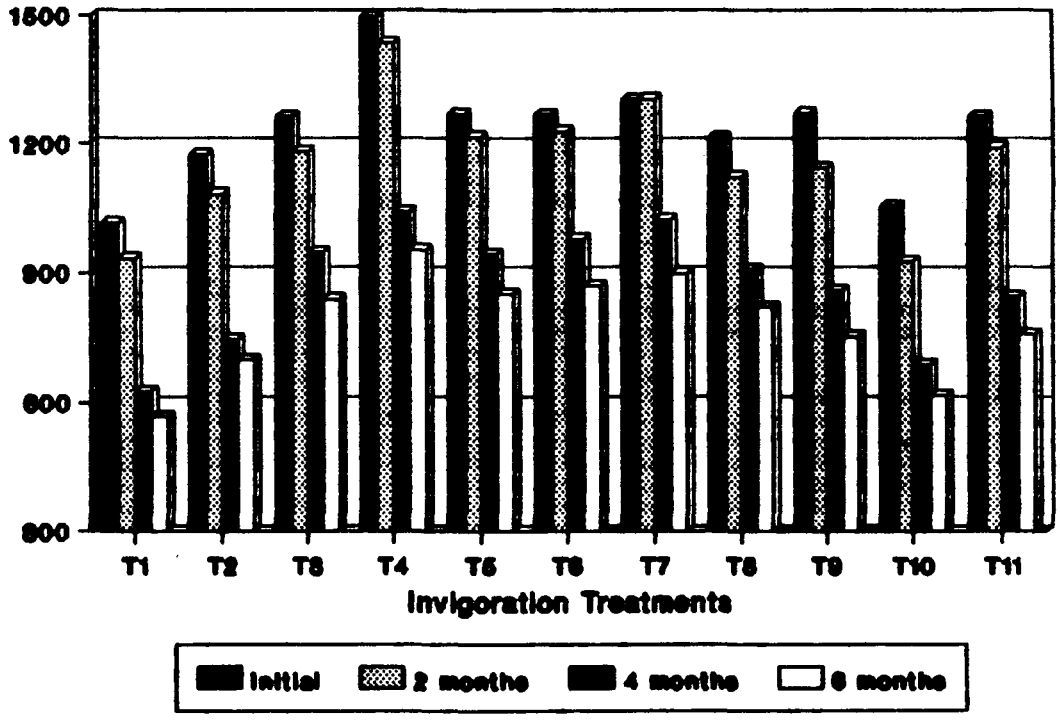


FIG 4.4 VIGOUR INDEX AS INFLUENCED BY SEED VIGOUR LEVELS AND INVIGORATION TREATMENTS IN RICE.

Vigour index differed significantly due to interaction effect of seed vigour levels and invigoration treatments. The highest vigour index was recorded in high vigour level V_1 with NaH_2PO_4 (1906), KH_2PO_4 (1629), $Na_2S_2O_3.5H_2O$ (1620), GA_3 (1594) and KNO_3 (1560) were found to be on par while Nacl (1467), Bio-gas slurry (1461), Hydration-dehydration (1442) and $Hgcl_2$ (1372) were found to be on par. PEG (1291) recorded lowest vigour index which was on par with control (1292), NaH_2PO_4 recorded 614 enhancement over untreated control.

High vigour level V_2 with NaH_2PO_4 recorded highest vigour index 1719). Bio-gas slurry (1517), $Na_2S_2O_3.5H_2O$ (1514), KNO_3 (1462), Nacl (1418), GA_3 (1404), $Hgcl_2$ (1393) and KH_2PO_4 (1391) were found to be on par. Hydration-dehydration (1316), PEG (1174) and untreated control (1170) were found to be on par. NaH_2PO_4 recorded 549 vigour index enhancement over untreated control.

Invigorating medium vigour seed V_3 with NaH_2PO_4 recorded significantly (1581) highest vigour index, KNO_3 (1413), $Na_2S_2O_3.5H_2O$ (1327), Nacl (1305), $Hgcl_2$ (1300) KH_2PO_4 (1283), GA_3 (1281) and Bio-gas slurry (1270) were found to be on par. Hydration-dehydration (1210) and PEG (1103) were found to be on par with each other. NaH_2PO_4 obtained 546 vigour index enhancement over untreated control (1035).

Invigorating low vigour seed V_4 with NaH_2PO_4 recorded (1210) highest vigour index which was on par with KNO_3 (1151), Nacl (1131), GA_3 (1091), Bio-gas slurry (1078) and $Hgcl_3$ (1061), while KH_2PO_4 (1046), Hydration-dehydration (1001) $Na_2S_2O_3.5H_2O$ (989) and PEG (883) were found to be on par NaH_2PO_4 obtained 369 units vigour index enhancement over untreated control (841).

Invigorating low vigour seed V_5 with NaH_2PO_4 obtained highest vigour index (1061) which was on par with $Nacl_1$ (1028), Bio-gas slurry (986), GA_3 (972), KH_2PO_4 (964), $Hgcl_2$ (944) and KNO_3 (926). While Hydration-dehydration (896), $Na_2S_2O_3.5H_2O$ (882), PEG (817) and untreated control (742) were found to be on par. NaH_2PO_4 obtained 319 units enhancement in vigour index over untreated control.

At Second month of storage the vigour index differed significantly among the vigour levels. The vigour index decreased with decrease invigour level. High vigour level V_1 recorded highest (1432) vigour index followed by V_2 (1340), V_3 (1225), V_4 (960) and the lowest vigour index was recorded in V_5 (866).

The vigour index due to seed invigoration treatments were significant. NaH_2PO_4 recorded highest (1435) vigour index which as on par with KNO_3 (1303). $Na_2S_2O_3.5H_2O$ (1228), GA_3 (1215), Bio-gas slurry (1190), KH_2PO_4 ((1180), Nacl (1143) and $Hgcl_2$ (1143) were found to

be on par, while Hydration-dehydration (1083), PEG (977) an untreated control were on par.

The vigour index differed significantly due to interaction effect of seed vigour levels and invigoration treatments. Highest vigour index was noticed in high vigour seed with NaH_2PO_4 (1787) which was on par with $Na_2S_2O_3.5H_2O$ (1559), KH_2PO_4 (1548), KNO_3 (1511) and GA_3 (1487). While Nacl (1433),Bio-gas slurry (1381), Hydration-dehydration (1342), $Hgcl_2$ (1271) and PEG and control (1225) were found to be on par.

High vigour level V_2 with NaH_2PO_4 (1699) recorded highest vigour index which was on par with KNO_3 (1445), $Na_2S_2O_3.5H_2O$ (1435), Bio-gas slurry (1407) and GA_3 (1394) were found to be on par. While KH_2PO_4 (1352), Nacl (1334), Hydration-dehydration (1254), $Hgcl_2$ (1229), PEG (1126) and control (1070) were found to be on par.

Invigorating medium vigour level V_3 with NaH_2PO_4 (1550) recorded highest vigour index which was on par with KNO_3 (1423), $Na_2S_2O_3.5H_2O$ (1346) and GA_3 (1267). While Bio-gas slurry (1220), Nacl (1201), $HgCl_2$ (1200), KH_2PO_4 (1195), Hydration-dehydration (1100), PEG (1010) and untreated control (969) were found to be on par.

Invigorating low vigour seed V_4 with NaH_2PO_4 obtained highest vigour index (1151) which was on par with

KNO_3 (1089), GA_3 (1008), Bio-gas slurry (1004), KH_2PO_4 (978), $HgCl_2$ (951), $Na_2S_2O_3.5H_2O$ (947), Hydration-dehydration (920) and Nacl (907), while lowest was recorded in untreated control (770) which was on par with PEG (833) and with all other treatments except NaH_2PO_4 and KNO_3.

Invigoration of low vigour seed V_5 with KNO_3 (1046) recorded highest vigour index which as on par with NaH_2PO_4 (989), $HgCl_2$ (962), Bio-gas slurry (959), GA_3 (919), $Na_2S_2O_3.5H_2O$ (854), Nacl (842), KH_2PO_4 (827) and Hydration-dehydration (800). Untreated control recorded lowest vigour index (635) which was on par with PEG (692).

At four months of storage vigour index decreased with decrease in the vigour level. The highest vigour index was recorded in V_1 (1143) followed by V_2 (987), V_3 (850), V_4 (720) and lowest was recorded with V_5 (667).

Vigour index differed significantly due to seed invigoration treatments. NaH_2PO_4 recorded (1042) highest vigour index which was on par with KNO_3 (1024), $Na_2S_2O_3.5H_2O$ (978), KH_2PO_4 (948) and GA_3 (943) were found to be on par while $HgCl_2$ (907), Nacl (859) and Bio-gas slurry (845) were on par. Hydration-dehydration obtained (748) vigour index. Untreated control recorded (626) lowest vigour index which was on par with PEG (687). The interaction effect due to seed vigour levels and seed invigoration treatments was significant.

High vigour seed V_1 with KNO_3 (1375) recorded highest vigour index which was on par with $Na_2S_2O_3.5H_2O$ (1340) and KH_2PO_4 (1306), NaH_2PO_4 (1239) and GA_3 (1232) were found to be on par with each other, while $HgCl_2$ (1120), Bio-gas slurry (1116) and Nacl (1096) were found to be on par. Untreated control recorded lowest vigour index (845) which was on par with PEG (920) and Hydration-dehydration (986).

Invigorating high vigour seed V_2 with NaH_2PO_4 (1148) obtained highest vigour index which was on par with GA_3 (1079), KNO_3 (1072), $HgCl_2$ (1067), $Na_2S_2O_3.5H_2O$ (1066) and Nacl (1024). Bio-gas slurry (1001) and KH_2PO_4 (1000) found to be on par with each other, while Hydration-dehydration (865) and PEG (813) found to be on par. Lowest vigour index was recorded in untreated control (724).

Invigorating medium vigour seed V_3 with NaH_2PO_4 (1036) recorded highest vigour index which as on par with $Na_2S_2O_3.5H_2O$ (984) and KNO_3 (951). While KH_2PO_4 (910), $HgCl_2$ (857), GA_3 (852), Nacl (847) and Bio-gas slurry (844) found to be on par. PEG (744) and Hydration-dehydration the lowest vigour index (623).

Invigoration of low vigour seed V_4 with NaH_2PO_4 (915) obtained highest vigour index which was on par with KNO_3 (895) and KH_2PO_4 (85), $HgCl_2$ (786), $Na_2S_2O_3.5H_2O$ (772),

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GA_3 (770) and Nacl (678) were found to be on par. While Bio-gas slurry (632), Hydration-dehydration (595) and PEG (518) were found to be on par. Untreated control recorded the lowest vigour index (505).

Invigorating low vigour seed V_5 with NaH_2PO_4 (873) obtained highest vigour index which was on par with KNO_3 (826) and GA_3 (785). $Na_2S_2O_3.5H_2O$ (728), $HgCl_2$ (702), KH_2PO_4 (675), Nacl (65) and Bio-gas slurry were on par whereas Hydration-dehydration obtained (588) vigour index. Untreated control recorded lowest (434) which was on par with PEG (440).

At six months of storage the vigour index significantly decreased with decrease in vigour level. V_1 recorded highest vigour index (967) followed by V_2 (900), V_3 (793), V_4 (66) and lowest was found in V_5 (601).

The vigour index due to invigoration treatments differed significantly. NaH_2PO_4 obtained highest (953) vigour index. KNO_3 (898), $Na_2S_2O_3.5H_2O$ (870) and GA_3 (851) were found to be on par. While KH_2PO_4 (839) and $HgCl_2$ (821) are on par with each other. Hydration-dehydration obtained (699) vigour index. Untreated control recorded lowest (567) vigour index.

The interaction effect due to seed vigour levels and seed invigoration treatments differed significantly.

The highest vigour index was recorded in high vigour level V_1 with NaH_2PO_4 (1186), which was on with $Na_2S_2O_3.5H_2O$ (1108), while KNO_3 (1074), KH_2PO_4 (1060), GA_3 (1053) and $HgCl_2$ (1004) were found to be significant. Bio-gas slurry (914), Hydration- dehydration (873), and Nacl (861) were on par. Untreated control recorded lowest vigour index (733) which was on par with PEG (776).

High vigour level V_2 with NaH_2PO_4 recorded highest vigour index (1075) which as on par with $Na_2S_2O_3.5H_2O$ (1002) and KNO_3 (997), while KH_2PO_4 (974), GA_3 (968) and $HgCl_2$ (963) were on par. Nacl (872), Bio-gas slurry (842) and Hydration-dehydration (820) were found to be on par. Untreated control recorded lowest (681) which was on par with PEG (681).

Invigorating medium vigour seed V_3 with NaH_2PO_4 (976) obtained highest vigour index which was on par with KNO_3 (918) and $Na_2S_2O_3.5H_2O$ (905), while KH_2PO_4 (840), GA_3 (813), Bio-gas slurry (800), $HgCl_2$ (798) and Nacl (795) were on par. PEG (687) and Hydration-dehydration (637) were on par with each other. Untreated control recorded lowest vigour index (551).

Invigoration of low vigour seed V_4 with KNO_3 (791) recorded highest vigour index which was on par with GA_3 (784), NaH_2PO_4 (736), KH_2PO_4 (714) and $HgCl_2$ (695). While $Na_2S_2O_3.5H_2O$ (686), Nacl (648), Bio-gas slurry (647) and

Hydration-dehydration (610) were found to be on par. Untreated control recorded the lowest (465) which was on par with PEG (484).

Invigorating low vigour seed V_5 with NaH_2PO_4 (794) recorded highest vigour index which was on par with KNO_3 (713). $Na_2S_2O_3.5H_2O$ and $HgCl_2$ (647), GA_3 (637), KH_2PO_4 (608), Bio-gas slurry (591), Nacl (587) and Hydration-dehydration (554) were found to be on par. Untreated control recorded the lowest (403) which was on par with PEG (430).

Irrespective of seed invigoration treatments, the vigour index declined in each of the vigour level Viz., V_1 (1512 to 967), V_2 (1407 to 900), V_3 (1283 to 793), V_4 (1044 to 660) and V_5 (929 to 601) at the end of 6th month of storage.

4.2.6 Electrical conductivity (E.C)

The results on Electrical conductivity as influenced by seed vigour levels, seed invigoration treatments and their interaction at different storage periods are presented in the Table 4.2.6.

Initially the Electrical Conductivity increased with decrease in seed vigour levels. The low vigour seed V_5 recorded highest (220 µ mhos/cm) followed by V_4 (202 µ mhos/cm), V_3 (182 µ mhos/cm) and V_2 (177 µ mhos/cm) were on

par with each other. The lowest Electrical conductivity was recorded in high vigour seed V_1 (168 µ mhos/cm).

The Electrical Conductivity due to invigoration treatments were significant. GA_3 recorded lowest (162 µ mhos/cm) which was on par with NaH_2PO_4 (165 µ mhos/cm), KNO_3 (118 µ mhos/cm) and $Na_2S_2O_3.5H_2O$ (179 µ mhos/cm) were found to be on par with each other, while $HgCl_2$ (182 µ mhos/cm), KH_2PO_4 (184 µ mhos/cm) and Bio-gas slurry (186 µ mhos/cm) were on par. Hydration-dehydration (190 µ mhos/cm) and Nacl (195 µ mhos/cm) were on par and significantly superior over untreated control (260 µ mhos/cm).

Electrical conductivity did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At second month of storage the electrical conductivity increased with decrease in vigour levels. V_5 recorded the highest electrical conductivity (230 µ mhos/cm) followed by V_4 (214 µ mhos/cm), V_3 (192 µ mhos/cm), V_4 (183 µ mhos/cm) and the lowest was recorded in V_5 (172 µ mhos/cm).

The electrical conductivity due to invigoration treatments were significant. GA_3 recorded lowest (171 µ mhos/cm). NaH_2PO_4 (182 µ mhos/cm), KNO_3 (185 µ mhos/cm) and $Na_2S_2O_3.5H_2O$ (187 µ mhos/cm) were on par, while $HgCl_2$ (190 µ

Table 4.2.6 Electrial conductivity (μ mhos/cm) as influenced by seed vigour levels and invigoration treatments

Treatments		Months after storage			
		Initial (0 months)	2 months	4 months	6 months
		Percent field emergence			
Vigour levels					
V_1	High	168	172	181	193
V_2	High	177	183	192	201
V_3	Medium	182	192	204	220
V_4	Low	202	214	225	238
V_5	Low	220	230	240	253
SEM ±		2.48	1.90	2.00	1.59
CD at 5%		6.87	5.28	5.21	4.40
Invigoration					
T_1	Control	261	269	277	288
T_2	Hyd delyd	190	199	214	230
T_3	KH_2PO_4	184	191	199	213
T_4	NaH_2PO_4	165	182	191	203
T_5	GA_3	162	171	184	194
T_6	$Na_2S_2O_3.5H_2O$	179	187	197	211
T_7	KNO_3	178	185	195	207
T_8	$Hgcl_2$	182	190	199	212
T_9	Nacl	195	199	207	221
T_{10}	PEG-6000	206	213	223	236
T_{11}	Biogas slurry	186	197	206	218
SEM ±		3.68	2.82	2.95	2.36
CD at 5%		10.19	7.82	8.18	6.53
CV %		6.97	4.5	5.73	3.36

mhos/cm), KH_2PO_4 (191 µ mhos/cm) and Bio-gas slurry (197 µ mhos/cm) recorded moderately high electrical conductivity and are on par. Hydration-dehydration (199 µ mhos/cm) was on par with Nacl (199 µ mhos/cm). Untreated control recorded the highest electrical conductivity (269 µ mhos/cm). Electrical conductivity did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At four months of storage the electrical conductivity increased with decrease in seed vigour levels. V_5 recorded highest electrical conductivity (240 µ mhos/cm) followed by V_4 (225 µ mhos/cm), V_3 (204 µ mhos/cm), V_2 (192 µ mhos/cm) and the highest electrical conductivity was obtained in V_5 (181 µ mhos/cm).

The electrical conductivity due to invigoration treatments were significant. GA_3 recorded the lowest (184 µ mhos/cm), KNO_3 (195 µ mhos/cm), $Na_2S_2O_3.5H_2O$ (197 µ mhos/cm), $HgCl_2$ (199 µ mhos/cm) and KH_2PO_4 (199 µ mhos/cm) were found to be on par while Bio-gas slurry (206 µ mhos/cm), Nacl (207 µ mhos/cm) and Hydration-dehydration (214 µ mhos/cm) were found to be on par. Highest electrical conductivity was recorded in untreated control (277 µ mhos/cm).

Electrical conductivity did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

At six months of storage the Electrical conductivity increased with decrease in seed vigour levels. The V_5 recorded highest electrical conductivity (253 µ mhos/cm) followed by V_2 (238 µ mhos/cm), V_3 (220 µ mhos/cm), V_4 (201 µ mhos/cm) and lowest was recorded in V_5 (193 µ mhos/cm).

The Electrical conductivity due to invigoration treatments were significant. GA_3 recorded the lowest electrical conductivity (194 µ mhos/cm). NaH_2PO_4 (203 µ mhos/cm) KNO_3 (207 µ mhos/cm) were on par with each other. $Na_2S_2O_3.5H_2O$ (211 µ mhos/cm), $HgCl_2$ (212 µ mhos/cm) and KH_2PO_4 (213 µ mhos/cm) were found to be on par while Bio-gas slurry (218 µ mhos/cm) and Nacl (221 µ mhos/cm) were on par with each other. Hydration-dehydration (230 µ mhos/cm) and PEG (236 µ mhos/cm) were found to be on par, control recorded the highest electrical conductivity (288 µ mhos/cm).

Electrical conductivity did not differ significantly due to interaction effect of seed vigour levels and invigoration treatments.

Over all there was considerable increase in Electrical conductivity of seed leachetes with decrease in vigour levels. Irrespective of seed invigoration treatments Electrical conductivity increased in all vigour levels V_1 (168 to 193 µ mhos/cm), V_2 (177 to 201 µ mhos/cm),

V_3 (182 to 220 µ mhos/cm), V_4 (202 to 238 µ mhos/cm) and V_5 (220 to 253 µ mhos/cm) at the end of 6th month of storage.

Irrespective of the vigour levels all the invigoration treatments recorded higher Electrical conductivity of seed leachetes at 6 month of storage over the untreated seed.

4.3 Field performance of invigorated seed

The field performance of the selected seed invigoration treatments was studied in five vigour levels of rice variety Mangala. The data recorded with respect to growth and yield parameters are as follows.

4.3.1.1 Plant height

The data on plant height (cm) as influenced by vigour levels and invigoration treatments are presented in Table 4.3.1 and depicted in Fig. 4.5.

The plant height 30 days after transplanting differed significantly for vigour levels. The differences in plant height among vigour levels V_1 (49.26 cm), V_2 (48.90 cm), V_3 (48.56 cm) and V_4 (48.29 cm) did not differ significantly. However, low vigour level V_5 (47.62 cm) recorded significantly lowest plant height than V_1 and V_2.

The plant height differed significantly among the seed invigoration treatments. GA_3 recorded highest plant height (49.52 cm) which was on par with KH_2PO_4 (49.46 cm), $Na_2S_2O_3.5H_2O$ (48.92 cm) and KNO_3 (48.74 cm). Control recorded the lowest plant height (47.28 cm) which was on par with hydration-dehydration (47.5 cm) and NaH_2PO_4 (48.18 cm). The interaction effect due to vigour levels and invigoration treatments did not differ significantly.

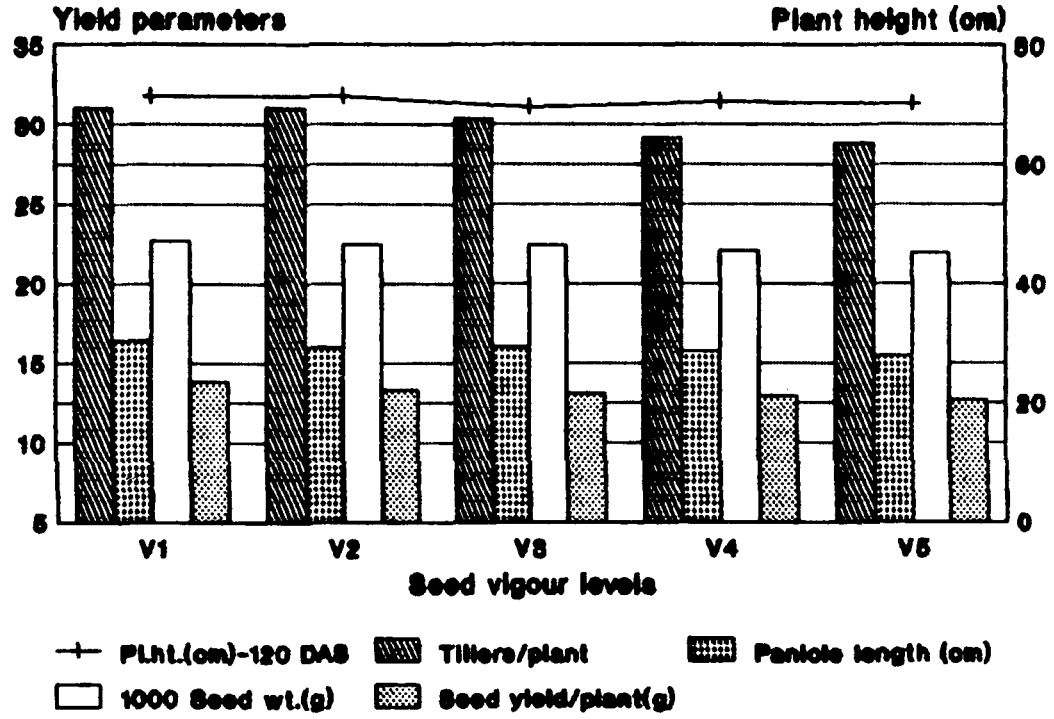
Plant height at harvesting (120 days after transplanting) differed significantly for vigour levels. High vigour seed V_1 (71.44 cm) recorded higher plant height which is on par with V_2 (71.43 cm), V_4 (71.50 cm). Lower plant height was recorded in V_3 (69.64 cm), V_4 (70.50 cm) and V_5 (70.21 cm) which are on par. The plant height did not differ significantly due to invigoration treatment. However, control recorded numerically lower plant height than invigoration treatments. The interaction effect due to vigour level and invigoration treatments did not differed significantly.

Yield parameters

The data on tillers per plant, Length of panicle, seed yield per plant and 1000 seed weight as influenced by vigour levels and invigoration treatments are presented in Table 4.3.1 and depicted fig. 4.5.

Table 4.3.1 Influence of seed invigoration treatments and seed vigour levels on plant height, number of tillers per plant, length of panicle, 1000 seed weight and seed yield

Vigour levels	Plant height		Tillers per plant	Length of Panicle (cm)	1000 seed weight (g)	Seed yield per plant (g)
	30 DAS	120 DAS				
V_1	49.26	71.44	31.08	16.39	22.68	13.81
V_2	48.90	71.43	31.04	15.94	22.43	13.34
V_3	48.56	69.64	30.36	15.99	22.36	13.11
V_4	48.29	70.50	29.15	15.75	22.07	12.92
V_5	47.62	70.21	28.82	15.43	21.92	12.70
SEM ±	0.34	0.36	0.54	0.17	0.30	0.28
CD at 5%	0.97	1.02	1.54	0.48	NS	0.79
T_1	47.28	68.81	28.33	14.39	20.50	11.58
T_2	47.56	70.10	29.56	15.26	21.65	12.14
T_3	49.46	72.10	30.19	16.26	22.35	13.34
T_4	48.18	70.20	30.80	16.54	23.40	14.00
T_5	49.52	71.90	30.32	16.09	22.50	13.57
T_6	48.92	71.40	30.58	16.58	22.45	13.74
T_7	48.74	70.00	30.86	16.20	23.20	13.87
SEM ±	0.40	0.42	0.64	0.20	0.35	0.33
CD at 5%	1.15	NS	1.82	0.57	1.00	0.93
CV %	2.61	1.89	6.67	3.95	4.98	7.85



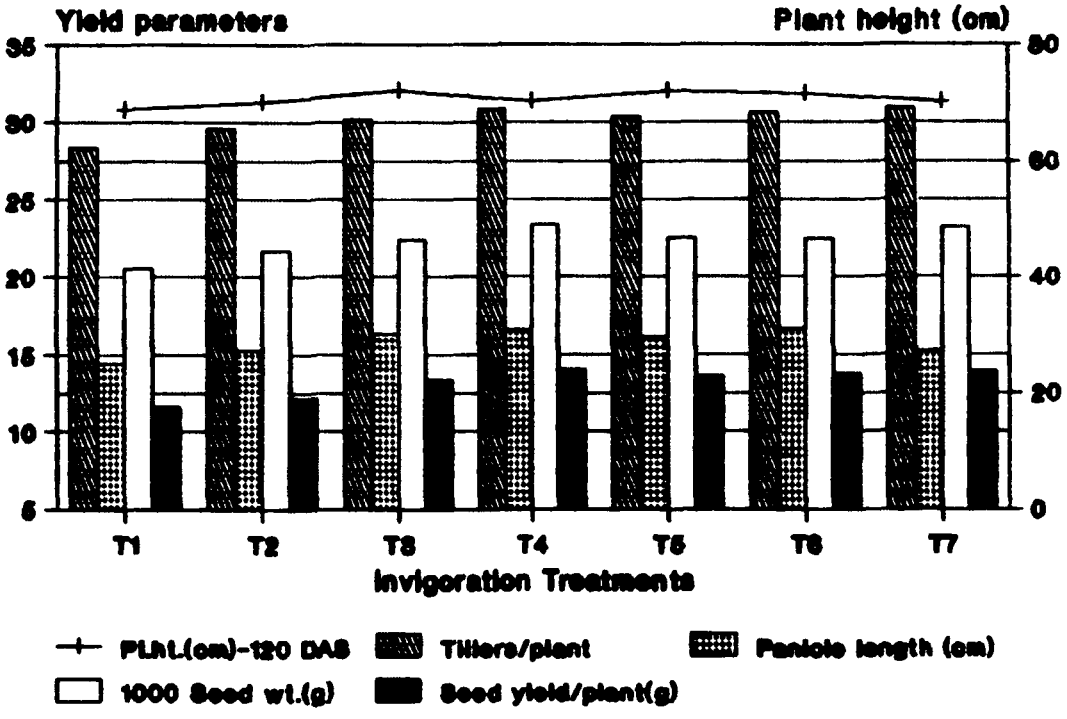


FIG 4.5 PLANT HEIGHT & YIELD PARAMETERS AS INFLUENCED BY SEED VIGOUR LEVELS AND INVIGORATION TREATMENTS IN RICE

4.3.1.2 Number of tillers per plant

Vigour levels differed significantly for number of tillers per plant. High vigour level V_1 recorded highest (31.08) number of tillers per plant which was on par with V_2 (31.04) and V_3 (30.36) but the medium vigour V_3 is on par with low vigour seed, V_4 (29.15) and V_5 (28.82).

The seed invigoration treatments differed significantly for number of tillers per plant. KNO_3 recorded (30.86) highest number of tillers which was on par with NaH_2PO_4 (30.80), $Na_2S_2O_3.5H_2O$ (30.58), GA_3 (30.32), KH_2PO_4 (30.19) and Hydration-dehydration (29.56). The control recorded significantly lowest (28.33) number of tillers which is on par with Hydration-dehydration. Interaction effect due to vigour levels and invigoration treatments did not differed significantly.

4.3.1.3 Length of Panicle

Length of panicles found significant among vigour levels. V_1 recorded highest panicle length (16.39 cm). Which was on par with V_2 (15.94 cm) and V_3 (15.99 cm). The lowest panicle length was recorded in V_5 (15.43 cm) which was on par with V_4 (15.75 cm). While V_2, V_3 and V_4 are on par.

The panicle length differed significantly due to invigoration treatments. Highest panicle length was recorded in $Na_2S_2O_3.5H_2O$ (16.58 cm) which was on par with NaH_2PO_4 (16.54 cm), KH_2PO_4 (16.26 cm), KNO_3 (16.20 cm) and GA_3 (16.09 cm). The control seed recorded significantly lowest panicle length (14.39 cm) than the Hydration-dehydration (15.26 cm). The interaction effect due to seed vigour levels and invigoration treatments did not differed significantly.

4.3.1.4 1000 seed weight

1000 seed weight did not differed significantly due to seed vigour levels. However it has decreased with increase in vigour level from V_1 (22.68 g) to V_5 (21.92 g).

Invigoration treatments significantly affect the 1000 seed weight. NaH_2PO_4 (23.40 g) recorded highest which was on par with KNO_3 (23.20 g), $Na_2S_2O_3.5H_2O$ (22.45 g), GA_3 (22.50 g) and KH_2PO_4 (22.35 g). The control recorded the lowest seed weight (20.50 g) and was inferior to hydration-dehydration (21.65 g). Interaction effect due to seed vigour level and invigoration treatments did not differed significantly.

4.3.1.5 Seed yield per plant

Seed yield per plant decreased linearly with decrease in seed vigour. High vigour seed V_1 (13.81 g)

recorded highest seed yield which was on par with V_2 (13.34 g) and V_3 (13.11 g) but significantly superior over low vigour seed, V_4 (12.92 g) and V_5 (12.70 g), V_2, V_3, V_4 and V_5 are on par.

Seed yield per plant differed significantly among the invigoration treatments. The highest seed yield per plant was recorded in NaH_2PO_4 (14.0 g) which was on par with KNO_3 (13.87 g), $Na_2S_2O_3.5H_2O$ (13.74 g), GA_3 (13.57 g) and KH_2PO_4 (13.34 g). The control seed recorded significantly lowest seed yield (11.58 g) per plant. But it is on par with hydration-dehydration (12.14 g). Interaction effect due to vigour levels and invigoration treatments did not differed significantly.

DISCUSSION

V DISCUSSION

The need has always been felt to have high quality seed to achieve optimum plant stand. Seed quality may differ between cultivars, among and with in seed lots but by proper seed management, this physiological seed quality variations can be improved. Loss of vigour and viability of seeds is associated with the ageing phenomenon and results in poor field stand and performance but many researchers advocated seed invigoration in promoting vigour, viability, storability and field performance. Pre sowing soaking seed treatment with various chemicals, growth regulators is being resorted for improving the physiological stamina of the seed, achieving uniform crop stand and further improvement quality of seed by minimizing the variations of seed quality with-in the seed vigour levels.

The results generated from the preliminary studies on standardization of soaking period for hydration-dehydration treatments and the studies related to effect of seed invigoration on different vigour level seed on storability and field performance in rice var. Mangala are discussed ins this chapter.

5.1 Standardization of period of soaking for hydration-dehydration treatments

Soaking low vigour paddy seeds for 4, 6 and 12 hrs. and drying back to original moisture has improved the germination. Prolonged soaking for 24 hrs. and 48 hrs. adversely affected the per cent germination. Marked improvement in root length, shoot length and vigour index were observed in 12 hrs. soaking than other soaking periods and seeds with no soaking. Root length and vigour index due to prolonged soaking not differed significantly over control, however shoot length was reduced considerably in 48 hrs. Similar beneficial effects for 12 hrs. soaking was reported in sunflower by Manmohan Kaur (1992); While Basu *et al.* (1976) and Basu and Pal (1979) observed improvement in germination and vigour for 6 hrs. soaking in stored rice seeds.

The beneficial effects of 12 hrs. soaking may be due to the sufficient imbibition of water by the seed thus enhancing physiological process of germination. Prolonged soaking to a point beyond the seed attains saturation would result in deterioration of seed due to anaerobic condition. Further prolonged soaking in water also result in leakage of essential soluble constituents of seed, which are resulted in reduced vigour and germination.

5.2 Effect of seed invigoration on storability of different vigour level seed

In the present investigation all the seed invigoration treatments found to improve storability of five vigour level (V_1 to V_5) seed of rice var Mangala having initial germination 93.5, 90.5, 84.74 and 70 per cents. The percentage germination decreased linearly with decrease in vigour levels. High vigour seed V_1, V_2 medium vigour seed V_3 and low vigour seed V_4 and V_5 recorded 96.04, 93.54, 89.84, 79.08 and 76.02 per cent germination respectively at the beginning of storage. Similar trend of decrease in germination with decrease in vigour level was observed 2^{nd}, 4^{th} and 6^{th} month after storage. The germination percentages of high (V_1 and V_2), medium (V_3) and low (V_4 and V_5) vigour seeds declined to 90.79, 88.55, 84.3, 72.85 and 69.45 per cent respectively at sixth month of storage.

Venkateshwara Rao (1990) reported in sorghum that the seed lots of high initial germination exhibited consistently higher germination and higher speed of germination through out the storage period as seed lots with low initial germination.

Improvement in germination due to invigoration treatments was observed in all the vigour levels over their respective control throughout the storage period. Maximum improvement in germination soon after invigoration

treatments was obtained with KNO_3 (89.2 %), NaH_2PO_4 (88.90 %), KH_2PO_4 (87.9 %), $Na_2S_2O_3.5H_2O$ (88.4 %), $Hgcl_2$ (87.4%) and Nacl (87.55 %), NaH_2PO_4 and KNO_3 have consistently shown improvement in germination even in the subsequent storage. Similar improvement was shown with GA_3 in four and six months of storage. The other invigoration treatments such as KH_2PO_4, $Na_2S_2O_3.5H_2O$ also performed well in improving the germination in the subsequent storage. Similar improvement in Germination during subsequent storage was obtained with NaH_2PO_4 in rice (Basu and Pal, 1979; Geetha *et al.*, 1974). Invigoration with $Na_2S_2O_3.5H_2O$ also improved germination in sunflower (Manmohan Kaur, 1992) land in carrot (Kundu and Basu, 1981).

Through hydration-dehydration, Biogas slurry and PEG-6000 maintained their superiority over control. Other invigoration treatments performed better throughout the storage period. The interaction effect due to vigour levels and invigoration treatments is significant in 4th and 6th months of storage. Highest germination was observed in high vigour seeds invigorated with NaH_2PO_4 and KNO_3. However the extent of increased germination was highest in medium vigour seed V_3 (10-12 %) followed by low vigour seed V_4 and V_5 (7-11 %) while it is 3-5 per cent in high vigour seeds (V_1 and V_2) over their respective controls in the subsequent storage.

Several researchers have obtained beneficial effects of hydration-dehydration in prolonging the storability of rice (Basu and Pal, 1980), wheat (Basu and Dasgupta, 1974; Rudrapal and Basu, 1982), Sunflower (Nagappa, 1983, Manmohan Kaur, 1992) and in maize (Dey and Mukherjee, 1986; Basu, 1990). Many workers have ascribed seed invigoration to phenomenon of repair endogenously formed free radical quenching and reorganisation of bioorganelles for the counteraction of physiological deterioration by hydration-dehydration and chemical treatments (Dasgupta *et al.*, 1977; Dey and Basu, 1982; Rudrapal and Nakamura, 1988).

Soaking-drying treatments to the seeds at the threshold of declining viability with and without salt dilute solutions significantly showed down the loss of viability of seeds of paddy cultivars under ambient storage conditions (Geetha and Vadivelu, 1994) but it is interesting to note that the results of this study revealed that invigorating the high quality seeds with a germination percentage of above 90 (Fresh seed) also found to be beneficial in maintaining germination in the subsequent storage.

Similar to laboratory germination the field emergence decreased linearly with decrease in vigour levels. High vigour seed V1, V_2, medium vigour seed V_3 and

low vigour seed V_4 and V_5 recorded 85.73, 84.55, 80.70, 70 and 65.85 per cent field emergence respectively at the beginning of the storage. Similar trend of decrease in field emergence with decrease in vigour level was observed 2nd, 4th and 6 months after storage. Field emergence of high (V_1 and V_2), medium (V_3) and low (V_4 and V_5) vigour seeds declined to 80.33, 79.61, 75.15, 63.0 and 59.76 per cent respectively at sixth month of storage.

All the seed invigoration treatments improved the field emergence over the untreated control irrespective of vigour levels throughout the storage period. Maximum improvement in field emergence was obtained with NaH_2PO_4 (80.33 %), KNO_3 (79.20 %), KH_2PO_4 (78.73 %). NaH_2PO_4 and KNO_3 have shown improvement in field emergence even in the subsequent storage. Similar improvements in field emergence was reported in cereals by Hofman *et al.* (1992), Eshanna and Kulkarni (1990) in Corn and Manmohan Kaur (1992) in sunflower.

Root length, shoot length and vigour index reduced linearly with decline in vigour levels through out the storage period. Root length, shoot length and vigour index was highest in high vigour seed while it was lower in low vigour seed through out the storage period. Seed invigoration with NaH_2PO_4, KNO_3, $Na_2S_2O_3.5H_2O$, GA_3 and KH_2PO_4 performed superiorly over other treatments over a period of storage for all the above parameters. Invigorating with

Biogas slurry, Nacl followed by hydration-dehydration found to be superior over untreated control.

Maximum improvement in root length, shoot length and vigour index was noticed in high vigour seeds invigorated with NaH_2PO_4, KH_2PO_4, KNO_3 and $Na_2S_2O_3.5H_2O$. Similar response for invigoration was observed in all the vigour levels over their respective controls during the entire period of storage. Similar improvement in seed quality parameters were reported by Basu and Dasgupta (1974) in wheat, Manmohan Kaur (1992) in sunflower for NaH_2PO_4 and hydration-dehydration.

The electrical conductivity of seed leachates substantially increased with decrease in vigour levels from V_1 to V_5 (168 to 220 µ mhos/cm) at the beginning of storage. Similar trend in EC was observed in subsequent storage periods in all the vigour levels. EC also increased over a period of storage in all the vigour levels at the end of storage the EC increased from 193 to 253 µ mhos/cm from high (V_1) to low (V_5) vigour seeds. Increase in EC with increase in storage period or increase in EC with decrease in vigour levels could be attributed to increased level of deterioration associated with membrane degradation (Berjenk and Villers, 1972; Agarwal, 1980; Ghosh *et al.*, 1981).

All the invigoration treatments recorded significantly lower EC over the untreated seed through out

the storage period. GA_3, KH_2PO_4, KNO_3 and $Na_2S_2O_3.5H_2O$ has shown superior performance in reducing the EC over different period of storage. Hydration-dehydration, Biogas slurry were superior to untreated control. Reduction in EC due to seed invigoration involving hydration-dehydration with and without chemicals may be attributed to their beneficial action on cell membrane functions, repair of cell organelles as envisaged by Simon (1974)and Dasgupta and Basu (1975).

Similar decreased EC was reported due to seed invigoration with $CaoCl_2$ in soybean (Singh *et al.*, 1981) and proline in Ragi, Paddy and Sun flower seeds (Raghavendra, 1980). Manmohan Kaur (1992) also observed lower EC due to seed priming treatments on low and high germinable seed lots of sunflower over untreated control.

The decline in viability and vigour of seeds with time could be due to the phenomenon of ageing associated with irreversible physical, physiological and biochemical changes occurring in them, accelerated by the fluctuations in Relative Humidity and Temperature of storage environment (Abdul Baki and Anderson, 1972). Of the possible bio-physical and bio-chemical changes of deterioration, free radical damage leading to a disruption of functions of cellular membrane assumes significance. Tappel (1973) and Harman and Mattick (1976) attributed free radical chain reactions and lipid peroxidation to cellular

senescence and concluded that these go hand in hand destroying lipoprotein membrane structures of vital bio organelles. The involvement of free radicals in the deterioration of seeds has been suggested by number of workers (Pammenter *et al.*, 1974; Dasgupta, *et al.*, 1977). Koostra and Harrington (1969) have suggested lipid oxidation during storage as a cause of solute leakage during storage. The loss of viability and vigour is associated with loss of integrity of cell membrane leading to increased leaching of substances from the seed (Heydecker, 1972). However, the free radicals should be quenched immediately after their generation much of the feature damage due to their chain damage could be prevented.

The beneficial effects of physico-chemical seed invigoration treatments could be based on the concept of free radical pathway as a vital factor in seed deterioration. Free radical destruction to large polymers and to membrane lipids could be considerably minimised by employing free radical obsorbents or scavengers, Radio protective agents like water, hydration-dehydration has grater radical quenching properties. Basu and Dasgupta (1978), Pathak and Basu (1980) demonstrated the beneficial effects of Hydration-dehydration treatments in reducing the physiological deterioration by minimizing lipid peroxidation and free radical chain reactions. In the present study invigoration of different vigour levels seeds

with and without chemicals have improved the germination and vigour in the subsequent storage thus it could be concluded that the beneficial effects of invigoration is possible even with seeds of high vigour with an initial germination of above 90 per cent. Dharmalingam and Basu (1978) and Basu and Pal (1979) have concluded that several antioxidants quench the free radicals and thus results in membrane repair mechanism and subsequently extend shelf life of seed.

From the present investigation we can conclude that seed quality parameters such as germination, root length, shoot length and vigour index have decreased linearly with decrease in vigour levels but the Electrical Conductivity increased with decrease in vigour levels. Seed quality parameters also decreased with increase in storage period. High vigour seed V_1 with initial germination of 94 per cent confined to show highest quality parameters throughout storage period. Similarly low vigour seeds V_4 and V_5 with initial germination of 75 and 71 per cent have shown more or less similar and low performance. All the seed invigoration treatments showed their superiority over the untreated control even before and after subsequent storage. Invigoration treatments NaH_2PO_4, KNO_3, KH_2PO_4, and $Na_2S_2O_3.5H_2O$ and GA_3 have shown significant improvement in germination in all the vigour level seed. In general the extent of increase in germination was more in medium vigour seed (10-12 %) followed by low vigour seed

(7-11 %). While it was less for high vigour seed (3-5%) with the best invigoration treatments such as NaH_2PO_4, KNO_3, KH_2PO_4, and $Na_2S_2O_3.5H_2O$. Invigoration with NaH_2PO_4, KNO_3, KH_2PO_4, maintained germination to that of initial mean germination of untreated seed even after 6 months of storage. Invigoration treatments found to improve other seed quality parameters over their respective control even after 6 months of storage. Hydration-dehydration alone has moderately improved the germination, field emergence and other seed quality parameters over untreated control.

5.3 Field performance of invigorated seed

Plant growth, yield and yield parameters except 1000 seed weight were found to be influenced by seed vigour levels. The differences in the plant height at 30 days after transplanting vigour levels V_1 to V_4 ranged from 49.26 to 48.29 cm did not affected significantly. While the lowest vigour level V_5 recorded significantly lower plant over the high vigour seed V_1 and V_2. The plant height at harvest was highest in high vigour seeds V_1 and V_2 than the low and medium vigour seeds.

The invigoration treatmentwise GA_3, KH_2PO_4, $Na_2S_2O_3.5H_2O$ and KNO_3 influenced the plant height at 30 days after transplanting. They found to influence the plant height while the different in plant height at harvest not differed significantly for invigoration treatments.

Increased plant height was due to invigoration was reported with GA_3 in Okra (Omran *et al.*, 1980) and Hydration-dehydration in Ragi (Karivaratha—Raju and Ramakrishna, 1985) and in sunflower Manmohan Kaur (1992) and with NaH_2PO_4 in sunflower (Basu and Dey, 1983).

Yield parameters such as seed yield per plant, Tillers per plant, panicle length were affected by vigour levels. Yield parameters linearly decreased with decrease in vigour levels, but the difference in 1000 seed weight due to vigour levels was not affected significantly. The maximum yield per plant was recorded in highest vigour level V_1 (13.87 g) with initial germination of 94 per cent. The yield was reduced by 3.52 per cent in V_2, 5.07 per cent in V_3, 6.44 per cent in V_4 and 8.04 per cent in V_5 with their initial germination of 91, 84, 74 and 70 per cent. However the differences in the yield among vigour levels V_2 to V_5 were not affected significantly. Similar association between decline in Germination, yield and yield components was observed by Venkateshwara—Rao (1990) in sorghum hybrids, soybean bylinn (1982) and Manjunath (1993) in groundnut. High (V_1, V_2) and medium (V_3) vigour seeds recorded higher tiller number per plant, but the lower (V_4 and V_5) vigour seed recorded significantly lower number of tillers than high vigour seed. Similarly higher panicle length was observed with high and medium vigour seeds. But the lower panicle length was recorded with low vigour seed V_4 followed by V_5. The difference between any two nearest

vigour levels were on par with respect to the yield parameters. Eventhough the constant plant density was maintained among the vigour levels there was a definite trend of yield decrease with decrease in vigour level. However, the maximum seed yield per plant was observed in very high vigour level seed V_1 (13.81 g) and V_2 (13.34 g) compared to low vigour seeds V_4 (12.92 g) and V_5 (12.70 g). Medium vigour seed V_3 (13.11 g) was on par with both high and low vigour seeds. The increased yield obtained with high vigour seed was mainly due to better crop growth, more number of tillers and increased panicle length. This might be due to poor performance of surviving plants produced by low vigour seed obtained by Funk *et al.*, (1962), Grabe, (1967) in Corn and Manjunath (1993) in Groundnut. 1000 seed weight did not differ significantly due to vigour levels. Siddique (1986) also did not observed significant difference among the vigour levels for 1000 seed weight, even through he has obtained significant difference in yield per plant due to differences in vigour levels.

The present findings clearly suggested that the maximum yield could be realised with high quality seeds V_1 with germination of 94 per cent followed by V_2 and V_3 with an initial germination of 91 and 84 per cent. Further the study reveals that the low vigour level (V_4 = 74% and V_5 = 70%) seeds with germination below certification level did not secure similar yields as that of high viability seed inspite of maintaining same population thus it is not

advisable to use low vigorous seeds with a germination below certification standards. Conclusions drawn by Abdulla and Roberts (1959) and Roberts (1972) is that unless there is reduction of viability down to 50 per cent, age of the seeds has no significant effect on yield when seed rates is compensated. But the results of our study contradict this hypothesis, but these results are more or less in conformity with the results obtained by Venkateshwara Rao (1990) and Manjunath (1993) who obtained reduced yield when the germination level had gone below 70 per cent.

Seed invigoration treatments with and without chemicals have influenced yield parameters-wise tillers per plant, panicle length, 1000 seed weight and yield per plant. With respect to plant height invigoration treatments viz., GA_3, KH_2PO_4, $Na_2S_2O_3.5H_2O$ and KNO_3 have improved the initial plant growth at 30 days. But the plant height at harvest was not significantly affected by invigoration treatments. The seed invigoration treatmentswise NaH_2PO_4 (14.0 g), KNO_3 (13.87 g), $Na_2S_2O_3.5H_2O$ (13.74 g), GA_3 (13.57 g) and KH_2PO_4 (13.34 g) out yielded the untreated seed. So, the per cent increase in yield due to invigoration is in the order of 4.6 to 19.78 per cent over control. Similar influence of invigoration treatments on panicle length, tillers per plant and 1000 seed weight was observed. Highest of tillers per plant was observed in KNO_3 (30.86) followed by NaH_2PO_4 (30.80), $Na_2S_2O_3.5H_2O$ (30.58) and GA_3 (30.32) which were significantly superior over untreated

control. Hydration-dehydration, KH_2PO_4 (30.19) along with untreated control were on par. Hydration-dehydration was on par with control seeds for 1000 seed weight whereas, all other principle treatments enhanced the 1000 seed weight. Thus the increased seed yield per plant due to invigoration treatments could be attributed to the similar positive effects of treatments on panicle length, number of tillers plant and 1000 seed weight. Hofmann *et al.* (1992) obtained increased yield by pre-sowing treatments in oats and wheat to the extent of 5 and 9 per cent respectively. Dollypan and Basu (1985), Dey and Mukherjee (1988) ascribed the invigoration of seed to increased enzymatic activity, Phenomenon of cellular repair, free radical quenching and reorganisation of bio-organelles. Several workers suggested that invigoration with NaH_2PO_4, $Na_2S_2O_3.5H_2O$, KNO_3, Nacl etc. acts as antioxidants, synergistic and therefore would have a control an effect of free radical chain reactions and also reduce the lipid peroxidation, which would otherwise destroy the semi permeable membrane structure causing leaching of substances from the seeds. Beneficial effects of seed treatment with GA_3 may be attributable to cell elongation and quicker cell multiplication in the meristematic portions as germination starts and it also remains physiologically active to build up food reserves and they also mobilise the nutrients towards the shoot and thus resulting better growth and development of the plant.

In the present study invigoration treatments involving chemicals such NaH_2PO_4, KNO_3, and $Na_2S_2O_3.5H_2O$, GA_3 and KH_2PO_4 were able to increase the yield per plant by 15.2 to 19.78 per cent over control, but the hydration-dehydration alone eventhough performed better for some of the yield parameters over control, did not differ with control for yield. Similar response for NaH_2PO_4 was observed by Basu and Dey (1983) in sunflower. Kundu and Basu (1981) also obtained higher yield in carrot for $Na_2S_2O_3.5H_2O$ and NaH_2PO_4.

It should be concluded that seed invigoration treatments not only improved germination and vigour in stored seeds but some of the treatments like NaH_2PO_4, KNO_3, and $Na_2S_2O_3.5H_2O$, etc., also found to enhance yield and yield parameters in rice.

Future line of work

1. Effectiveness of seed invigoration treatments on different vigour level seed for large scale application needs to be investigated.

2. Use of various plant products, bio-ingredients to know the effect of invigoration can be studied.

3. The influence of second line invigoration on invigorated and stored seed can be studied.

4. Seed microflora associated with invigorated seeds using various chemicals and halogens needs to be investigated.

5. Influence of temperature of soaking media on the effect of invigoration may also be studied.

SUMMARY

VI SUMMARY

Laboratory and Field studies were undertaken to study the effect of seed invigoration on different vigour level seed in Rice at the Seed Technology Laboratory, G.K.V.K., and main Research Station, Hebbal respectively during 1994-95. The results obtained from the studies on i) Standardization of period of soaking for hydration-dehydration treatments, ii) Effect of seed invigoration treatments on different vigour level seed on storability and iii) Influence of seed invigoration on growth and yield in rice variety "Mangala" are summarized as follows.

Soaking for 4 hrs, 6 hrs, 12 hrs and dried back to original moisture improved the germination, Root length, Shoot length and vigour index over control. Highest improvement was observed in 12 hrs soakings while soaking for 48 hrs reduced germination, Root length, Shoot length and vigour index over the control. Germination decreased linearly and significantly with decrease in vigour level. High vigour seed V_1 (96.04%) recorded high germination followed by V_2 (93.54%), V_3 (89.54%), V_4 (79.09%) and V_5 (76.02%). The germination declined to 90.79, 88.55, 84.3, 72.85 and 69.45 per cent respectively after 6 months of storage. The rate of decline in germination was slow in high and medium vigour seeds while it was moderately high in low vigour seeds ranging from 5.25 to 6.53

per cent. All invigoration treatments improved the germination percentage of different vigour level seeds over their respective controls. Invigorating with KNO_3 (89.20%), NaH_2PO_4 (88.90%), $Na_2S_2O_3$.$5H_2O$ (88.4%) and KH_2PO_4 (87.90%) have showed highest improvement in germination and are on par, while hydration—dehydration gave 85.70 per cent germination over control seed (82.4%). Irrespective of vigour levels all the invigoration treatments except PEG enhanced the mean germination per cent at 4 months of storage over the initial germination of untreated seed. Invigorating with NaH_2PO_4 (84.47%) and KNO_3 (84.27%) recorded maximum germination followed by KH_2PO_4 at 6 months of storage over other treatments while the untreated seed recorded 76.73 per cent germination. Seed invigorating with these chemicals at 6 months have maintained the germination to that of initial germination of control seed.

Field emergence decreased linearly with decrease in vigour levels from V_1 (85.73%) to V_5 (66.85%). Initially all invigoration treatments except PEG enhanced field emergence over control. GA_3 and NaH_2PO_4 and KNO_3 consistently recorded highest field emergence followed by $Na_2S_2O_3$.$5H_2O$ at different months of storage. The rate of enhance in field emergence due to invigoration was more in low vigour seed than high and medium vigour seed and also higher response was noticed with advance in storage over respective controls.

Root length deceased linearly with decrease in vigour level from V_1 (8.55 cm) to V_5 (6.45 cm) and deceased with increase in storage period in each of the seed vigour levels. All invigoration treatments except PEG showed significant improvement in root length over control seed at different months of storage. Invigoration with NaH_2PO_4, KNO_3 and $Na_2S_2O_3.5H_2O$ recorded consistently highest root length at different months of storage.

Shoot length and vigour index also declined with decline in vigour levels. All invigoration treatments except PEG enhanced the shoot length and vigour index over control at different months of storage. NaH_2PO_4, KNO_3, GA_3 showed higher response followed by KH_2PO_4 and $Na_2S_2O_3.5H_2O$.

Electrical conductivity of seed leachates increased with decrease in vigour levels from V_1 (168 μ mhos/cm) to V_5 (220 μ mhos/cm). All the invigoration treatments recorded lower EC of seed leachates at different months of storage over the untreated seed. GA_3, NaH_2PO_4 and KNO_3 recorded consistently lowest EC of seed leachates followed by KNO_3 and $Na_2S_2O_3.5H_2O$ at different months of storage. EC increased with increase in storage period in all the vigour levels and invigoration treatments.

Plant height at 30 DAT decreased linearly with decrease in vigour level from V_1 (49.26 cm) to V_5 (47.62 cm). But the low [V_4 (48.29 cm) and V_5 (47.62 cm)] and medium vigour [V_3 (48.56 cm)] seed did not differ significantly for plant height. All the selected invigoration treatments were superior in plant height over untreated control. Invigoration with GA_3, KH_2PO_4, $Na_2S_2O_3.5H_2O$ and KNO_3 recorded higher plant height than other treatments. Hydration, dehydration, NaH_2PO_4 and control did not differ for plant height.

At harvest high vigour seed V_1 (71.44 cm) and V_2 (71.43 cm) recorded higher plant height over medium [V_3 (69.64 cm)] and low vigour seed V_4 (70.50 cm) and V_5 (70.21 cm). Invigoration treatments recorded higher plant height than the control but the differences were not significant.

The yield and yield components such as tillers per plant, panicle length, 1000 seed weight and seed yield per plant decreased linearly with decrease in vigour levels. Seed invigoration treatments recorded higher tiller number per plant, panicle length and seed yield per plant over untreated control. High V_1 (31.08) and V_2 (31.84) and medium V_3 (30.36) vigour level seed recorded significantly more number of tillers than low vigour seed V_4 (29.15) and V_5 (28.82). Similarly high vigour V_1 (16.39 cm) and V_2 (15.94 cm) and

medium vigour V_3 (15.99 cm) seeds recorded higher panicle length than low vigour seed V_4 (15.75 cm) and V_5 (15.43 cm).

Invigoration with KNO_3 (30.86) and NaH_2PO_4 (30.80) recorded maximum number tillers followed by $Na_2S_3O_3.5H_2O$ (30.58), GA_3 (30.32) and KH_2PO_4 (30.19). Hydration-dehydration (29.56) did not differ with control (28.33) for tiller number.

Maximum panicle length was observe due to seed invigoration involving chemicals (16.09 to 16.58 cm). While Hydration-dehydration alone had moderately improved the panicle length (15.26 cm) over control (14.39 cm).

The difference in 1000 seed weight due to vigour levels were not significant. Invigoration treatments affected the 1000 seed weight. Maximum seed weight was observed in NaH_2PO_4 (23.40 g), KNO_3 (23.20 g), Hydration -dehydration recorded 21.64 g which is on par with GA_3 (22.50 g). $Na_2S_2O_3.5H_2O$ (22.45 g) and KH_2PO_4 (22.35 g), while the control recorded the lowest 1000 seed weight (20.50 g).

High vigour seed V_1 (13.81 g) recorded maximum seed yield per plant followed by V_2 (13.34 g) and V_3 (13.11 g). The lowest yield was recorded in low vigour seed V_5 (12.70 g) followed by V_4 (12.92 g). The difference in yield among V_2, V_3, V_4 and V_5 did not differ.

All invigoration treatments except hydration-dehydration improved the yield over control. Maximum yield was recorded in NaH_2PO_4 (14 g), followed by KNO_3 (13.87 g), $Na_2S_2O_3.5H_2O$ (13.74 g), GA_3 (13.57 g) and KH_2PO_4(13.34 g), lowest yield was recorded in control (11.58 g) which was on par with hydration-dehydration (12.14 g).

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* Original not seen